IN THE UNITED STATES DISTRICT COURT
FOR THE SOUTHERN DISTRICT OF TEXAS

WESTERNGECO L.L.C.,	)	
	)	
Plaintiff,	)	
	)	
v.	)	Civil Action No. 4:13-cv-02725
	)	
PETROLEUM GEO-SERVICES ASA,	)	Hon. Lynn N. Hughes
PGS GEOPHYSICAL AS, and	)	
PETROLEUM GEO-SERVICES, INC.,	)	**Jury Trial Demanded**
	)	
Defendants.	)	

FIRST AMENDED COMPLAINT

DEMAND FOR JURY TRIAL

Plaintiff WesternGeco L.L.C., for its First Amended Complaint against Defendants Petroleum Geo-Services ASA, PGS Geophysical AS and Petroleum Geo-Services, Inc. (collectively, Geo) hereby alleges as follows and demands a jury trial on all issues so triable.

THE PARTIES

1. Plaintiff WesternGeco L.L.C. (Western) is a Delaware corporation having a principal place of business at 10001 Richmond Avenue, Houston, Texas 77042-4299.

2. Upon information and belief, Defendant Petroleum Geo-Services ASA (Geo ASA) is a Norwegian corporation having a principal place of business at Strandveien 4, P.O. Box 89, NO-1325, Lysaker, Norway, and using offices and conducting business operations in Houston, Texas and Austin, Texas as set forth herein.

3. Upon information and belief, Defendant PGS Geophysical AS (Geo A/S) is a Norwegian corporation having a principal place of business at Strandvein 4, P.O. Box 290, N-1326, Lysaker, Norway and using offices and conducting business operations in Houston, Texas

as set forth herein. Upon information and belief, Defendant Geo A/S is a wholly-owned subsidiary of Defendant Geo ASA.

4. Upon information and belief, Defendant Petroleum Geo-Services, Inc. (Geo Inc.) is a Delaware corporation having a principal place of business at 15150 Memorial Drive, Houston, Texas 77079 and having an agent for service of process registered with the Texas Secretary of State's office. Upon information and belief, Defendant Geo Inc. is a wholly-owned subsidiary of Defendant Geo ASA.

NATURE OF THE ACTION

5. This is a civil action for the willful infringement of United States Patent Nos. 7,293,520 (the '520 patent), 7,080,607 (the '607 patent), 7,162,967 (the '967 patent), and 6,691,038 (the '038 patent) (collectively, Patents-in-Suit). This action arises under the Patent Laws of the United States, 35 U.S.C. § 1, *et seq*.

JURISDICTION AND VENUE

6. This Court has subject matter jurisdiction over the infringement action pursuant to 28 U.S.C. §§ 1331 and 1338(a).

7. Geo ASA, Geo A/S and Geo Inc. are each subject to personal jurisdiction in this Court as evidenced by, *inter alia*, their presence in Texas and their systematic and continuous contacts with the State of Texas.

Geo ASA

8. Upon information and belief, Geo ASA has an active business presence in this district. For example, the 2009 and 2010 Annual Reports for Geo ASA list three "worldwide offices" located in Texas, two in Houston and one in Austin. Geo ASA's 2011 and 2012 Reports list five offices in Texas, four in Houston and one in Austin. (Ex. E) Upon information and

belief, these offices include Geo ASA's business activities, and not merely the activities of its subsidiaries. For example, the 2009 Annual Report defined "PGS or the Company" as Geo ASA, and then stated that "PGS [*i.e.*, Geo ASA] operates through the business units: Marine and Data Processing & Technology" and that "PGS [*i.e.*, Geo ASA] acquires and processes seismic data." Upon information and belief, Geo ASA employees have repeatedly conducted business in Houston offices throughout the period of infringement, *i.e.*, 2007 to present.

9. Upon information and belief, Geo ASA uses and has used Houston addresses and Houston-based agents in its legal, financial, and business dealings, and to petition the federal government. For example, Geo ASA SEC filings from 2007 to 2013 include Geo ASA's disclosure of a Houston-based agent for service of process. (Ex. F) Geo ASA's SEC filings, investor presentations and website recite a Houston-area telephone number for "investor services." (Ex. G) A 2009 Geo ASA Intellectual Property Agreement recited a Houston contact address for Geo ASA and invoked Texas law. (Ex. H) Geo ASA similarly used a Houston address in a 2010 federal trademark filing for its GeoStreamer mark, which is used in the accused marine seismic surveys. (Ex. I) And Geo ASA's filings in a 2013 bankruptcy case in Delaware recite a Houston business address for Geo ASA. (Ex. J)

Geo A/S

10. Upon information and belief, Geo A/S has an active business presence in this district. As set forth in greater detail below, on information and belief, Geo A/S employees have used Houston business addresses when interacting with ION Geophysical Corp. and its affiliates (collectively, ION) to negotiate for, purchase, and supply the DigiFIN and Lateral Controller products accused of infringement. For example, Geo A/S contracts with ION regarding DigiFIN

recite a Houston business address for Geo A/S, are "governed by and construed according to the laws of Harris County, Texas" and are enforceable "by arbitration to be held in Houston, Texas."

Geo Inc.

11. Upon information and belief, Geo Inc. has an active business presence in this district. For example, a sworn affidavit of James Brasher, Vice President and Senior Legal Counsel of Geo Inc. provided by Geo Inc. to Western on April 23, 2010 in connection with *WesternGeco L.L.C. v. ION Geophysical Corp.*, No. 4:09-CV-01827 (S.D. Tex.) ("the *ION* litigation") stated that Geo Inc. "markets seismic services to customers in the United States." (Ex. K) As another example, Geo ASA's Annual Reports from at least 2009-2012 disclose a Geo Inc. office on Memorial Drive in Houston, Texas which, on information and belief, is Geo Inc.'s primary place of business.

"Geo"

12. Upon information and belief, Geo ASA and its subsidiaries, including Geo A/S and Geo Inc., operate together as an integrated business based on business units that cut across legal entities, rather than based on the business entities themselves. As set forth below, each Geo entity may thereby contribute to, induce and cause actions of other Geo entities, with the knowledge and intent that those actions will have effects within this judicial district.

13. For example, upon information and belief, Geo ASA, Geo A/S and Geo Inc. employees have attended and plan to attend conferences and trade shows within this judicial district to promote their commercial interests under the generic name "PGS," *i.e.*, "Geo," without distinguishing between any specific legal entities. This promotion has included advertisements for the products and services accused of infringing Western's Patents-in-Suit. Upon information and belief, Geo exhibited at the 2013 Society of Exploration Geophysicists International

Exposition and Annual Meeting (Expo), that took place in Houston, Texas in September 2013, in order to promote products and services incorporating ION's DigiFIN and Lateral Controller that infringe Western's Patents-in-Suit. Upon information and belief, Geo employees have attended and exhibited at prior Expo annual meetings, including those within this judicial district, in order to promote products and services incorporating ION's DigiFIN and Lateral Controller that infringe Western's Patents-in-Suit.

14. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. share a website: http://www.pgs.com. Upon information and belief, Geo ASA employees are responsible for at least some of the content on this site. Upon information and belief, this website is accessible nationally and internationally, and is active in interstate commerce. This website touts and advertises the products, components and services accused of infringement in this Complaint. This judicial district comprises one of the largest worldwide markets for the advertised marine seismic services, and upon information and belief, Geo ASA, Geo A/S and Geo Inc. each intend for customers and potential customers within this judicial district to access this website and to purchase Geo products and services. This website additionally lists major U.S. offices and career opportunities in Houston and Austin, including a recruitment event at the annual International Association of Geophysical Contractors meeting held in Houston targeted towards "Geoscience professors and students from local universities." (Ex. L)

Additional Bases for Specific Jurisdiction

15. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. are each additionally subject to personal jurisdiction in this Court due to their specific activities in the State of Texas relating to the supply, marketing and selling of products and services, and

components thereof, that infringe the Patents-in-Suit as alleged and stated within this section and throughout this Complaint.

16. Venue is proper in this judicial district pursuant to 28 U.S.C. §§ 1391 and 1400(b).

THE PATENTS

17. On November 13, 2007, the ’520 patent, titled “Control System For Positioning Of A Marine Seismic Streamers,” was duly and legally issued to Western as assignee. The ’520 patent teaches and claims control systems and streamer positioning devices for a variety of steering modes in marine seismic surveys. These steering modes enable sophisticated geophysical exploration for natural resources, promote the efficiency and efficacy of seismic surveys, and improve the safety of those operations. Western is the current assignee of the ’520 patent, and is the owner of the right to sue and to recover for any current or past infringement of that patent. A copy of the ’520 patent is attached hereto as Exhibit A.

18. On July 25, 2006, the ’607 patent, titled “Seismic Data Acquisition Equipment Control System,” was duly and legally issued to Western as assignee. The ’607 patent teaches and claims prediction and control units for use with streamer positioning devices to dynamically manage measurements and commands for lateral steering. This prediction and control allows operators to overcome the limitations of mis-measurements and signal latency across the many square miles of a marine seismic survey array. Western is the current assignee of the ’607 patent, and is the owner of the right to sue and to recover for any current or past infringement of that patent. A copy of the ’607 patent is attached hereto as Exhibit B.

19. On January 16, 2007, the ’967 patent, titled “Control System For Positioning Of Marine Seismic Streamers,” was duly and legally issued to Western as assignee. The ’967

patent teaches and claims a steering system apportioned between a shipboard global control system and local control systems on streamer positioning devices spread out across a seismic array. This distributed control balances the measurement, computing power and communication requirements across the various components of the marine seismic vessel and array to improve steering. Western is the current assignee of the ’967 patent, and is the owner of the right to sue and to recover for any current or past infringement of that patent. A copy of the ’967 patent is attached hereto as Exhibit C.

20. On February 10, 2004, the ’038 patent, titled “Active Separation Tracking And Positioning System For Towed Seismic Arrays,” was duly and legally issued to Western as assignee. The ’038 patent teaches and claims an array tracking and positioning system for repeating seismic surveys of the same location over time. This system allows for time-lapse, or 4-D seismic surveys, which allow reservoirs and formations to be monitored over time to manage the production of natural resources. Western is the current assignee of the ’038 patent, and is the owner of the right to sue and to recover for any current or past infringement of that patent. A copy of the ’038 patent is attached hereto as Exhibit D.

GEO AND DIGIFIN

21. Upon information and belief, every DigiFIN and Lateral Controller supplied or used by Geo, as discussed below, was manufactured in and supplied from the United States.

22. The supplying or causing the supply of DigiFIN and/or the Lateral Controller in or from the United States was found to infringe the ’520 patent, the ’607 patent, the ’967 patent, and the ’038 patent in the *ION* litigation, the judgment, verdict and rulings of which are hereby incorporated by reference. Western was not compensated for some or all of Geo’s infringement as a result of the *ION* litigation. For example, the *ION* Court limited the royalty

damages that Western could seek from ION in order to ensure that ION maintained a profit, while recognizing that Western's harm for the infringement was greater than such a royalty and allowing Western to seek higher royalty damages from ION's customers.

23. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each have been aware of the Patents-in-Suit and that DigiFIN and/or the Lateral Controller could infringe those patents since at least around September 2008, when ION discussed the possibility of such infringement with at least Vidar Hovland and Paul Courtenay, Geo employees as discussed below.

24. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. additionally each have been aware of the Patents-in-Suit and that DigiFIN and/or the Lateral Controller could infringe those patents since at least around December 8, 2009, when Western provided Geo with a copy of Western's Complaint in the *ION* litigation.

25. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. additionally each have been aware since around June 11, 2012 of the summary judgment in the *ION* litigation that supplying or causing to be supplied DigiFIN and the Lateral Controller for use in marine seismic surveys outside the United States infringes the '520 patent.

26. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. additionally each have been aware since around August 16, 2012 of the jury verdict in the *ION* litigation that supplying or causing to be supplied DigiFIN and/or the Lateral Controller for use in marine seismic surveys outside the United States infringes claims 18, 19, and 23 of the '520 patent; claim 15 of the '607 patent; claim 15 of the '967 patent; and claim 14 of the '038 patent under 35 U.S.C. §§ 271(f)(1) and (2).

Geo ASA

27. Upon information and belief, Geo ASA has caused the supply of DigiFIN and the Lateral Control in or from the United States for use in marine seismic surveys, and induced and contributed to the use, sale and offer for sale of DigiFIN and the Lateral Controller in surveys within the United States.

28. In a March 26, 2010 letter to Western, counsel for Geo Inc. disclosed that "Petroleum Geo-Services ASA [Geo ASA] is responsible for outfitting the marine vessels and for maintaining the records regarding what equipment is used on these vessels for its various customers." (Ex. M) Geo Inc.'s counsel further stated that "acquisition of equipment for [the infringing vessels] is under the direction and control of Petroleum Geo-Services ASA [Geo ASA]." Espen Sandvik, general counsel for Geo ASA at the time, was included in this correspondence.

29. Upon information and belief, Geo ASA began working with ION to design DigiFIN in 2005, and the infringing supply and use of DigiFIN began in 2007 and continued into at least 2012.

30. Upon information and belief, following meetings in Houston in 2005, Geo ASA entered into a DigiFIN Launch Partner Agreement with ION in 2006, which required ION to supply DigiFINs from the United States for use abroad. This agreement was executed by Vidar Hovland, a self-described employee of Geo ASA at the time.

31. Upon information and belief, in 2007, Oyvind Hillesund, an employee of Geo ASA at the time, contacted ION while working from a Houston address to continue the discussion of "Lateral Steering," the technology that would be embodied in DigiFIN. In 2009, an attorney for Geo Inc. confirmed to Western that Mr. Hillesund was an employee of Geo ASA.

(Ex. N) Espen Sandvik, general counsel for Geo ASA at the time, was also included in this confirmatory correspondence. Upon information and belief, in 2007, Sverre Olsen, an employee of Geo ASA at the time, met with ION in Houston to discuss the results of preliminary DigiFIN tests.

32. Upon information and belief, in 2007, Rune Eng, an employee of Geo ASA at the time, stated in a press release that Geo was "actively involved in maturing this [DigiFIN] technology through the ION-PGS Launch Partner Agreement, which enables first adoption of the technology by PGS" and that Geo was "pleased with the results of the tests on the *Atlantic Explorer* and *Pacific Explorer*." (Ex. O) Press releases from Geo ASA at this time describe Mr. Eng as "Group President Marine of Petroleum Geo-Services ASA," *i.e.*, Geo ASA. (Ex. P)

33. Upon information and belief, in a 2008 Geo ASA presentation to investors, Sverre Strandenes promoted the "DigiFIN Steerable streamers" on Geo's *Ramform Sovereign* vessel as resulting in "[f]aster deployment and retrieval" and "reduced tangling risk and faster line turns." (Ex. Q) Press releases from Geo ASA at this time describe Mr. Strandenes as "Group President Data Processing & Technology of Petroleum Geo-Services ASA," *i.e.*, Geo ASA. (Ex. P)

34. Upon information and belief, Geo ASA entered into Master Purchase Agreements with ION in 2009 and 2010 for acquiring DigiFIN. The agreements were signed by Vidar Hovland, a Geo ASA employee at the time as set forth above. The 2009 and 2010 Master Purchase Agreements were "governed by and construed according to the laws of Harris County, Texas" and enforceable "by arbitration to be held in Houston, Texas."

35. Upon information and belief, Geo ASA approved expenditures for DigiFIN. For example, on information and belief, Geo ASA authorized expenditures for the purchase of

184 DigiFIN units for the "DigiFIN System for the [Geo vessel] Ramform Sterling for their Statoil Job during Summer 2009." This expenditure was approved by Gottfred Langseth, the CFO of Geo ASA. The expenditure also required the approval of Rune Eng, a Geo ASA employee at the time as discussed above. By approving these expenditures, Geo ASA caused DigiFIN to be supplied in and from the United States. As set forth below, this infringed Western's patents under 35 U.S.C. § 271(f).

36. Upon information and belief, Geo ASA caused similar infringing supplies of DigiFIN from Houston to go to at least Geo's *Ramform Sovereign*, *Ramform Viking*, and *Apollo* vessels over the ensuing years.

37. Upon information and belief, Geo ASA participated in applications to the United States to perform seismic surveys with these vessels offshore of Texas using ports in Galveston and offices in Houston. For example, a 2013 permit application for the *PGS Apollo* was signed by Sverre Strandenes, a Geo ASA employee as discussed above, certifying the accuracy of all the information contained therein. (Ex. R) The resulting permit was likewise signed by Mr. Strandenes as "permittee." (Ex. S) As set forth below, the use, sale or offer for sale of DigiFIN in marine seismic surveys within the United States infringes Western's patents under 35 U.S.C. § 271(a), and Geo ASA induced and contributed to such infringement under 35 U.S.C. § 271 (b) and (c), respectively.

Geo A/S

38. Upon information and belief, Geo A/S purchased DigiFIN from ION from 2007 through at least 2012. Geo A/S took title to those DigiFIN while in ION's warehouse, shipped those DigiFIN into this judicial district, and supplied those DigiFIN in or from this judicial district for use on marine seismic surveys within and outside the United States. Upon

information and belief, Geo A/S has performed marine seismic surveys using DigiFIN and the Lateral Controller within the United States' Exclusive Economic Zone (EEZ).

39. Upon information and belief, Geo A/S entered into a Master Purchase Agreement with ION in 2008 for acquiring, *inter alia*, DigiFIN. The 2008 Master Purchase Agreement was "governed by and construed according to the laws of Harris County, Texas" and enforceable "by arbitration to be held in Houston, Texas." The agreement further states it is "between PGS Geophysical Inc. [*sic* Geo A/S] and ION."

40. The 2009 Master Purchase Agreement discussed above in paragraph 34 similarly states that it is "between PGS Geophysical Inc. [*sic* Geo A/S] and ION." To the extent the agreement was not between Geo ASA and ION, as averred above, upon information and belief it was between Geo A/S and ION.

41. Upon information and belief, Geo A/S entered into a Master Purchase Agreement with ION in 2010-2012 for acquiring, *inter alia*, DigiFIN. The 2011-2012 Master Purchase Agreement was "governed by and construed according to the laws of Harris County, Texas" and enforceable "by arbitration to be held in Houston, Texas." The agreement describes Geo A/S as "a company incorporated and organized under the laws of Texas."

42. To the extent that any of Mr. Hovland, Mr. Courtenay, Mr. Hillesund, Mr. Olsen, Mr. Eng or Mr. Standenes were not employees of Geo ASA as set forth above, upon information and belief they were employees of Geo A/S, and Western incorporates the above averments herein accordingly.

43. Upon information and belief, Geo A/S supplied or caused the supply of DigiFIN in or from the United States to at least the *Ramform Sterling*, *Ramform Sovereign*, *Ramform Viking*, and *Apollo*, thereby infringing Western's patents under 35 U.S.C. § 271(f).

44. Upon information and belief, Geo A/S has used, sold or offered for sale marine seismic systems including DigiFIN within the United States, including seismic surveys with the United States' Exclusive Economic Zone, thereby infringing Western's patents under 35 U.S.C. § 271(a). To the extent Geo A/S did not perform these surveys, it induced and contributed to such infringement under 35 U.S.C. § 271(b) and (c), respectively.

Geo Inc.

45. Upon information and belief, Geo Inc. markets, offers for sale, and sells marine seismic surveys including the accused DigiFIN and Lateral Controller. For example, Geo Inc. provided an affidavit in the *ION* litigation stating that Geo Inc. "markets seismic services to customers in the United States."

46. Upon information and belief, Geo Inc. employees and resources are used to perform marine seismic surveys using DigiFIN within the EEZ. For example, Geo applications to the U.S. government and permits received from the U.S. government for such surveys list Geo Inc.'s principle office as whom "[t]he activity will be conducted by" and the location for "the individual(s) in charge of the field operations." To the extent Geo A/S did not perform these surveys as set forth above, on information and belief, Geo Inc. did and thereby infringed Western's patents under 35 U.S.C. § 271(a). To the extent Geo Inc. did not perform these surveys, it induced and contributed to such infringement under 35 U.S.C. § 271(b) and (c), respectively.

47. The 2008 and 2009 Master Purchase Agreements state that they are "between PGS Geophysical Inc. [*sic* Geo Inc.] and ION." To the extent neither Geo ASA nor Geo A/S entered into either of these agreements, upon information and belief, Geo Inc. did, and to the extent Mr. Hillesund or any of the other Geo employees referenced above was neither an

employee of Geo ASA nor Geo A/S, upon information and belief, they were an employee of Geo Inc., and Geo Inc. thereby infringed Western's Patents-in-Suit under 35 U.S.C. § 271(f) as well.

COUNT I – INFRINGEMENT OF THE '520 PATENT

48. Western repeats and incorporates by reference the allegations set forth in paragraphs 1-47 above.

49. Geo ASA, Geo A/S and Geo Inc. each have infringed the '520 patent, literally and/or under the doctrine of equivalents, by making, using, offering to sell, selling, supplying and/or causing to be supplied in or from the United States products and services incorporating DigiFIN and the Lateral Controller—or components thereof—and/or inducing and/or contributing to such conduct by each other and/or other Geo entities, without authority and in violation of 35 U.S.C. § 271(a), (b), (c) and/or (f). Geo Inc. previously argued that the importation of seismic data can infringe a United States patent under 35 U.S.C. § 271(g). To the extent Geo Inc. is correct, Geo ASA, Geo A/S and Geo Inc. each infringe under this provision as well.

50. The DigiFIN and/or Lateral Controller comprise a substantial portion of the components of the system covered by the '520 patent. For example, the DigiFIN units supplied from the United States used on Geo's marine seismic vessels comprise streamer positioning devices as recited in claim 18 of the '520 patent. The Lateral Controller also supplied from the United States and intended to be combined with the DigiFIN units is configured to operate in one or more control modes selected from a feather angle mode, a turn control mode, and a streamer separation mode. The similar supply of DigiFIN, as well as DigiFIN and the Lateral Controller, from the United States for their intended use abroad by Geo's competitors was found to infringe the '520 patent under 35 U.S.C. § 271(f) in the *ION* litigation. The DigiFIN and Lateral

Controller are especially made and adapted for use in the invention of the ’520 patent and are not staple articles or commodities of commerce suitable for substantial noninfringing uses.

Geo ASA

51. Upon information and belief, Geo ASA, by entering into a Launch Partner Agreement with ION in 2006, working with ION to finalize and test DigiFIN, entering into Master Purchase Agreements with ION in 2009 and 2010, approving expenditures for the purchase of DigiFIN and the Lateral Controller, purchasing DigiFIN and the Lateral Controller, applying for U.S. permits for conducting seismic surveys, and/or equipping vessels with DigiFIN and the Lateral Controller, supplied or caused to be supplied the DigiFIN and Lateral Controller in or from the United States so as to actively induce their combination outside the United States in a manner that would infringe the ’520 patent if such combination occurred within the United States in violation of at least 35 U.S.C. § 271(f). Upon further information and belief, Geo ASA contributed to and induced Geo A/S’s and/or Geo Inc.’s infringement, as set forth below, in violation of at least 35 U.S.C. § 271(b) and (c), respectively.

Geo A/S

52. Upon information and belief, Geo A/S, by entering into a Launch Partner Agreement with ION in 2006, working with ION to finalize and test DigiFIN, entering into Master Purchase Agreements with ION in 2008, 2009, 2010, and 2011-2012, purchasing DigiFIN and the Lateral Controller, applying for U.S. permits for conducting seismic surveys, and/or equipping vessels with DigiFIN and the Lateral Controller, supplied or caused to be supplied the DigiFIN and Lateral Controller in or from the United States so as to actively induce their combination outside the United States in a manner that would infringe the ’520 patent if such combination occurred within the United States in violation of at least 35 U.S.C. § 271(f).

Upon information and belief, Geo A/S, by using, selling or offering for sale marine seismic systems including DigiFIN within the United States, including seismic surveys within the EEZ, infringed Western's patents under 35 U.S.C. § 271(a). Upon further information and belief, to the extent Geo A/S did not perform these surveys, it induced Geo Inc.'s infringement, as set forth below, in violation of at least 35 U.S.C. § 271(b) and (c), respectively.

Geo Inc.

53. Upon information and belief, Geo Inc., by working with ION to finalize and test DigiFIN, entering into Master Purchase Agreements with ION in 2008 and 2009, applying for U.S. permits for conducting seismic surveys, and/or equipping vessels with DigiFIN and the Lateral Controller, supplied or caused to be supplied the DigiFIN and Lateral Controller in or from the United States so as to actively induce their combination outside the United States in a manner that would infringe the '520 patent if such combination occurred within the United States in violation of at least 35 U.S.C. § 271(f). Upon information and belief, Geo Inc., by using, selling or offering for sale marine seismic systems including DigiFIN within the United States, including seismic surveys within the EEZ, infringed Western's patents under 35 U.S.C. § 271(a). Upon further information and belief, to the extent Geo Inc. did not perform these surveys, it induced and contributed to such infringement under 35 U.S.C. § 271(b) and (c), respectively.

Knowledge and Willfulness

54. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each were aware that the DigiFIN and the Lateral Controller products were made and adapted to infringe Western's '520 patent, and Geo ASA, Geo A/S and Geo Inc. each intended that DigiFIN and the Lateral Controller would be combined outside the United States in a manner that would infringe Western's '520 patent if such a combination occurred within the United States. Upon

information and belief, Geo ASA, Geo A/S and Geo Inc. each specifically intended to induce infringement of the ’520 patent, and were aware that they have induced acts that constitute infringement. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each have contributed to the infringement of the ’520 patent, and were aware that they have contributed to acts that constitute infringement.

55. None of Geo ASA, Geo A/S, or Geo Inc. has any license or other authority from Western or any other person or entity to practice the subject matter claimed by the ’520 patent.

56. Western has, at all relevant times, complied with the notice provisions of 35 U.S.C. § 287(a) with respect to the ’520 patent.

57. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each have been aware of the ’520 patent at all relevant times.

58. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each have willfully infringed the ’520 patent. Geo ASA’s, Geo A/S’s, and Geo Inc.’s willful infringement of the ’520 patent renders this an exceptional case pursuant to 35 U.S.C. § 285.

COUNT II – INFRINGEMENT OF THE ’607 PATENT

59. Western repeats and incorporates by reference the allegations set forth in paragraphs 1-58 above.

60. Geo ASA, Geo A/S and Geo Inc. each have infringed the ’607 patent, literally and/or under the doctrine of equivalents, by making, using, offering to sell, selling, supplying and/or causing to be supplied in or from the United States products and services incorporating DigiFIN and the Lateral Controller—or components thereof—and/or inducing and/or contributing to such conduct by each other and/or other Geo entities, without authority and in

violation of 35 U.S.C. § 271(a), (b), (c) and/or (f). Geo Inc. previously argued that the importation of seismic data can infringe a United States patent under 35 U.S.C. § 271(g). To the extent Geo Inc. is correct, Geo ASA, Geo A/S and Geo Inc. each infringe under this provision as well.

61. The DigiFIN and/or Lateral Controller comprise a substantial portion of the components of the system covered by the '607 patent. For example, the DigiFIN units supplied from the United States used on Geo's marine seismic vessels comprise streamer positioning devices as recited in claim 15 of the '607 patent. The Lateral Controller also supplied from the United States and intended to be combined with the DigiFIN units is a control unit adapted to use predicted positions to calculate desired changes in positions of the DigiFIN units. The similar supply of DigiFIN, as well as DigiFIN and the Lateral Controller, from the United States for their intended use abroad by Geo's competitors was found to infringe the '607 patent under 35 U.S.C. § 271(f) in the *ION* litigation. The DigiFIN and Lateral Controller are especially made and adapted for use in the invention of the '607 patent and are not staple articles or commodities of commerce suitable for substantial noninfringing uses.

Geo ASA

62. Upon information and belief, Geo ASA, by entering into a Launch Partner Agreement with ION in 2006, working with ION to finalize and test DigiFIN, entering into Master Purchase Agreements with ION in 2009 and 2010, approving expenditures for the purchase of DigiFIN and the Lateral Controller, purchasing DigiFIN and the Lateral Controller, applying for U.S. permits for conducting seismic surveys, and/or equipping vessels with DigiFIN and the Lateral Controller, supplied or caused to be supplied the DigiFIN and Lateral Controller in or from the United States so as to actively induce their combination outside the United States

in a manner that would infringe the ’607 patent if such combination occurred within the United States in violation of at least 35 U.S.C. § 271(f). Upon further information and belief, Geo ASA contributed to and induced Geo A/S’s and/or Geo Inc.’s infringement, as set forth below, in violation of at least 35 U.S.C. § 271(b) and (c), respectively.

Geo A/S

63. Upon information and belief, Geo A/S, by entering into a Launch Partner Agreement with ION in 2006, working with ION to finalize and test DigiFIN, entering into Master Purchase Agreements with ION in 2008, 2009, 2010, and 2011-2012, purchasing DigiFIN and the Lateral Controller, applying for U.S. permits for conducting seismic surveys, and/or equipping vessels with DigiFIN and the Lateral Controller, supplied or caused to be supplied the DigiFIN and Lateral Controller in or from the United States so as to actively induce their combination outside the United States in a manner that would infringe the ’607 patent if such combination occurred within the United States in violation of at least 35 U.S.C. § 271(f). Upon information and belief, Geo A/S, by using, selling or offering for sale marine seismic systems including DigiFIN within the United States, including seismic surveys within the EEZ, infringed Western’s patents under 35 U.S.C. § 271(a). Upon further information and belief, to the extent Geo A/S did not perform these surveys, it induced Geo Inc.’s infringement, as set forth below, in violation of at least 35 U.S.C. § 271(b) and (c), respectively.

Geo Inc.

64. Upon information and belief, Geo Inc., by working with ION to finalize and test DigiFIN, entering into Master Purchase Agreements with ION in 2008 and 2009, applying for U.S. permits for conducting seismic surveys, and/or equipping vessels with DigiFIN and the Lateral Controller, supplied or caused to be supplied the DigiFIN and Lateral Controller in or

from the United States so as to actively induce their combination outside the United States in a manner that would infringe the ’607 patent if such combination occurred within the United States in violation of at least 35 U.S.C. § 271(f). Upon information and belief, Geo Inc., by using, selling or offering for sale marine seismic systems including DigiFIN within the United States, including seismic surveys within the EEZ, infringed Western’s patents under 35 U.S.C. § 271(a). Upon further information and belief, to the extent Geo Inc. did not perform these surveys, it induced and contributed to such infringement under 35 U.S.C. § 271(b) and (c), respectively.

Knowledge and Willfulness

65. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each were aware that the DigiFIN and the Lateral Controller products were made and adapted to infringe Western’s ’607 patent, and Geo ASA, Geo A/S and Geo Inc. each intended that DigiFIN and the Lateral Controller would be combined outside the United States in a manner that would infringe Western’s ’607 patent if such a combination occurred within the United States. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each specifically intended to induce infringement of the ’607 patent, and were aware that they have induced acts that constitute infringement. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each have contributed to the infringement of the ’607 patent, and were aware that they have contributed to acts that constitute infringement.

66. None of Geo ASA, Geo A/S, or Geo Inc. has any license or other authority from Western or any other person or entity to practice the subject matter claimed by the ’607 patent.

67. Western has, at all relevant times, complied with the notice provisions of 35 U.S.C. § 287(a) with respect to the ’607 patent.

68. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each have been aware of the ’607 patent at all relevant times.

69. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each have willfully infringed the ’607 patent. Geo ASA’s, Geo A/S’s, and Geo Inc.’s willful infringement of the ’607 patent renders this an exceptional case pursuant to 35 U.S.C. § 285.

COUNT III – INFRINGEMENT OF THE ’967 PATENT

70. Western repeats and incorporates by reference the allegations set forth in paragraphs 1-69 above.

71. Geo ASA, Geo A/S and Geo Inc. each have infringed the ’967 patent, literally and/or under the doctrine of equivalents, by making, using, offering to sell, selling, supplying and/or causing to be supplied in or from the United States products and services incorporating DigiFIN and the Lateral Controller—or components thereof—and/or inducing and/or contributing to such conduct by each other and/or other Geo entities, without authority and in violation of 35 U.S.C. § 271(a), (b), (c) and/or (f). Geo Inc. previously argued that the importation of seismic data can infringe a United States patent under 35 U.S.C. § 271(g). To the extent Geo Inc. is correct, Geo ASA, Geo A/S and Geo Inc. each infringe under this provision as well.

72. The DigiFIN and/or Lateral Controller comprise a substantial portion of the components of the system covered by the ’967 patent. For example, the DigiFIN units supplied from the United States include a local controller as recited in claim 15 of the ’967 patent. The Lateral Controller also supplied from the United States and intended to be combined with the DigiFIN units comprises a global controller as claimed when integrated as part of the shipboard control system on Geo’s vessels. The similar supply of DigiFIN, as well as DigiFIN and the

Lateral Controller, from the United States for their intended use abroad by Geo's competitors was found to infringe the '967 patent under 35 U.S.C. § 271(f) in the *ION* litigation. The DigiFIN and Lateral Controller are especially made and adapted for use in the invention of the '967 patent and are not staple articles or commodities of commerce suitable for substantial noninfringing uses.

Geo ASA

73. Upon information and belief, Geo ASA, by entering into a Launch Partner Agreement with ION in 2006, working with ION to finalize and test DigiFIN, entering into Master Purchase Agreements with ION in 2009 and 2010, approving expenditures for the purchase of DigiFIN and the Lateral Controller, purchasing DigiFIN and the Lateral Controller, applying for U.S. permits for conducting seismic surveys, and/or equipping vessels with DigiFIN and the Lateral Controller, supplied or caused to be supplied the DigiFIN and Lateral Controller in or from the United States so as to actively induce their combination outside the United States in a manner that would infringe the '967 patent if such combination occurred within the United States in violation of at least 35 U.S.C. § 271(f). Upon further information and belief, Geo ASA contributed to and induced Geo A/S's and/or Geo Inc.'s infringement, as set forth below, in violation of at least 35 U.S.C. § 271(b) and (c), respectively.

Geo A/S

74. Upon information and belief, Geo A/S, by entering into a Launch Partner Agreement with ION in 2006, working with ION to finalize and test DigiFIN, entering into Master Purchase Agreements with ION in 2008, 2009, 2010, and 2011-2012, purchasing DigiFIN and the Lateral Controller, applying for U.S. permits for conducting seismic surveys, and/or equipping vessels with DigiFIN and the Lateral Controller, supplied or caused to be

supplied the DigiFIN and Lateral Controller in or from the United States so as to actively induce their combination outside the United States in a manner that would infringe the ’967 patent if such combination occurred within the United States in violation of at least 35 U.S.C. § 271(f). Upon information and belief, Geo A/S, by using, selling or offering for sale marine seismic systems including DigiFIN within the United States, including seismic surveys within the EEZ, infringed Western’s patents under 35 U.S.C. § 271(a). Upon further information and belief, to the extent Geo A/S did not perform these surveys, it induced Geo Inc.’s infringement, as set forth below, in violation of at least 35 U.S.C. § 271(b) and (c), respectively.

Geo Inc.

75. Upon information and belief, Geo Inc., by working with ION to finalize and test DigiFIN, entering into Master Purchase Agreements with ION in 2008 and 2009, applying for U.S. permits for conducting seismic surveys, and/or equipping vessels with DigiFIN and the Lateral Controller, supplied or caused to be supplied the DigiFIN and Lateral Controller in or from the United States so as to actively induce their combination outside the United States in a manner that would infringe the ’967 patent if such combination occurred within the United States in violation of at least 35 U.S.C. § 271(f). Upon information and belief, Geo Inc., by using, selling or offering for sale marine seismic systems including DigiFIN within the United States, including seismic surveys within the EEZ, infringed Western’s patents under 35 U.S.C. § 271(a). Upon further information and belief, to the extent Geo Inc. did not perform these surveys, it induced and contributed to such infringement under 35 U.S.C. § 271(b) and (c), respectively.

Knowledge and Willfulness

76. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each were aware that the DigiFIN and the Lateral Controller products were made and adapted to infringe

Western's '967 patent, and Geo ASA, Geo A/S and Geo Inc. each intended that DigiFIN and the Lateral Controller would be combined outside the United States in a manner that would infringe Western's '967 patent if such a combination occurred within the United States. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each specifically intended to induce infringement of the '967 patent, and were aware that they have induced acts that constitute infringement. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each have contributed to the infringement of the '967 patent, and were aware that they have contributed to acts that constitute infringement.

77. None of Geo ASA, Geo A/S, or Geo Inc. has any license or other authority from Western or any other person or entity to practice the subject matter claimed by the '967 patent.

78. Western has, at all relevant times, complied with the notice provisions of 35 U.S.C. § 287(a) with respect to the '967 patent.

79. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each have been aware of the '967 patent at all relevant times.

80. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each have willfully infringed the '967 patent. Geo ASA's, Geo A/S's, and Geo Inc.'s willful infringement of the '967 patent renders this an exceptional case pursuant to 35 U.S.C. § 285.

COUNT IV – INFRINGEMENT OF THE '038 PATENT

81. Western repeats and incorporates by reference the allegations set forth in paragraphs 1-80 above.

82. Geo ASA, Geo A/S and Geo Inc. each have infringed the '038 patent, literally and/or under the doctrine of equivalents, by making, using, offering to sell, selling, supplying

and/or causing to be supplied in or from the United States products and services incorporating DigiFIN and the Lateral Controller—or components thereof—and/or inducing and/or contributing to such conduct by each other and/or other Geo entities, without authority and in violation of 35 U.S.C. § 271(a), (b), (c) and/or (f). Geo Inc. previously argued that the importation of seismic data can infringe a United States patent under 35 U.S.C. § 271(g). To the extent Geo Inc. is correct, Geo ASA, Geo A/S and Geo Inc. each infringe under this provision as well.

83. The DigiFIN and/or Lateral Controller comprise a substantial portion of the components of the system covered by the '038 patent. For example, the DigiFIN units supplied from the United States comprise active streamer positioning devices (ASPDs) as recited in claim 14 of the '038 patent. The Lateral Controller also supplied from the United States and intended to be combined with the DigiFIN units issues vertical and horizontal commands to the DigiFIN units to maintain specific streamer array geometries. The similar supply of DigiFIN, as well as DigiFIN and the Lateral Controller, from the United States for their intended use abroad by Geo's competitors was found to infringe the '038 patent under 35 U.S.C. § 271(f) in the *ION* litigation. The DigiFIN and Lateral Controller are especially made and adapted for use in the invention of the '038 patent and are not staple articles or commodities of commerce suitable for substantial noninfringing uses.

Geo ASA

84. Upon information and belief, Geo ASA, by entering into a Launch Partner Agreement with ION in 2006, working with ION to finalize and test DigiFIN, entering into Master Purchase Agreements with ION in 2009 and 2010, approving expenditures for the purchase of DigiFIN and the Lateral Controller, purchasing DigiFIN and the Lateral Controller,

applying for U.S. permits for conducting seismic surveys, and/or equipping vessels with DigiFIN and the Lateral Controller, supplied or caused to be supplied the DigiFIN and Lateral Controller in or from the United States so as to actively induce their combination outside the United States in a manner that would infringe the ’038 patent if such combination occurred within the United States in violation of at least 35 U.S.C. § 271(f). Upon further information and belief, Geo ASA contributed to and induced Geo A/S’s and/or Geo Inc.’s infringement, as set forth below, in violation of at least 35 U.S.C. § 271(b) and (c), respectively.

Geo A/S

85. Upon information and belief, Geo A/S, by entering into a Launch Partner Agreement with ION in 2006, working with ION to finalize and test DigiFIN, entering into Master Purchase Agreements with ION in 2008, 2009, 2010, and 2011-2012, purchasing DigiFIN and the Lateral Controller, applying for U.S. permits for conducting seismic surveys, and/or equipping vessels with DigiFIN and the Lateral Controller, supplied or caused to be supplied the DigiFIN and Lateral Controller in or from the United States so as to actively induce their combination outside the United States in a manner that would infringe the ’038 patent if such combination occurred within the United States in violation of at least 35 U.S.C. § 271(f). Upon information and belief, Geo A/S, by using, selling or offering for sale marine seismic systems including DigiFIN within the United States, including seismic surveys within the EEZ, infringed Western’s patents under 35 U.S.C. § 271(a). Upon further information and belief, to the extent Geo A/S did not perform these surveys, it induced Geo Inc.’s infringement, as set forth below, in violation of at least 35 U.S.C. § 271(b) and (c), respectively.

Geo Inc.

86. Upon information and belief, Geo Inc., by working with ION to finalize and test DigiFIN, entering into Master Purchase Agreements with ION in 2008 and 2009, applying for U.S. permits for conducting seismic surveys, and/or equipping vessels with DigiFIN and the Lateral Controller, supplied or caused to be supplied the DigiFIN and Lateral Controller in or from the United States so as to actively induce their combination outside the United States in a manner that would infringe the ’038 patent if such combination occurred within the United States in violation of at least 35 U.S.C. § 271(f). Upon information and belief, Geo Inc., by using, selling or offering for sale marine seismic systems including DigiFIN within the United States, including seismic surveys within the EEZ, infringed Western’s patents under 35 U.S.C. § 271(a). Upon further information and belief, to the extent Geo Inc. did not perform these surveys, it induced and contributed to such infringement under 35 U.S.C. § 271(b) and (c), respectively.

Knowledge and Willfulness

87. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each were aware that the DigiFIN and the Lateral Controller products were made and adapted to infringe Western’s ’038 patent, and Geo ASA, Geo A/S and Geo Inc. each intended that DigiFIN and the Lateral Controller would be combined outside the United States in a manner that would infringe Western’s ’038 patent if such a combination occurred within the United States. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each specifically intended to induce infringement of the ’038 patent, and were aware that they have induced acts that constitute infringement. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each have contributed to the infringement of the ’038 patent, and were aware that they have contributed to acts that constitute infringement.

88. None of Geo ASA, Geo A/S, or Geo Inc. has any license or other authority from Western or any other person or entity to practice the subject matter claimed by the ’038 patent.

89. Western has, at all relevant times, complied with the notice provisions of 35 U.S.C. § 287(a) with respect to the ’038 patent.

90. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each have been aware of the ’038 patent at all relevant times.

91. Upon information and belief, Geo ASA, Geo A/S and Geo Inc. each have willfully infringed the ’038 patent. Geo ASA’s, Geo A/S’s, and Geo Inc.’s willful infringement of the ’038 patent renders this an exceptional case pursuant to 35 U.S.C. § 285.

PRAYER FOR RELIEF

WHEREFORE, Plaintiff Western prays for judgment:

A. Adjudging that Defendants Geo ASA, Geo A/S and Geo Inc. have infringed the ’520 patent;

B. Adjudging that Defendants Geo ASA, Geo A/S and Geo Inc. have infringed the ’607 patent;

C. Adjudging that Defendants Geo ASA, Geo A/S and Geo Inc. have infringed the ’967 patent;

D. Adjudging that Defendants Geo ASA, Geo A/S and Geo Inc. have infringed the ’038 patent;

E. Awarding Western damages adequate to compensate for Geo ASA’s, Geo A/S’s, and Geo Inc.’s infringement of the ’520 patent, the ’607 patent, the ’967 patent and the ’038 patent, together with interest and costs as fixed by the Court;

F. Adjudging that Geo ASA's, Geo A/S's, and Geo Inc.'s infringement of the '520 patent, the '607 patent, the '967 patent and the '038 patent has been willful and trebling all damages awarded to Western for such infringement pursuant to 35 U.S.C. § 284;

G. Enjoining Geo ASA, Geo A/S and Geo Inc., and any of their agents or related entities, from making, using, offering to sell, selling, supplying and/or causing to be supplied in or from the United States products and services that practice the subject matter of the '520 patent, the '607 patent, the '967 patent and the '038 patent pursuant to 35 U.S.C. § 283;

H. Enjoining Geo ASA, Geo A/S and Geo Inc., and any of their agents or related entities, from making, using, offering to sell, selling and/or supplying in or from the United States components of systems or methods that practice, or otherwise aiding or inducing Geo's customers or other persons or entities to practice, the subject matter of the '520 patent, the '607 patent, the '967 patent and the '038 patent pursuant to 35 U.S.C. § 283;

I. Declaring this case to be exceptional within the meaning of 35 U.S.C. § 285 and awarding Western the attorney fees, costs and expenses it incurs in this action; and

J. Awarding Western such other and further relief as the Court deems just and proper.

DEMAND FOR JURY TRIAL

Pursuant to Federal Rule of Civil Procedure 38, Plaintiff Western hereby demands a trial by jury for all the issues so triable.

Dated: April 7, 2014

Respectfully submitted,

/s/ Lee L. Kaplan

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CERTIFICATE OF SERVICE

I hereby certify that a true and correct copy of the above and foregoing instrument has been forwarded to all counsel of record pursuant to Federal Rules of Civil Procedure on this the 7th day of April, 2014.

/s/ Lee L. Kaplan

Exhibit A

US007293520B2

(12) **United States Patent**
Hillesund et al.

(10) **Patent No.: US 7,293,520 B2**
(45) **Date of Patent: *Nov. 13, 2007**

(54) **CONTROL SYSTEM FOR POSITIONING OF A MARINE SEISMIC STREAMERS**

(75) Inventors: **Oyvind Hillesund**, Histon (GB); **Simon Hastings Bittleston**, Bury St Edmunds (GB)

(73) Assignee: **WesternGeco, L.L.C.**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 102 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/455,042**

(22) Filed: **Jun. 16, 2006**

(65) **Prior Publication Data**

US 2006/0231007 A1 Oct. 19, 2006

(51) **Int. Cl.**
B63B 21/66 (2006.01)
G01V 1/38 (2006.01)

(52) **U.S. Cl.** **114/244**; 367/19

(58) **Field of Classification Search** 114/162, 114/163, 242, 244, 246, 253
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,375,800	A	4/1968	Cole et al.	114/235
3,412,705	A	11/1968	Nesson	115/12
3,434,446	A	3/1969	Cole	114/235
3,440,992	A	4/1969	Chance	114/235
3,560,912	A	2/1971	Spink et al.	340/3
3,605,674	A	9/1971	Weese	114/235 B
3,648,642	A	3/1972	Fetrow et al.	114/235
3,774,570	A	11/1973	Pearson	114/235 B
3,896,756	A	7/1975	Pearson et al.	114/235 B
3,931,608	A	1/1976	Cole	367/17
3,943,483	A	3/1976	Strange	340/7 PC
3,961,303	A	6/1976	Paitson	367/17
4,033,278	A	7/1977	Waters	114/245
4,063,213	A	12/1977	Itria et al.	367/17
4,087,780	A	5/1978	Itria et al.	367/17
4,222,340	A	9/1980	Cole	114/245
4,227,479	A	10/1980	Gertler et al.	114/312
4,290,124	A	9/1981	Cole	367/18

(Continued)

FOREIGN PATENT DOCUMENTS

AU 199853305 12/1997

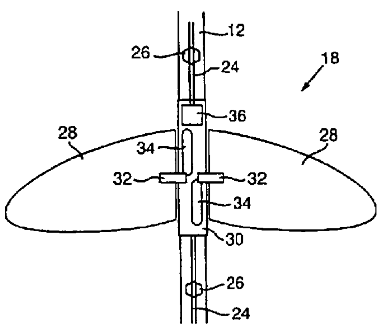
(Continued)

Primary Examiner—Jesús D Sotelo
(74) *Attorney, Agent, or Firm*—Liangang (Mark) Ye; Jeffrey E. Griffin

(57) **ABSTRACT**

A method of controlling a streamer positioning device (**18**) configured to be attached to a marine seismic streamer (**12**) and towed by seismic survey vessel (**10**) and having a wing and a wing motor for changing the orientation of the wing. The method includes the steps of: obtaining an estimated velocity of the streamer positioning device, calculating a desired change in the orientation of the wing using the estimated velocity of the streamer positioning device, and actuating the wing motor to produce the desired change in the orientation of the wing. The invention also involves an apparatus for controlling a streamer positioning device including means for obtaining an estimated velocity of the streamer positioning device, means for calculating a desired change in the orientation of the wing using the estimated velocity of the streamer positioning device, and means for actuating the wing motor to produce the desired change in the orientation of the wing.

34 Claims, 3 Drawing Sheets



U.S. PATENT DOCUMENTS

4,313,392	A	2/1982	Guenther et al.	114/244
4,323,989	A	4/1982	Huckabee et al.	367/17
4,404,664	A	9/1983	Zachariadis	367/19
4,463,701	A	8/1984	Pickett et al.	114/245
4,484,534	A	11/1984	Thillaye du Boullay	114/244
4,694,435	A	9/1987	Magneville	367/17
4,709,355	A	11/1987	Woods et al.	367/16
4,711,194	A	12/1987	Fowler	114/245
4,723,501	A	2/1988	Hovden et al.	114/144 B
4,729,333	A	3/1988	Kirby et al.	114/244
4,745,583	A	5/1988	Motal	367/18
4,766,441	A	8/1988	Phillips	343/709
4,767,183	A	8/1988	Martin	350/96.23
4,843,996	A	7/1989	Darche	114/245
4,890,568	A *	1/1990	Dolengowski	114/246
4,890,569	A	1/1990	Givens	114/349
4,912,684	A	3/1990	Fowler	367/76
4,992,990	A	2/1991	Langeland	367/19
5,042,413	A	8/1991	Benoit	114/244
5,052,814	A	10/1991	Stubblefield	367/15
5,402,745	A	4/1995	Wood	114/244
5,443,027	A	8/1995	Owsley et al.	114/244
5,507,243	A	4/1996	Williams et al.	114/245
5,517,202	A	5/1996	Patel	343/709
5,517,463	A	5/1996	Hornbostel et al.	367/13
5,529,011	A	6/1996	Williams, Jr.	114/245
5,532,975	A	7/1996	Elholm	367/16
5,619,474	A	4/1997	Kuche	367/17
5,642,330	A	6/1997	Santopietro	367/131
5,790,472	A	8/1998	Workman et al.	367/19
5,913,280	A *	6/1999	Nielsen et al.	114/242
5,973,995	A *	10/1999	Walker et al.	367/20
6,011,752	A	1/2000	Ambs et al.	367/17
6,011,753	A	1/2000	Chien	367/21
6,016,286	A	1/2000	Olivier et al.	367/17
6,144,342	A	11/2000	Bertheas et al.	343/709
6,459,653	B1	10/2002	Kuche	367/17
6,525,992	B1	2/2003	Olivier et al.	367/17
6,549,653	B1	4/2003	Osawa et al.	382/162
6,879,542	B2	4/2005	Soreau et al.	367/17
6,932,017	B1 *	8/2005	Hillesund et al.	114/244

FOREIGN PATENT DOCUMENTS

AU	734810 B	6/2001
CA	2270719	12/1997
DE	69702673 T	4/2001
EP	0193215	1/1986
EP	0319716	6/1989
EP	0321705	6/1989
EP	0525391	2/1993
EP	0390987	12/1993
EP	0613025	8/1994
EP	0581441	8/1997
EP	0909701	1/2003
GB	2093610	9/1982
GB	2122562	1/1984
GB	2320706	7/1998
GB	2331971	6/1999
GB	2342081	4/2000
NO	992701	6/1999
WO	WO95/31735	11/1995
WO	WO96/21163	7/1996
WO	WO97/11395	3/1997
WO	WO97/30361	8/1997
WO	WO97/45006	12/1997
WO	WO98/28636	7/1998
WO	WO99/04293	1/1999

* cited by examiner

Fig.1.
Prior Art

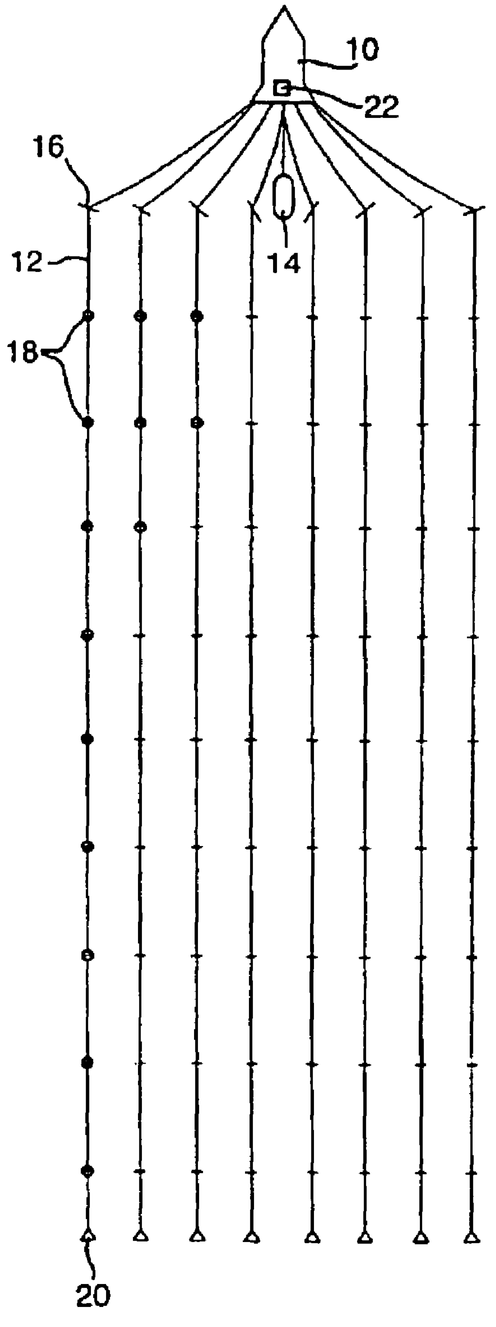


Fig.2.

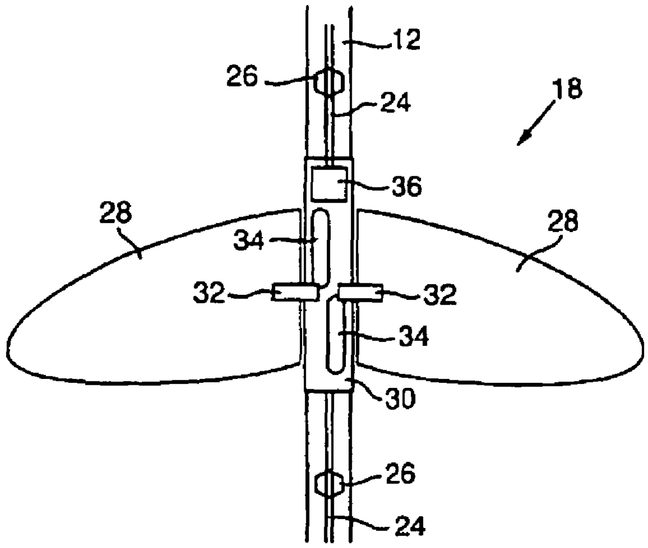


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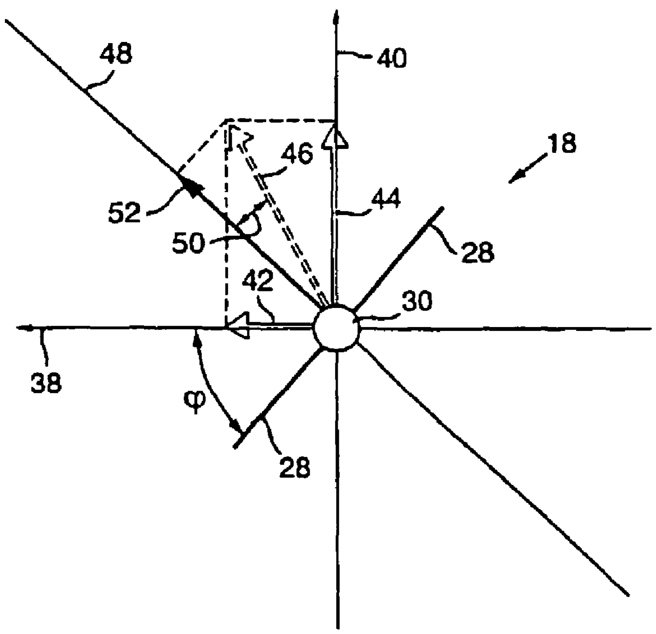
Fig.3.



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18
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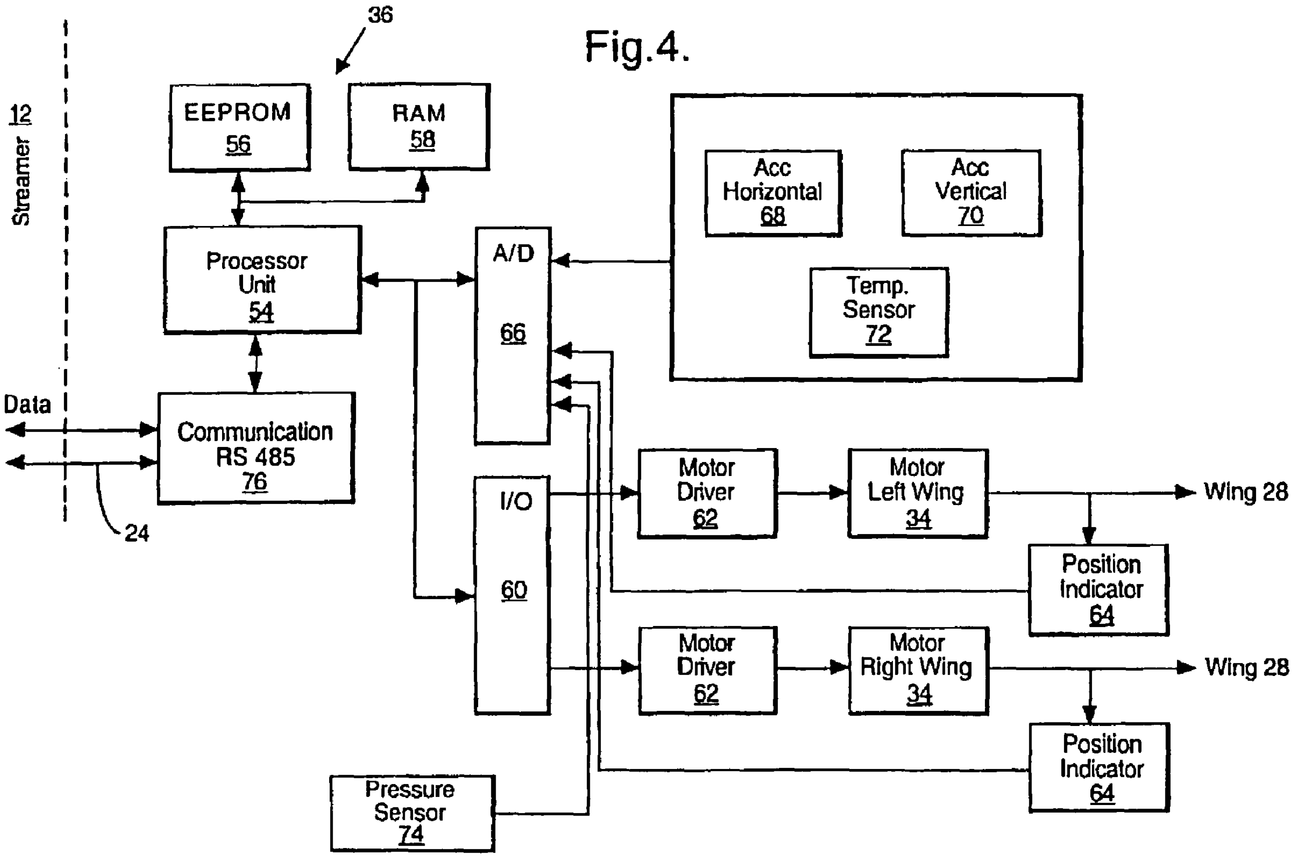
Fig.4.


36
12
Streamer
EEPROM
56
RAM
58
Processor
Unit
54
Data
Communication
RS 485
76
24
A/D
66
I/O
60
Acc
Horizontal
68
Acc
Vertical
70
Temp.
Sensor
72
Motor
Driver
62
Motor
Left Wing
34
Wing 28
Position
Indicator
64
Motor
Driver
62
Motor
Right Wing
34
Wing 28
Position
Indicator
64
Pressure
Sensor
74

CONTROL SYSTEM FOR POSITIONING OF A MARINE SEISMIC STREAMERS

CROSS-REFERENCE TO RELATED APPLICATIONS

Applicant claims priority under 35 U.S.C. § 120 from Ser. No. 11/070,614, filed Mar. 2, 2005, now U.S. Pat. No. 7,080,607, which was a continuation of parent application Ser. No. 09/787,723, filed Jul. 2, 2001, now U.S. Pat. No. 6,932,017, which was a 35 U.S.C. § 371 national stage filing from Patent Cooperation Treaty application number PCT/IB99/01590, filed Sep. 28, 1999, which in turn claimed priority from Great Britain patent application number 9821277.3, filed Oct. 1, 1998, from which Applicant claims foreign priority under 35 U.S.C. § 119, all of which are incorporated herein by reference. This application is also related to co-pending application Ser. Nos. 11/454,352 and 11/454,349, filed simultaneously herewith, which also are both incorporated herein by reference.

BACKGROUND OF THE INVENTION

This invention relates generally to systems for controlling seismic data acquisition equipment and particularly to a system for controlling a marine seismic streamer positioning device.

A marine seismic streamer is an elongate cable-like structure, typically up to several thousand meters long, which contains arrays of seismic sensors, known as hydrophones, and associated electronic equipment along its length, and which is used in marine seismic surveying. In order to perform a 3D marine seismic survey, a plurality of such streamers are towed at about 5 knots behind a seismic survey vessel, which also tows one or more seismic sources, typically air guns. Acoustic signals produced by the seismic sources are directed down through the water into the earth beneath, where they are reflected from the various strata. The reflected signals are received by the hydrophones, and then digitized and processed to build up a representation of the subsurface geology.

The horizontal positions of the streamers are typically controlled by a deflector, located at the front end or "head" of the streamer, and a tail buoy, located at the back end or "tail" of the streamer. These devices create tension forces on the streamer which constrain the movement of the streamer and cause it to assume a roughly linear shape. Cross currents and transient forces cause the streamer to bow and undulate, thereby introducing deviations into this desired linear shape.

The streamers are typically towed at a constant depth of approximately ten meters, in order to facilitate the removal of undesired "ghost" reflections from the surface of the water. To keep the streamers at this constant depth, control devices known as "birds", are typically attached at various points along each streamer between the deflector and the tail buoy, with the spacing between the birds generally varying between 200 and 400 meters. The birds have hydrodynamic deflecting surfaces, referred to as wings, that allow the position of the streamer to be controlled as it is towed through the water. When a bird is used for depth control purposes only, it is possible for the bird to regularly sense its depth using an integrated pressure sensor and for a local controller within the bird to adjust the wing angles to maintain the streamer near the desired depth using only a desired depth value received from a central control system.

While the majority of birds used thus far have only controlled the depth of the streamers, additional benefits can

be obtained by using properly controlled horizontally steerable birds, particularly by using the types of horizontally and vertically steerable birds disclosed in our published PCT International Application No. WO 98/28636. The benefits that can be obtained by using properly controlled horizontally steerable birds can include reducing horizontal out-of-position conditions that necessitate reacquiring seismic data in a particular area (i.e. in-fill shooting), reducing the chance of tangling adjacent streamers, and reducing the time required to turn the seismic acquisition vessel when ending one pass and beginning another pass during a 3D seismic survey.

It is estimated that horizontal out-of-position conditions reduce the efficiency of current 3D seismic survey operations by between 5 and 10%, depending on weather and current conditions. While incidents of tangling adjacent streamers are relatively rare, when they do occur they invariably result in prolonged vessel downtime. The loss of efficiency associated with turning the seismic survey vessel will depend in large part on the seismic survey layout, but typical estimates range from 5 to 10%. Simulations have concluded that properly controlled horizontally steerable birds can be expected to reduce these types of costs by approximately 30%.

One system for controlling a horizontally steerable bird, as disclosed in UK Patent GB 2093610 B, is to utilize a manually-operated central control system to transmit the magnitudes and directions of any required wing angle changes to the birds. While this method greatly simplifies the circuitry needed within the bird itself, it is virtually impossible for this type of system to closely regulate the horizontal positions of the birds because it requires manual input and supervision. This becomes a particularly significant issue when a substantial number of streamers are deployed simultaneously and the number of birds that must be controlled goes up accordingly.

Another system for controlling a horizontally steerable bird is disclosed in our published PCT International Application No. WO 98/28636. Using this type of control system, the desired horizontal positions and the actual horizontal positions are received from a remote control system and are then used by a local control system within the birds to adjust the wing angles. The actual horizontal positions of the birds may be determined every 5 to 10 seconds and there may be a 5 second delay between the taking of measurements and the determination of actual streamer positions. While this type of system allows for more automatic adjustment of the bird wing angles, the delay period and the relatively long cycle time between position measurements prevents this type of control system from rapidly and efficiently controlling the horizontal position of the bird. A more deterministic system for controlling this type of streamer positioning device is therefore desired.

It is therefore an object of the present invention to provide for an improved method and apparatus for controlling a streamer positioning device.

An advantage of the present invention is that the position of the streamer may be better controlled, thereby reducing the need for in-fill shooting, reducing the chance of streamer tangling, and reducing the time needed to turn the seismic survey vessel.

Another advantage of the present invention is that noise in marine seismic data associated with streamer position overcorrection and streamer positioning errors can be significantly reduced.

SUMMARY OF THE INVENTION

The present invention provides methods and apparatus for controlling the positions of marine seismic streamers in an array of such streamers being towed by a seismic survey vessel, the streamers having respective streamer positioning devices disposed therealong and each streamer positioning device having a wing and a wing motor for changing the orientation of the wing so as to steer the streamer positioning device laterally, said methods and apparatus involving (a) obtaining an estimated velocity of the streamer positioning devices, (b) for at least some of the streamer positioning devices, calculating desired changes in the orientation of their wings using said estimated velocity, and (c) actuating the wing motors to produce said desired changes in wing orientation.

The invention and its benefits will be better understood with reference to the detailed description below and the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of a seismic survey vessel and associated seismic data acquisition equipment;

FIG. **2** is a schematic horizontal cross-sectional view through a marine seismic streamer and an attached streamer positioning device;

FIG. **3** is a schematic vertical cross-sectional view through the streamer positioning device from FIG. **2**; and

FIG. **4** is a schematic diagram of the local control system architecture of the streamer positioning device from FIG. **2**.

DETAILED DESCRIPTION OF THE INVENTION

In FIG. **1**, a seismic survey vessel **10** is shown towing eight marine seismic streamers **12** that may, for instance, each be 3000 meters in length. The outermost streamers **12** in the array could be 700 meters apart, resulting in a horizontal separation between the streamers of 100 meters in the regular horizontal spacing configuration shown. A seismic source **14**, typically an airgun or an array of airguns, is also shown being towed by the seismic survey vessel **10**. At the front of each streamer **12** is shown a deflector **16** and at the rear of every streamer is shown a tail buoy **20**. The deflector **16** is used to horizontally position the end of the streamer nearest the seismic survey vessel **10** and the tail buoy **20** creates drag at the end of the streamer farthest from the seismic survey vessel **10**. The tension created on the seismic streamer by the deflector **16** and the tail buoy **20** results in the roughly linear shape of the seismic streamer **12** shown in FIG. **1**.

Located between the deflector **16** and the tail buoy **20** are a plurality of streamer positioning devices known as birds **18**. Preferably the birds **18** are both vertically and horizontally steerable. These birds **18** may, for instance, be located at regular intervals along the streamer, such as every 200 to 400 meters. The vertically and horizontally steerable birds **18** can be used to constrain the shape of the seismic streamer **12** between the deflector **16** and the tail buoy **20** in both the vertical (depth) and horizontal directions.

In the preferred embodiment of the present invention, the control system for the birds **18** is distributed between a global control system **22** located on or near the seismic survey vessel **10** and a local control system located within or near the birds **18**. The global control system **22** is typically connected to the seismic survey vessel's navigation system and obtains estimates of system wide parameters, such as the vessel's towing direction and velocity and current direction and velocity, from the vessel's navigation system.

The most important requirement for the control system is to prevent the streamers **12** from tangling. This requirement becomes more and more important as the complexity and the total value of the towed equipment increases. The trend in the industry is to put more streamers **12** on each seismic survey vessel **10** and to decrease the horizontal separation between them. To get better control of the streamers **12**, horizontal steering becomes necessary. If the birds **18** are not properly controlled, horizontal steering can increase, rather than decrease, the likelihood of tangling adjacent streamers. Localized current fluctuations can dramatically influence the magnitude of the side control required to properly position the streamers. To compensate for these localized current fluctuations, the inventive control system utilizes a distributed processing control architecture and behavior-predictive model-based control logic to properly control the streamer positioning devices.

In the preferred embodiment of the present invention, the global control system **22** monitors the actual positions of each of the birds **18** and is programmed with the desired positions of or the desired minimum separations between the seismic streamers **12**. The horizontal positions of the birds **18** can be derived, for instance, using the types of acoustic positioning systems described in our U.S. Pat. No. 4,992,990 or in our PCT International Patent Application No. WO 98/21163. Alternatively, or additionally, satellite-based global positioning system equipment can be used to determine the positions of the equipment. The vertical positions of the birds **18** are typically monitored using pressure sensors attached to the birds, as discussed below.

The global control system **22** preferably maintains a dynamic model of each of the seismic streamers **12** and utilizes the desired and actual positions of the birds **18** to regularly calculate updated desired vertical and horizontal forces the birds should impart on the seismic streamers **12** to move them from their actual positions to their desired positions. Because the movement of the seismic streamer **12** causes acoustic noise (both from seawater flow past the bird wing structures as well as cross current flow across the streamer skin itself), it is important that the streamer movements be restrained and kept to the minimum correction required to properly position the streamers. Any streamer positioning device control system that consistently overestimates the type of correction required and causes the bird to overshoot its intended position introduces undesirable noise into the seismic data being acquired by the streamer. In current systems, this type of over-correction noise is often balanced against the "noise" or "smearing" caused when the seismic sensors in the streamers **12** are displaced from their desired positions.

The global control system **22** preferably calculates the desired vertical and horizontal forces based on the behavior of each streamer and also takes into account the behavior of the complete streamer array. Due to the relatively low sample rate and time delay associated with the horizontal position determination system, the global control system **22** runs position predictor software to estimate the actual locations of each of the birds **18**. The global control system **22** also checks the data received from the vessel's navigation system and the data will be filled in if it is missing. The interface between the global control system **22** and the local control system will typically operate with a sampling frequency of at least 0.1 Hz. The global control system **22** will typically acquire the following parameters from the vessel's navigation system: vessel speed (m/s), vessel heading (degrees), current speed (m/s), current heading (degrees), and the location of each of the birds in the horizontal plane in a vessel fixed coordinate system. Current speed and heading can also be estimated based on the average forces acting on the streamers **12** by the birds **18**. The global control system **22** will preferably send the following values to the local bird controller: demanded vertical force, demanded horizontal force, towing velocity, and crosscurrent velocity.

The towing velocity and crosscurrent velocity are preferably "water-referenced" values that are calculated from the vessel speed and heading values and the current speed and heading values, as well as any relative movement between the seismic survey vessel **10** and the bird **18** (such as while the vessel is turning), to produce relative velocities of the bird **18** with respect to the water in both the "in-line" and the "cross-line" directions. Alternatively, the global control system **22** could provide the local control system with the horizontal velocity and water in-flow angle. The force and velocity values are delivered by the global control system **22** as separate values for each bird **18** on each streamer **12** continuously during operation of the control system.

The "water-referenced" towing velocity and crosscurrent velocity could alternatively be determined using flowmeters or other types of water velocity sensors attached directly to the birds **18**. Although these types of sensors are typically quite expensive, one advantage of this type of velocity determination system is that the sensed in-line and cross-line velocities will be inherently compensated for the speed and heading of marine currents acting on said streamer positioning device and for relative movements between the vessel **10** and the bird **18**.

FIG. **2** shows a type of bird **18** that is capable of controlling the position of seismic streamers **12** in both the vertical and horizontal directions. A bird **18** of this type is also disclosed in our PCT International Application No. WO 98/28636. While a number of alternative designs for the vertically and horizontally steerable birds **18** are possible, including those utilizing one full-moving wing with ailerons, three full-moving wings, and four full-moving wings, the independent two-wing principal is, conceptually, the simplest and most robust design.

In FIG. **2**, a portion of the seismic streamer **12** is shown with an attached bird **18**. A communication line **24**, which may consist of a bundle of fiber optic data transmission cables and power transmission wires, passes along the length of the seismic streamer **12** and is connected to the seismic sensors, hydrophones **26**, that are distributed along the length of the streamer, and to the bird **18**. The bird **18** preferably has a pair of independently moveable wings **28** that are connected to rotatable shafts **32** that are rotated by wing motors **34** and that allow the orientation of the wings **28** with respect to the bird body **30** to be changed. When the shafts **32** of the bird **18** are not horizontal, this rotation causes the horizontal orientation of the wings **28** to change and thereby changes the horizontal forces that are applied to the streamer **12** by the bird.

The motors **34** can consist of any type of device that is capable of changing the orientation of the wings **28**, and they are preferably either electric motors or hydraulic actuators. The local control system **36** controls the movement of the wings **28** by calculating a desired change in the angle of the wings and then selectively driving the motors **34** to effectuate this change. While the preferred embodiment depicted utilizes a separate motor **34** for each wing **28**, it would be also be possible to independently move the wings **28** using a single motor **34** and a selectively actuatable transmission mechanism.

When the bird **18** uses two wings **28** to produce the horizontal and vertical forces on the streamer **12**, the required outputs of the local control system **36** are relatively simple, the directions and magnitudes of the wing movements required for each of the wings **28**, or equivalently the magnitude and direction the motors **34** need to be driven to produce this wing movement. While the required outputs of the local control system **36** for such a two full moving wing design is quite simple, the structure and operation of the overall system required to coordinate control of the device is relatively complicated.

FIG. **3** shows a schematic vertical cross-sectional view through the streamer positioning device shown in FIG. **2** that will allow the operation of the inventive control system to be described in more detail. The components of the bird **18** shown in FIG. **3** include the wings **28** and the body **30**. Also shown in FIG. **3** are a horizontal coordinate axis **38** and a vertical coordinate axis **40**. During operation of the streamer positioning control system, the global control system **22** preferably transmits, at regular intervals (such as every five seconds) a desired horizontal force **42** and a desired vertical force **44** to the local control system **36**.

The desired horizontal force **42** and the desired vertical force **44** are combined within the local control system **36** to calculate the magnitude and direction of the desired total force **46** that the global control system **22** has instructed the local control system to apply to the streamer **12**. The global control system **22** could alternatively provide the magnitude and direction of the desired total force **46** to the local control system **36** instead of the desired horizontal force **42** and the desired vertical force **44**.

While the desired horizontal force **42** and the desired vertical force **44** are preferably calculated by the global control system **22**, it is also possible for the local control system **36** in the inventive control system to calculate one or both of these forces using a localized displacement/force conversion program. This type of localized conversion program may, for instance, use a look-up table or conversion routine that associates certain magnitudes and directions of vertical or horizontal displacements with certain magnitudes and directions of changes in the vertical or horizontal forces required. Using this type of embodiment, the global control system **22** can transmit location information to the local control system **36** instead of force information. Instead of the desired vertical force **44**, the global control system **22** can transmit a desired vertical depth and the local control system **36** can calculate the magnitude and direction of the deviation between the desired depth and the actual depth. Similarly, instead of transmitting a desired horizontal force **42**, the global control system **22** can transmit the magnitude and direction of the displacement between the actual horizontal position and the desired horizontal position of the bird **18**. One advantage to this alternative type of system is that the required vertical force can be rapidly updated as the local control system receives updated depth information from the integrated pressure sensor. Other advantages of this type of alternative system include reducing communication traffic on the communication line **24** and simplifying the programming needed to convert the measured vertical and/or horizontal displacements into corresponding forces to be applied by the birds **18**.

When the local control system **36** has a new desired horizontal force **42** and desired vertical force **44** to be applied, the wings **28** will typically not be in the proper orientation to provide the direction of the desired total force **46** required. As can be seen in FIG. **3**, the wings **28** introduce a force into the streamer **12** along an axis perpendicular to the rotational axis of the wings **28** and perpendicular to the streamer. This force axis **48** is typically not properly aligned with the desired total force **46** when new desired horizontal and vertical force values are received from the global control system **22** or determined by the local control system **36** and some rotation of the bird **18** is required before the bird can produce this desired total force **46**. As can be seen, the force axis **48** is directly related to the bird roll angle, designated in FIG. **3** as ϕ.

The local control system **36** optimizes the control process by projecting the desired total force **46** onto the force axis **48** (i.e. multiplying the magnitude of the desired total force by the cosine of the deviation angle **50**) to produce an intermediate desired force **52** and then adjusting the wing common angle α (the angle of the wings with respect to the bird body **30**, or the average angle if there is a non-zero splay angle) to produce this magnitude of force along the force axis. The calculated desired common wing angle is compared to the current common wing angle to calculate a desired change in the common wing angle and the wing motors **34** are actuated to produce this desired change in the orientation of the wings.

A splay angle is then introduced into the wings **28** to produce a rotational movement in the bird body **30** (i.e. to rotate the force axis **48** to be aligned with the desired total force **46**). The splay angle is the difference between the angles of the wings **28** with respect to the bird body **30**. As the bird body **30** rotates and the force axis **48** becomes more closely aligned with the desired total force **46**, the bird roll angle and the bird roll angular velocity are monitored, the splay angle is incrementally reduced, and the common angle is incrementally increased until the intermediate desired force **52** is in the same direction and of the same magnitude as the desired total force. The local control system **36** carefully regulates the splay angle to ensure that the streamer is stable in roll degree of freedom. The calculated common wing angle and the splay angle are also regulated by the local control system **36** to prevent the wings **28** from stalling and to ensure that the splay angle is prioritized.

When using the type of birds described in our published PCT International Application No. WO 98/28636, where the bird **18** is rigidly attached, and cannot rotate with respect, to the streamer **12**, it is important for the control system to take the streamer twist into account. If this is not taken into account, the bird **18** can use all of its available splay angle to counter the twist in the streamer **12**. The bird **18** will then be unable to reach the demanded roll angle and the generated force will decrease. The inventive control system incorporates two functions for addressing this situation; the anti-twist function and the untwist function.

In the anti-twist function, the streamer twist is estimated by weightfunction filtering the splay angle measurements instead of simply averaging the splay angle measurements to improve the bandwidth of the estimation. The anti-twist function engages when the estimated twist has reached a critical value and it then overrides the normal shortest path control of the calculated roll angle. The anti-twist function forces the bird **18** to rotate in the opposite direction of the twist by adding +/−180 degrees to the demanded roll angle. Once the twist has been reduced to an acceptable value, the anti-twist function disengages and the normal shortest path calculation is continued.

The untwist function is implemented by the global control system **22** which monitors the splay angle for all of the birds **18** in each streamer **12**. At regular intervals or when the splay angle has reached a critical value, the global control system **22** instructs each local control system **36** to rotate each bird **18** in the opposite direction of the twist. The number of revolutions done by each bird **18** is monitored and the untwist function is disengaged once the twist has reached an acceptable level. FIG. **4** is a schematic diagram of the architecture of the local control system **36** for the bird **18**. The local control system **36** consists of a central processor unit **54**, having EEPROM **56** and RAM **58** memory, an input/output subsystem **60** that is connected to a pair of motor drivers **62**, and an analog to digital conversion unit **66**. The motor drivers **62** are connected to and actuate the wing motors **34** to produce the desired change the orientation of the wings **28** with respect to the bird body **30**.

The wing motor **34**/wing **28** units are also connected to wing position indicators **64** that sense the relative positions of the wings and provide measurements to the analog to digital conversion unit **66** which converts the analog wing position indicator **64** measurements into digital format and conveys these digital values to the central processor unit **54**. Various types of wing position indicators **64** can be used, including resistive angle or displacement sensors inductive sensors, capacitive sensors, hall sensors, or magneto-restrictive sensors.

A horizontal accelerometer **68** and a vertical accelerometer **70**, placed at right angles with respect to one another, are also connected to the analog to digital conversion unit **66** and these accelerometers convey measurements that allow the central processor unit **54** to determine the roll angle and roll rate of the bird **18**. An angular velocity vibrating rate gyro (rategyro) can also be used to measure the roll rate of the bird **18**. A temperature sensor **72** is connected to the analog to digital conversion unit **66** to provide temperature measurements that allow the horizontal accelerometer **68** and the vertical accelerometer **70** to be calibrated.

A pressure sensor **74** is also connected to the analog to digital conversion unit **66** to provide the central processor unit **54** with measurements of the water pressure at the bird **18**. To calculate an appropriate depth value, the measured pressure values must be filtered to limit the disturbance from waves. This is done in the inventive control system with a weightfunction filter that avoids the large phase displacements caused by mean value filters. Instead of using an instantaneous depth value or simply calculating an average depth value over a given period of time (and thereby incorporating a large phase displacement into the depth value), the inventive control system uses a differentially weighted pressure filtering scheme. First the pressure values are transformed into depth values by dividing the pressure sensor reading by the seawater density and gravitational acceleration. These depth values are then filtered using a weight function filter. Typical incremental weighting functions values range from 0.96 to 0.90 (sample weights of 1.0, 0.9, 0.81, 0.729, etc.) and the filter will typically process depth values received over a period of at least 100 seconds.

The central processor unit **54** is also connected to a RS485 communications unit **76** that allows information to be exchanged between the local control system **36** and the global control system **22** over the communication line **24** that passes through the streamer **12**. The RS485 bus may, for instance, utilize Neuron chips that communicate using a Local Operating Network protocol to control the data transfer.

Preferably, the central processor unit **54** and associated components comprise a MicroChip 17C756 processor. This type of microprocessor has very low power requirements, a dual UART on-chip, 12-channel, 10 bit ADC on-chip, 908×8 RAM, 16 k×16 ROM, and 50 digital I/O channels. The software running on the central processor unit **54** will typically consist of two units, the local control unit and the hardware control unit. It is typically not possible to pre-load both of these program units into the EEPROM **56** and it is possible to update these program units without having to open the bird **18**. The on-chip memory may thus only initially contain a boot-routine that enables the loading of software units into the external memory via the RS485 communication unit **76**. The external program memory (EEPROM **56**) will typically be a non-volatile memory so that these program units do not have to be re-loaded after every power down.

The central processor unit **54** must be able to run the local control system software fast enough to secure the sampling frequency needed for effective local bird control. This may mean, for instance, a sample rate of 10 Hz, which may be 10 to 100 times faster than the sample rate of the communications between the global control system **22** and the local control system **36**. As discussed above, the central processor unit **54** will also receive data from sensors attached to the bird **18**. The sensed values include bird roll angle, bird roll angular velocity (roll rate), the wing angles, and the static pressure of the water. These values are typically delivered to the central processor unit **54** at a sample rate of at least 10 Hz. The following values may be transmitted from the local control system **36** to the global control system **22** using the RS485 communication unit **76**: the measured roll angle, the measured roll rate, the measured wing angles, the measured water pressure, the calculated depth, and the calculated wing forces.

The system has been designed with a redundant communication system to increase its overall reliability. The bird **18** will typically have a backup communications channel, such as by overlaying a backup control signal on top of the power line current. This backup communications channel is particularly important because in the event of loss of communications to the bird **18** there would otherwise be no method for instructing the bird **18** to bring the streamer **12** to surface so the defective communications equipment can be repaired or replaced.

In contrast to previous streamer position device control systems, the present control system converts the desired horizontal force **42** and the desired vertical force **44** into a desired roll angle ϕ and a desired common wing angle α by deterministic calculations, rather than using an "incremental change/measured response/further incremental change based on measured response" type of feedback control circuit. The desired roll angle ϕ can be calculated in the manner discussed in the text describing FIG. **3** above. The magnitude of the force F imparted by the wings **28** along the force axis **48** can, for instance, be deterministically calculated using the following formula:

$$F=0.5\rho A C_L(V_{tow}\cos(\alpha)-V_{current}\sin(\alpha))^2$$

where: ρ=water density;

A=wing area;

C_L=wing lift coefficient;

α=common wing angle;

V_{tow}=towing velocity; and

$V_{current}$=crosscurrent velocity.

A similar deterministic calculation could be made using a calculated coefficient that incorporates the towing velocity of the bird **18**. A gain factor GF, for instance, could be calculated as follows:

$$GF=0.5\rho A C_L(V_{tow})^2$$

which could be simply multiplied by $\cos(\alpha)^2$ to estimate the force that would be applied for a given common angle.

One of the beneficial elements of the inventive control system is that the desired change in the orientation of the wing **28** is calculated using an estimate of the velocity of the bird **18** rather than simply relying on a feedback-loop type of control system that operates in the same manner regardless of the vessel speed. Because the force produced by wing **28** is proportional to the velocity of the device squared, a much more precise calculation of the desired change in the wing orientation can be made by using an estimate of the device velocity.

The inventive control system is based on shared responsibilities between the global control system **22** located on the seismic survey vessel **10** and the local control system **36** located on the bird **18**. The global control system **22** is tasked with monitoring the positions of the streamers **12** and providing desired forces or desired position information to the local control system **36**. The local control system **36** within each bird **18** is responsible for adjusting the wing splay angle to rotate the bird to the proper position and for adjusting the wing common angle to produce the magnitude of total desired force required.

The inventive control system will primarily operate in two different control modes: a feather angle control mode and a turn control mode. In the feather angle control mode, the global control system **22** attempts to keep each streamer in a straight line offset from the towing direction by a certain feather angle. The feather angle could be input either manually, through use of a current meter, or through use of an estimated value based on the average horizontal bird forces. Only when the crosscurrent velocity is very small will the feather angle be set to zero and the desired streamer positions be in precise alignment with the towing direction.

The turn control mode is used when ending one pass and beginning another pass during a 3D seismic survey, sometimes referred to as a "line change". The turn control mode consists of two phases. In the first part of the turn, every bird **18** tries to "throw out" the streamer **12** by generating a force in the opposite direction of the turn. In the last part of the turn, the birds **18** are directed to go to the position defined by the feather angle control mode. By doing this, a tighter turn can be achieved and the turn time of the vessel and equipment can be substantially reduced. Typically during the turn mode adjacent streamers will be depth separated to avoid possible entanglement during the turn and will be returned to a common depth as soon as possible after the completion of the turn. The vessel navigation system will typically notify the global control system **22** when to start throwing the streamers **12** out, and when to start straightening the streamers.

In extreme weather conditions, the inventive control system may also operate in a streamer separation control mode that attempts to minimize the risk of entanglement of the streamers. In this control mode, the global control system **22** attempts to maximize the distance between adjacent streamers. The streamers **12** will typically be separated in depth and the outermost streamers will be positioned as far away from each other as possible. The inner streamers will then be regularly spaced between these outermost streamers, i.e. each bird **18** will receive desired horizontal forces **42** or desired horizontal position information that will direct the bird **18** to the midpoint position between its adjacent streamers.

While the embodiment of the inventive control system described above is shown in connection with a "bird" type of streamer positioning device, it will be readily understood that the control system method and apparatus may also be used in connection with streamer positioning devices that are characterized as "deflectors" or steerable "tail buoys" because they are attached to either the front end or the back end of the streamer **12**.

The present invention includes any novel feature or novel combination of features disclosed herein, either explicitly or implicitly.

What is claimed is:

1. A method comprising:

(a) towing an array of streamers each having a plurality of streamer positioning devices there along contributing to steering the streamers;

(b) controlling the streamer positioning devices with a control system configured to operate in one or more control modes selected from a feather angle mode, a turn control mode, and a streamer separation mode.

2. The method of claim **1** wherein the control mode is the feather angle mode, and the controlling comprises the control system attempting to keep each streamer in a straight line offset from a towing direction by a feather angle.

3. The method of claim **2** comprising inputting the feather angle manually.

4. The method of claim **2** comprising inputting the feather angle using an estimated value based on an average of horizontal forces on the streamer positioning devices.

5. The method of claim **2** comprising setting the feather angle to zero when crosscurrent velocity is very small and desired streamer positions are in alignment with the towing direction.

6. The method of claim **1** wherein the towing comprises ending one pass, turning a towing vessel having the streamers attached thereto while throwing out the streamers before beginning another pass, with the control mode in the turn control mode during the turning and throwing out.

7. The method of claim **6** comprising turning during a 3D seismic survey.

8. The method of claim **6** comprising turning during a line change.

9. The method of claim **6** comprising commanding each streamer positioning device to generate a force in an opposite direction of the turning, and then commanding each streamer positioning device to go to a position defined by the feather angle control mode.

10. The method of claim **6** comprising separating adjacent streamers by depth during the turning mode to avoid possible entanglement during the turning.

11. The method of claim **10** comprising returning adjacent streamers to a common depth after the completion of the turning.

12. The method of claim **6** comprising notifying the control system, via a vessel navigation system, when to start throwing the streamers out, and when to start straightening the streamers.

13. The method of claim **1** wherein the control mode is the streamer separation mode, the control system attempting to minimize the risk of entanglement of the streamers.

14. The method of claim **13** comprising the control system attempting to maximize distance between adjacent streamers.

15. The method of claim **13** comprising separating the streamers in depth.

16. The method of claim **15** wherein the array of streamers comprises two streamers, and comprising positioning the two streamers as far away from each other as possible.

17. The method of claim **15** wherein the array of streamers comprises three or more streamers, the array comprising one port-most streamer, one starboard-most streamer and at least one inner streamer and comprising positioning the port-most and starboard-most streamers as far away form each other as possible.

18. An apparatus comprising:

(a) an array of streamers each having a plurality of streamer positioning devices there along;

(b) a control system configured to use a control mode selected from a feather angle mode, a turn control mode, a streamer separation mode, and two or more of these modes.

19. The apparatus of claim **18** wherein the control mode is the feather angle mode, and the controlling comprises the control system attempting to keep each streamer in a straight line offset from a towing direction by a feather angle.

20. The apparatus of claim **19** comprising inputting the feather angle manually.

21. The apparatus of claim **19** comprising inputting the feather angle using an estimated value based on an average of horizontal forces on the streamer positioning devices.

22. The apparatus of claim **19** comprising setting the feather angle to zero when crosscurrent velocity is very small and desired streamer positions are in alignment with the towing direction.

23. The apparatus of claim **18** wherein the towing comprises ending one pass, turning a towing vessel having the streamers attached thereto while throwing out the streamers before beginning another pass, with the control mode in the turn control mode during the turning and throwing out.

24. The apparatus of claim **23** comprising turning during a 3D seismic survey.

25. The apparatus of claim **23** comprising turning during a line change.

26. The apparatus of claim **23** comprising commanding each streamer positioning device to generate a force in an opposite direction of the turning, and then commanding each streamer positioning device to go to a position defined by the feather angle control mode.

27. The apparatus of claim **23** comprising separating adjacent streamers by depth during the turning mode to avoid possible entanglement during the turning.

28. The apparatus of claim **27** comprising returning adjacent streamers to a common depth after the completion of the turning.

29. The apparatus of claim **23** comprising notifying the control system, via a vessel navigation system, when to start throwing the streamers out, and when to start straightening the streamers.

30. The apparatus of claim **18** wherein the control mode is the streamer separation mode, the control system attempting to minimize the risk of entanglement of the streamers.

31. The apparatus of claim **30** comprising the control system attempting to maximize distance between adjacent streamers.

32. The apparatus of claim **30** comprising separating the streamers in depth.

33. The apparatus of claim **32** wherein the array of streamers comprises two streamers, and comprising positioning the two streamers as far away from each other as possible.

34. The apparatus of claim **32** wherein the array of streamers comprises three or more streamers, the array comprising one port-most streamer, one starboard-most streamer and at least one inner streamer and comprising positioning the port-most and starboard-most streamers as far away from each other as possible.

* * * * *

Exhibit B

US007080607B2

(12) **United States Patent**
Hillesund et al.

(10) **Patent No.: US 7,080,607 B2**
(45) **Date of Patent: *Jul. 25, 2006**

(54) **SEISMIC DATA ACQUISITON EQUIPMENT CONTROL SYSTEM**

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(73) Assignee: **WesternGeco, L.L.C.**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/070,614**

(22) Filed: **Mar. 2, 2005**

(65) **Prior Publication Data**

US 2005/0188908 A1 Sep. 1, 2005

Related U.S. Application Data

(63) Continuation of application No. 09/787,723, filed as application No. PCT/IB99/01590 on Sep. 28, 1999, now Pat. No. 6,932,017.

(30) **Foreign Application Priority Data**

Oct. 1, 1998 (GB) 9821277.3

(51) **Int. Cl.**
B63B 21/66 (2006.01)
B63B 21/56 (2006.01)

(52) **U.S. Cl.** **114/244**

(58) **Field of Classification Search** 114/162, 114/163, 242–246, 253

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,375,800 A	4/1968	Cole et al.	....	114/235
3,412,705 A	11/1968	Nesson	....	115/12
3,434,446 A	3/1969	Cole	....	114/235
3,440,992 A	4/1969	Chance	....	114/235
3,560,912 A	2/1971	Spink et al.	....	340/3
3,605,674 A	9/1971	Weese	....	114/235 B
3,648,642 A	3/1972	Fetrow et al.	....	114/235
3,774,570 A	11/1973	Pearson	....	114/235 B

(Continued)

FOREIGN PATENT DOCUMENTS

AU 199853305 12/1997

(Continued)

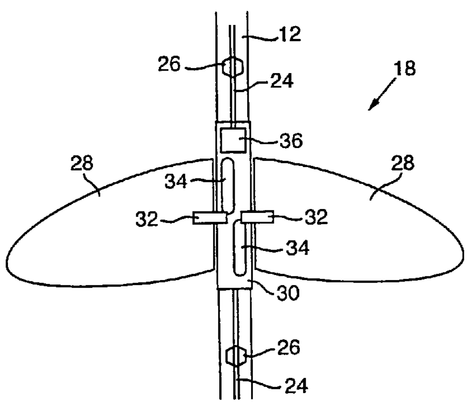
Primary Examiner—Jesus D. Sotelo

(74) *Attorney, Agent, or Firm*—WesternGeco, L.L.C.

(57) **ABSTRACT**

A method of controlling a streamer positioning device configured to be attached to a marine seismic streamer and towed by a seismic survey vessel and having a wing and a wing motor for changing the orientation of the wing. The method includes the steps of: obtaining an estimated velocity of the streamer positioning device, calculating a desired change in the orientation of the wing using the estimated velocity of the streamer positioning device, and actuating the wing motor to produce the desired change in the orientation of the wing. The invention also involves an apparatus for controlling a streamer positioning device including means for obtaining an estimated velocity of the streamer positioning device, means for calculating a desired change in the orientation of the wing using the estimated velocity of the streamer positioning device, and means for actuating the wing motor to produce the desired change in the orientation of the wing.

25 Claims, 3 Drawing Sheets



U.S. PATENT DOCUMENTS

3,896,756 A		7/1975	Pearson et al.	114/235 B
3,931,608 A		1/1976	Cole	367/17
3,943,483 A		3/1976	Strange	340/7 PC
3,961,303 A		6/1976	Paitson	367/17
4,033,278 A		7/1977	Waters	114/245
4,063,213 A		12/1977	Itria et al.	367/17
4,087,780 A		5/1978	Itria et al.	367/17
4,222,340 A		9/1980	Cole	114/245
4,227,479 A		10/1980	Gertler et al.	114/312
4,290,124 A		9/1981	Cole	367/18
4,313,392 A		2/1982	Guenther et al.	114/244
4,323,989 A		4/1982	Huckabee et al.	367/17
4,404,664 A		9/1983	Zachariadis	367/19
4,463,701 A		8/1984	Pickett et al.	114/245
4,484,534 A		11/1984	Thillaye du Boullay	114/244
4,676,183 A	*	6/1987	Conboy	114/245
4,694,435 A		9/1987	Magneville	367/17
4,709,355 A		11/1987	Woods et al.	367/16
4,711,194 A		12/1987	Fowler	114/245
4,723,501 A		2/1988	Hovden et al.	114/144 B
4,729,333 A		3/1988	Kirby et al.	114/244
4,745,583 A		5/1988	Motal	367/18
4,766,441 A		8/1988	Phillips	343/709
4,767,183 A		8/1988	Martin	350/96.23
4,843,996 A		7/1989	Darche	114/245
4,890,568 A	*	1/1990	Dolengowski	114/246
4,890,569 A		1/1990	Givens	114/349
4,912,684 A		3/1990	Fowler	367/76
4,992,990 A		2/1991	Langeland et al.	367/19
5,042,413 A		8/1991	Benoit	114/244
5,052,814 A		10/1991	Stubblefield	367/15
5,402,745 A		4/1995	Wood	114/244
5,443,027 A		8/1995	Owsley et al.	114/244
5,507,243 A		4/1996	Williams et al.	114/245
5,517,202 A		5/1996	Patel	343/709
5,517,463 A		5/1996	Hornbostel et al.	367/13
5,529,011 A		6/1996	Williams, Jr.	114/245
5,532,975 A		7/1996	Elholm	367/16
5,619,474 A		4/1997	Kuche	367/17
5,642,330 A		6/1997	Santopietro	367/131
5,790,472 A		8/1998	Workman et al.	367/19
6,011,752 A		1/2000	Ambs et al.	367/17
6,011,753 A		1/2000	Chien	367/21
6,016,286 A		1/2000	Olivier et al.	367/17
6,144,342 A		11/2000	Bertheas et al.	343/709
6,459,653 B1		10/2002	Kuche	367/17
6,525,992 B1		2/2003	Olivier et al.	367/17
6,549,653 B1		4/2003	Osawa et al.	382/162
6,879,542 B1		4/2005	Soreau et al.	367/17

FOREIGN PATENT DOCUMENTS

AU	734810 B	6/2001
CA	2270719	12/1997
DE	69702673 T	4/2001
EP	0193215	1/1986
EP	0319716	6/1989
EP	0321705	6/1989
EP	0525391	2/1993
EP	0390987	12/1993
EP	613025 A1 *	8/1994
EP	0581441	8/1997
EP	0909701	1/2003
GB	2093610	9/1982
GB	2122562	1/1984
GB	2331971	6/1999
GB	2342081	4/2000
NO	992701	6/1999
WO	WO95/31735	11/1995
WO	WO96/21163	7/1996
WO	WO97/11395	3/1997
WO	WO97/30361	8/1997
WO	WO97/45006	12/1997
WO	WO98/28636	7/1998
WO	WO99/04293	1/1999

* cited by examiner

Fig.1.

Prior Art

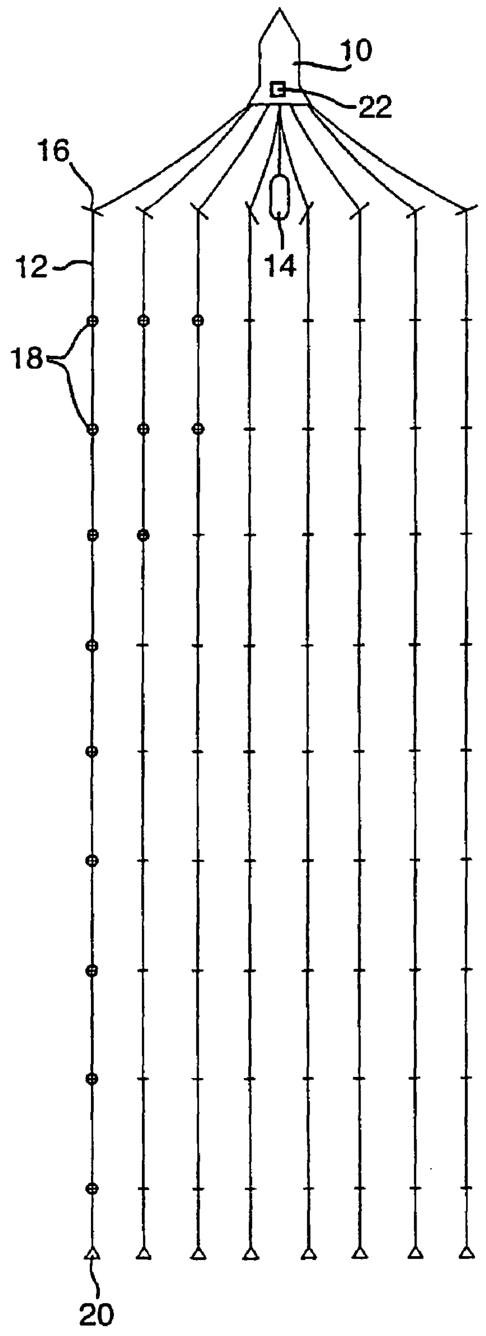
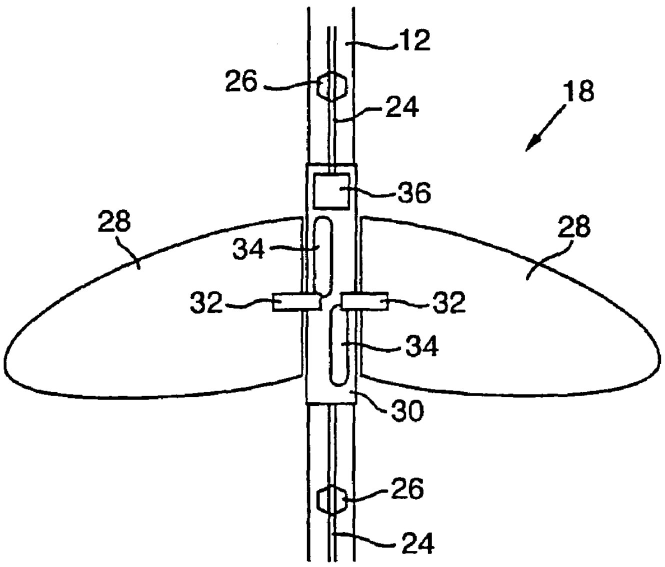


Fig.2.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26
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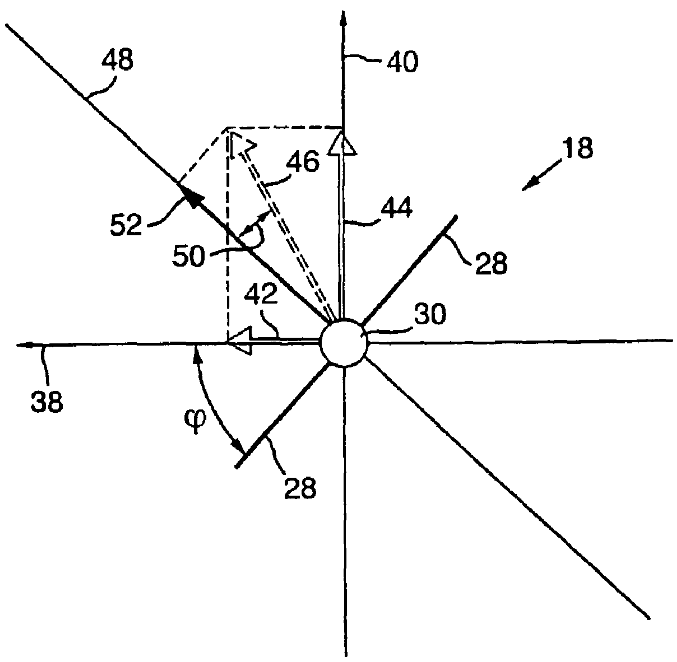
Fig.3.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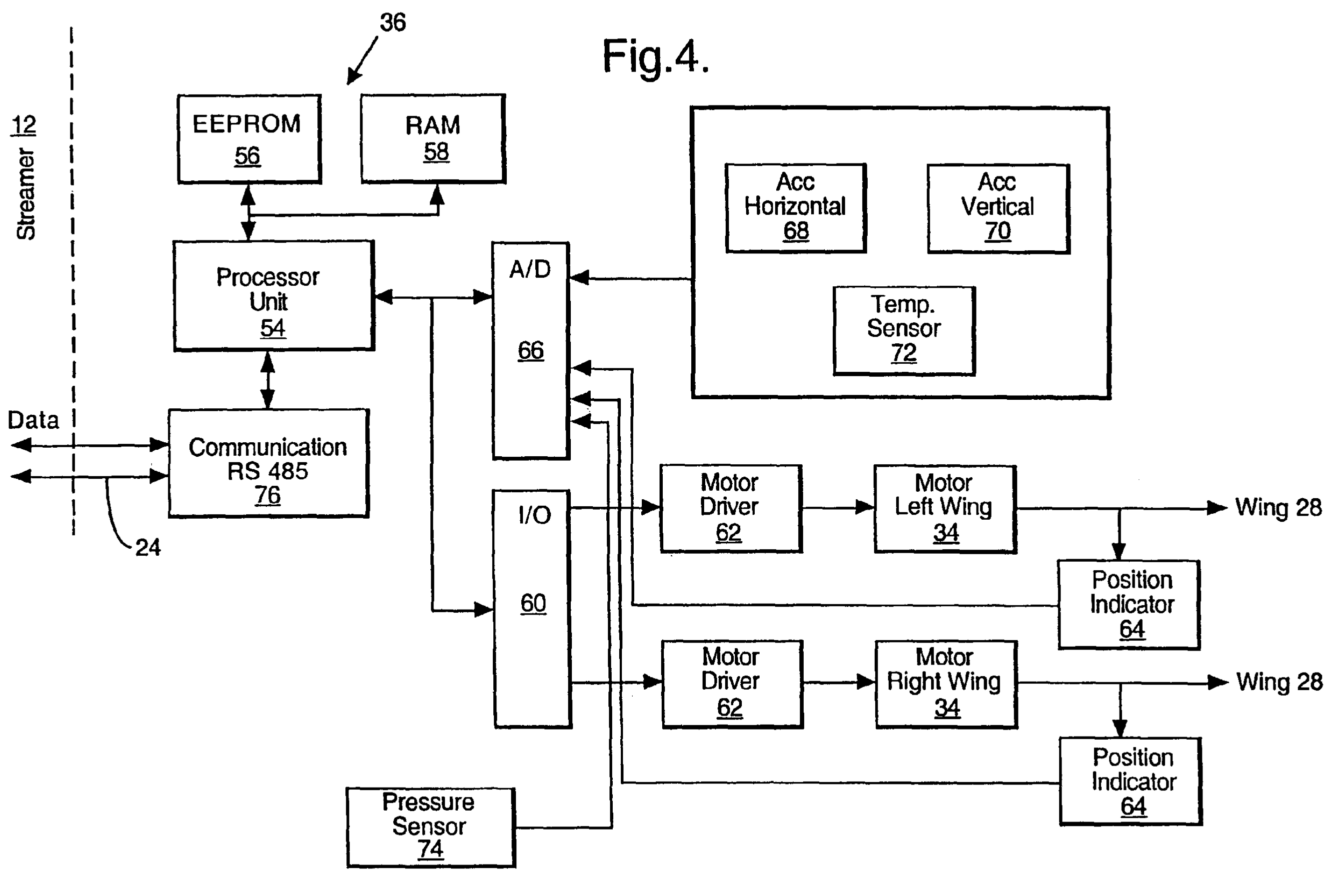
18
46
44
52
50
28
42
30
38
φ
28

Fig.4.



36
12
Streamer
EEPROM
56
RAM
58
Processor
Unit
54
A/D
66
Acc
Horizontal
68
Acc
Vertical
70
Temp.
Sensor
72
Data
Communication
RS 485
76
24
I/O
60
Motor
Driver
62
Motor
Left Wing
34
Wing 28
Position
Indicator
64
Motor
Driver
62
Motor
Right Wing
34
Wing 28
Position
Indicator
64
Pressure
Sensor
74

SEISMIC DATA ACQUISITON EQUIPMENT CONTROL SYSTEM

Applicant claims priority and continuation under 35 U.S.C. § 120 from parent application Ser. No. 09/787,723, filed Jul. 2, 2001, now U.S. Pat. No. 6,932,017, which was a 35 U.S.C. § 371 national stage filing from Patent Cooperation Treaty application number PCT/IB99/01590, filed Sep. 28, 1999, which in turn claimed priority from Great Britain patent application number 9821277.3, filed Oct. 1, 1998, from which Applicant has claimed foreign priority under 35 U.S.C. § 119.

BACKGROUND OF THE INVENTION

This invention relates generally to systems for controlling seismic data acquisition equipment and particularly to a system for controlling a marine seismic streamer positioning device.

A marine seismic streamer is an elongate cable-like structure, typically up to several thousand meters long, which contains arrays of seismic sensors, known as hydrophones, and associated electronic equipment along its length, and which is used in marine seismic surveying. In order to perform a 3D marine seismic survey, a plurality of such streamers are towed at about 5 knots behind a seismic survey vessel, which also tows one or more seismic sources, typically air guns. Acoustic signals produced by the seismic sources are directed down through the water into the earth beneath, where they are reflected from the various strata. The reflected signals are received by the hydrophones, and then digitized and processed to build up a representation of the subsurface geology.

The horizontal positions of the streamers are typically controlled by a deflector, located at the front end or "head" of the streamer, and a tail buoy, located at the back end or "tail" of the streamer. These devices create tension forces on the streamer which constrain the movement of the streamer and cause it to assume a roughly linear shape. Cross currents and transient forces cause the streamer to bow and undulate, thereby introducing deviations into this desired linear shape.

The streamers are typically towed at a constant depth of approximately ten meters, in order to facilitate the removal of undesired "ghost" reflections from the surface of the water. To keep the streamers at this constant depth, control devices known as "birds", are typically attached at various points along each streamer between the deflector and the tail buoy, with the spacing between the birds generally varying between 200 and 400 meters. The birds have hydrodynamic deflecting surfaces, referred to as wings, that allow the position of the streamer to be controlled as it is towed through the water. When a bird is used for depth control purposes only, it is possible for the bird to regularly sense its depth using an integrated pressure sensor and for a local controller within the bird to adjust the wing angles to maintain the streamer near the desired depth using only a desired depth value received from a central control system.

While the majority of birds used thus far have only controlled the depth of the streamers, additional benefits can be obtained by using properly controlled horizontally steerable birds, particularly by using the types of horizontally and vertically steerable birds disclosed in our published PCT International Application No. WO 98/28636. The benefits that can be obtained by using properly controlled horizontally steerable birds can include reducing horizontal out-of-position conditions that necessitate reacquiring seismic data in a particular area (i.e. in-fill shooting), reducing the chance of tangling adjacent streamers, and reducing the time required to turn the seismic acquisition vessel when ending one pass and beginning another pass during a 3D seismic survey.

It is estimated that horizontal out-of-position conditions reduce the efficiency of current 3D seismic survey operations by between 5 and 10%, depending on weather and current conditions. While incidents of tangling adjacent streamers are relatively rare, when they do occur they invariably result in prolonged vessel downtime. The loss of efficiency associated with turning the seismic survey vessel will depend in large part on the seismic survey layout, but typical estimates range from 5 to 10%. Simulations have concluded that properly controlled horizontally steerable birds can be expected to reduce these types of costs by approximately 30%.

One system for controlling a horizontally steerable bird, as disclosed in UK Patent GB 2093610 B, is to utilize a manually-operated central control system to transmit the magnitudes and directions of any required wing angle changes to the birds. While this method greatly simplifies the circuitry needed within the bird itself, it is virtually impossible for this type of system to closely regulate the horizontal positions of the birds because it requires manual input and supervision. This becomes a particularly significant issue when a substantial number of streamers are deployed simultaneously and the number of birds that must be controlled goes up accordingly.

Another system for controlling a horizontally steerable bird is disclosed in our published PCT International Application No. WO 98/28636. Using this type of control system, the desired horizontal positions and the actual horizontal positions are received from a remote control system and are then used by a local control system within the birds to adjust the wing angles. The actual horizontal positions of the birds may be determined every 5 to 10 seconds and there may be a 5 second delay between the taking of measurements and the determination of actual streamer positions. While this type of system allows for more automatic adjustment of the bird wing angles, the delay period and the relatively long cycle time between position measurements prevents this type of control system from rapidly and efficiently controlling the horizontal position of the bird. A more deterministic system for controlling this type of streamer positioning device is therefore desired.

It is therefore an object of the present invention to provide for an improved method and apparatus for controlling a streamer positioning device.

An advantage of the present invention is that the position of the streamer may be better controlled, thereby reducing the need for in-fill shooting, reducing the chance of streamer tangling, and reducing the time needed to turn the seismic survey vessel.

Another advantage of the present invention is that noise in marine seismic data associated with streamer position overcorrection and streamer positioning errors can be significantly reduced.

SUMMARY OF THE INVENTION

The present invention involves a method of controlling a streamer positioning device configured to be attached to a marine seismic streamer and towed by a seismic survey vessel and having a wing and a wing motor for changing the orientation of the wing. The method includes the steps of: obtaining an estimated velocity of the streamer positioning device, calculating a desired change in the orientation of the wing using the estimated velocity of the streamer positioning device, and actuating the wing motor to produce the desired change in the orientation of the wing. The present invention also involves an apparatus for controlling a streamer positioning device. The apparatus includes means for obtaining an estimated velocity of the streamer positioning device, means for calculating a desired change in the orientation of the wing using the estimated velocity of the streamer positioning device, and means for actuating the wing motor to effectuate the desired change in the orientation of the wing. The invention and its benefits will be better understood with reference to the detailed description below and the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of a seismic survey vessel and associated seismic data acquisition equipment,

FIG. **2** is a schematic horizontal cross-sectional view through a marine seismic streamer and an attached streamer positioning device;

FIG. **3** is a schematic vertical cross-sectional view through the streamer positioning device from FIG. **2**; and

FIG. **4** is a schematic diagram of the local control system architecture of the streamer positioning device from FIG. **2**.

DETAILED DESCRIPTION OF THE INVENTION

In FIG. **1**, a seismic survey vessel **10** is shown towing eight marine seismic streamers **12** that may, for instance, each be 3000 meters in length. The outermost streamers **12** in the array could be 700 meters apart, resulting in a horizontal separation between the streamers of 100 meters in the regular horizontal spacing configuration shown. A seismic source **14**, typically an airgun or an array of airguns, is also shown being towed by the seismic survey vessel **10**. At the front of each streamer **12** is shown a deflector **16** and at the rear of every streamer is shown a tail buoy **20**. The deflector **16** is used to horizontally position the end of the streamer nearest the seismic survey vessel **10** and the tail buoy **20** creates drag at the end of the streamer farthest from the seismic survey vessel **10**. The tension created on the seismic streamer by the deflector **16** and the tail buoy **20** results in the roughly linear shape of the seismic streamer **12** shown in FIG. **1**.

Located between the deflector **16** and the tail buoy **20** are a plurality of streamer positioning devices known as birds **18**. Preferably the birds **18** are both vertically and horizontally steerable. These birds **18** may, for instance, be located at regular intervals along the steamer, such as every 200 to 400 meters. The vertically and horizontally steerable birds **18** can be used to constrain the shape of the seismic streamer **12** between the deflector **16** and the tail buoy **20** in both the vertical (depth) and horizontal directions.

In the preferred embodiment of the present invention, the control system for the birds **18** is distributed between a global control system **22** located on or near the seismic survey vessel **10** and a local control system located within or near the birds **18**. The global control system **22** is typically connected to the seismic survey vessel's navigation system and obtains estimates of system wide parameters, such as the vessel's towing direction and velocity and current direction and velocity, from the vessel's navigation system.

The most important requirement for the control system is to prevent the streamers **12** from tangling. This requirement becomes more and more important as the complexity and the total value of the towed equipment increases. The trend in the industry is to put more streamers **12** on each seismic survey vessel **10** and to decrease the horizontal separation between them. To get better control of the streamers **12**, horizontal steering becomes necessary. If the birds **18** are not properly controlled, horizontal steering can increase, rather than decrease, the likelihood of tangling adjacent streamers. Localized current fluctuations can dramatically influence the magnitude of the side control required to properly position the streamers. To compensate for these localized current fluctuations, the inventive control system utilizes a distributed processing control architecture and behavior-predictive model-based control logic to properly control the streamer positioning devices.

In the preferred embodiment of the present invention, the global control system **22** monitors the actual positions of each of the birds **18** and is programmed with the desired positions of or the desired minimum separations between the seismic steamers **12**. The horizontal positions of the birds **18** can be derived, for instance, using the types of acoustic positioning systems described in our U.S. Pat. No. 4,992,990 or in our PCT International Patent Application No. WO 98/21163. Alternatively, or additionally, satellite-based global positioning system equipment can be used to determine the positions of the equipment. The vertical positions of the birds **18** are typically monitored using pressure sensors attached to the birds, as discussed below.

The global control system **22** preferably maintains a dynamic model of each of the seismic streamers **12** and utilizes the desired and actual positions of the birds **18** to regularly calculate updated desired vertical and horizontal forces the birds should impart on the seismic streamers **12** to move them from their actual positions to their desired positions. Because the movement of the seismic streamer **12** causes acoustic noise (both from seawater flow past the bird wing structures as well as cross current flow across the streamer skin itself), it is important that the streamer movements be restrained and kept to the minimum correction required to properly position the streamers. Any streamer positioning device control system that consistently overestimates the type of correction required and causes the bird to overshoot its intended position introduces undesirable noise into the seismic data being acquired by the streamer. In current systems, this type of over-correction noise is often balanced against the "noise" or "smearing" caused when the seismic sensors in the streamers **12** are displaced from their desired positions.

The global control system **22** preferably calculates the desired vertical and horizontal forces based on the behavior of each streamer and also takes into account the behavior of the complete streamer array. Due to the relatively low sample rate and time delay associated with the horizontal position determination system, the global control system **22** runs position predictor software to estimate the actual locations of each of the birds **18**. The global control system **22** also checks the data received from the vessel's navigation system and the data will be filled in if it is missing. The interface between the global control system **22** and the local control system will typically operate with a sampling frequency of at least 0.1 Hz. The global control system **22** will typically acquire the following parameters from the vessel's navigation system: vessel speed (m/s), vessel heading (degrees), current speed (m/s), current heading (degrees), and the location of each of the birds in the horizontal plane in a vessel fixed coordinate system. Current speed and heading can also be estimated based on the average forces acting on the streamers **12** by the birds **18**. The global control system

22 will preferably send the following values to the local bird controller: demanded vertical force, demanded horizontal force, towing velocity, and crosscurrent velocity.

The towing velocity and crosscurrent velocity are preferably "water-referenced" values that are calculated from the vessel speed and heading values and the current speed and heading values, as well as any relative movement between the seismic survey vessel **10** and the bird **18** (such as while the vessel is turning), to produce relative velocities of the bird **18** with respect to the water in both the "in-line" and the "cross-line" directions. Alternatively, the global control system **22** could provide the local control system with the horizontal velocity and water in-flow angle. The force and velocity values are delivered by the global control system **22** as separate values for each bird **18** on each streamer **12** continuously during operation of the control system.

The "water-referenced" towing velocity and crosscurrent velocity could alternatively be determined using flowmeters or other types of water velocity sensors attached directly to the birds **18**. Although these types of sensors are typically quite expensive, one advantage of this type of velocity determination system is that the sensed in-line and cross-line velocities will be inherently compensated for the speed and heading of marine currents acting on said streamer positioning device and for relative movements between vessel **10** and the bird **18**.

FIG. **2** shows a type of bird **18** that is capable of controlling the position of seismic streamers **12** in both the vertical and horizontal directions. A bird **18** of this type is also disclosed in our PCT International Application No. WO 98/28636. While a number of alternative designs for the vertically and horizontally steerable birds **18** are possible, including those utilizing one full-moving wing with ailerons, three full-moving wings, and four full-moving wings, the independent two-wing principal is, conceptually, the simplest and most robust design.

In FIG. **2**, a portion of the seismic streamer **12** is shown with an attached bird **18**. A communication line **24**, which may consist of a bundle of fiber optic data transmission cables and power transmission wires, passes along the length of the seismic streamer **12** and is connected to the seismic sensors, hydrophones **26**, that are distributed along the length of the streamer, and to the bird **18**. The bird **18** preferably has a pair of independently moveable wings **28** that are connected to rotatable shafts **32** that are rotated by wing motors **34** and that allow the orientation of the wings **28** with respect to the bird body **30** to be changed. When the shafts **32** of the bird **18** are not horizontal, this rotation causes the horizontal orientation of the wings **28** to change and thereby changes the horizontal forces that are applied to the streamer **12** by the bird.

The motors **34** can consist of any type of device that is capable of changing the orientation of the wings **28**, and they are preferably either electric motors or hydraulic actuators. The local control system **36** controls the movement of the wings **28** by calculating a desired change in the angle of the wings and then selectively driving the motors **34** to effectuate this change. While the preferred embodiment depicted utilizes a separate motor **34** for each wing **28**, it would be also be possible to independently move the wings **28** using a single motor **34** and a selectively actuatable transmission mechanism.

When the bird **18** uses two wings **28** to produce the horizontal and vertical forces on the streamer **12**, the required outputs of the local control system **36** are relatively simple, the directions and magnitudes of the wing movements required for each of the wings **28**, or equivalently the magnitude and direction the motors **34** need to be driven to produce this wing movement. While the required outputs of the local control system **36** for such a two full moving wing design is quite simple, the structure and operation of the overall system required to coordinate control of the device is relatively complicated.

FIG. **3** shows a schematic vertical cross-sectional view through the streamer positioning device shown in FIG. **2** that will allow the operation of the inventive control system to be described in more detail. The components of the bird **18** shown in FIG. **3** include the wings **28** and the body **30**. Also shown in FIG. **3** are a horizontal coordinate axis **38** and a vertical coordinate axis **40**. During operation of the streamer positioning control system, the global control system **22** preferably transmits, at regular intervals (such as every five seconds) a desired horizontal force **42** and a desired vertical force **44** to the local control system **36**.

The desired horizontal force **42** and the desired vertical force **44** are combined within the local control system **36** to calculate the magnitude and direction of the desired total force **46** that the global control system **22** has instructed the local control system to apply to the streamer **12**. The global control system **22** could alternatively provide the magnitude and direction of the desired total force **46** to the local control system **36** instead of the desired horizontal force **42** and the desired vertical force **44**.

While the desired horizontal force **42** and the desired vertical force **44** are preferably calculated by the global control system **22**, it is also possible for the local control system **36** in the inventive control system to calculate one or both of these forces using a localized displacement/force conversion program. This type of localized conversion program may, for instance, use a look-up table or conversion routine that associates certain magnitudes and directions of vertical or horizontal displacements with certain magnitudes and directions of changes in the vertical or horizontal forces required. Using this type of embodiment, the global control system **22** can transmit location information to the local control system **36** instead of force information. Instead of the desired vertical force **44**, the global control system **22** can transmit a desired vertical depth and the local control system **36** can calculate the magnitude and direction of the deviation between the desired depth and the actual depth. Similarly, instead of transmitting a desired horizontal force **42**, the global control system **22** can transmit the magnitude and direction of the displacement between the actual horizontal position and the desired horizontal position of the bird **18**. One advantage to this alternative type of system is that the required vertical force can be rapidly updated as the local control system receives updated depth information from the integrated pressure sensor. Other advantages of this type of alternative system include reducing communication traffic on the communication line **24** and simplifying the programming needed to convert the measured vertical and/or horizontal displacements into corresponding forces to be applied by the birds **18**.

When the local control system **36** has a new desired horizontal force **42** and desired vertical force **44** to be applied, the wings **28** will typically not be in the proper orientation to provide the direction of the desired total force **46** required. As can be seen in FIG. **3**, the wings **28** introduce a force into the streamer **12** along an axis perpendicular to the rotational axis of the wings **28** and perpendicular to the streamer. This force axis **48** is typically not properly aligned with the desired total force **46** when new desired horizontal and vertical force values are received from the global control system **22** or determined by the local control system **36** and some rotation of the bird **18** is required before the bird can produce this desired total force **46**. As can be seen, the force axis **48** is directly related to the bird roll angle, designated in FIG. **3** as ϕ.

The local control system **36** optimizes the control process by projecting the desired total force **46** onto the force axis **48** (i.e. multiplying the magnitude of the desired total force by the cosine of the deviation angle **50**) to produce an intermediate desired force **52** and then adjusting the wing common angle α (the angle of the wings with respect to the bird body **30**, or the average angle if there is a non-zero splay angle) to produce this magnitude of force along the force axis. The calculated desired common wing angle is compared to the current common wing angle to calculate a desired change in the common wing angle and the wing motors **34** are actuated to produce this desired change in the orientation of the wings.

A splay angle is then introduced into the wings **28** to produce a rotational movement in the bird body **30** (i.e. to rotate the force axis **48** to be aligned with the desired total force **46**). The splay angle is the difference between the angles of the wings **28** with respect to the bird body **30**. As the bird body **30** rotates and the force axis **48** becomes more closely aligned with the desired total force **46**, the bird roll angle and the bird roll angular velocity are monitored, the splay angle is incrementally reduced, and the common angle is incrementally increased until the intermediate desired force **52** is in the same direction and of the same magnitude as the desired total force. The local control system **36** carefully regulates the splay angle to ensure that the streamer is stable in roll degree of freedom. The calculated common wing angle and the splay angle are also regulated by the local control system **36** to prevent the wings **28** from stalling and to ensure that the splay angle is prioritized.

When using the type of birds described in our published PCT International Application No. WO 98/28636, where the bird **18** is rigidly attached, and cannot rotate with respect, to the streamer **12**, it is important for the control system to take the streamer twist into account. If this is not taken into account, the bird **18** can use all of its available splay angle to counter the twist in the streamer **12**. The bird **18** will then be unable to reach the demanded roll angle and the generated force will decrease. The inventive control system incorporates two functions for addressing this situation; the anti-twist function and the untwist function.

In the anti-twist function, the streamer twist is estimated by weightfunction filtering the splay angle measurements instead of simply averaging the splay angle measurements to improve the bandwidth of the estimation. The anti-twist function engages when the estimated twist has reached a critical value and it then overrides the normal shortest path control of the calculated roll angle. The anti-twist function forces the bird **18** to rotate in the opposite direction of the twist by adding +/−180 degrees to the demanded roll angle. Once the twist has been reduced to an acceptable value, the anti-twist function disengages and the normal shortest path calculation is continued.

The untwist function is implemented by the global control system **22** which monitors the splay angle for all of the birds **18** in each streamer **12**. At regular intervals or when the splay angle has reached a critical value, the global control system **22** instructs each local control system **36** to rotate each bird **18** in the opposite direction of the twist. The number of revolutions done by each bird **18** is monitored and the untwist function is disengaged once the twist has reached an acceptable level.

FIG. **4** is a schematic diagram of the architecture of the local control system **36** for the bird **18**. The local control system **36** consists of a central processor unit **54**, having EEPROM **56** and RAM **58** memory, an input/output subsystem **60** that is connected to a pair of motor drivers **62**, and an analog to digital conversion unit **66**. The motor drivers **62** are connected to and actuate the wing motors **34** to produce the desired change the orientation of the wings **28** with respect to the bird body **30**.

The wing motor **34**/wing **28** units are also connected to wing position indicators **64** that sense the relative positions of the wings and provide measurements to the analog to digital conversion unit **66** which converts the analog wing position indicator **64** measurements into digital format and conveys these digital values to the central processor unit **54**. Various types of wing position indicators **64** can be used, including resistive angle or displacement sensors, inductive sensors, capacitive sensors, hall sensors, or magneto-restrictive sensors.

A horizontal accelerometer **68** and a vertical accelerometer **70**, placed at right angles with respect to one another, are also connected to the analog to digital conversion unit **66** and these accelerometers convey measurements that allow the central processor unit **54** to determine the roll angle and roll rate of the bird **18**. An angular velocity vibrating rate gyro (rategyro) can also be used to measure the roll rate of the bird **18**. A temperature sensor **72** is connected to the analog to digital conversion unit **66** to provide temperature measurements that allow the horizontal accelerometer **68** and the vertical accelerometer **70** to be calibrated.

A pressure sensor **74** is also connected to the analog to digital conversion unit **66** to provide the central processor unit **54** with measurements of the water pressure at the bird **18**. To calculate an appropriate depth value, the measured pressure values must be filtered to limit the disturbance from waves. This is done in the inventive control system with a weightfunction filter that avoids the large phase displacements caused by mean value filters. Instead of using an instantaneous depth value or simply calculating an average depth value over a given period of time (and thereby incorporating a large phase displacement into the depth value), the inventive control system uses a differentially weighted pressure filtering scheme. First the pressure values are transformed into depth values by dividing the pressure sensor reading by the seawater density and gravitational acceleration. These depth values are then filtered using a weight function filter. Typical incremental weighting functions values range from 0.96 to 0.90 (sample weights of 1.0, 0.9, 0.81, 0.729, etc.) and the filter will typically process depth values received over a period of at least 100 seconds.

The central processor unit **54** is also connected to a RS485 communications unit **76** that allows information to be exchanged between the local control system **36** and the global control system **22** over the communication line **24** that passes through the streamer **12**. The RS485 bus may, for instance, utilize Neuron chips that communicate using a Local Operating Network protocol to control the data transfer.

Preferably, the central processor unit **54** and associated components comprise a MicroChip 17C756 processor. This type of microprocessor has very low power requirements, a dual UART on-chip, 12-channel, 10 bit ADC on-chip, 908×8 RAM, 16k×16 ROM, and 50 digital I/O channels. The software running on the central processor unit **54** will typically consist of two units, the local control unit and the hardware control unit. It is typically not possible to pre-load both of these program units into the EEPROM **56** and it is possible to update these program units without having to open the bird **18**. The on-chip memory may thus only initially contain a boot-routine that enables the loading of software units into the external memory via the RS485 communication unit **76**. The external program memory (EEPROM **56**) will typically be a non-volatile memory so that these program units do not have to be re-loaded after every power down.

The central processor unit **54** must be able to run the local control system software fast enough to secure the sampling frequency needed for effective local bird control. This may mean, for instance, a sample rate of 10 Hz, which may be 10 to 100 times faster than the sample rate of the communications between the global control system **22** and the local control system **36**. As discussed above, the central processor unit **54** will also receive data from sensors attached to the bird **18**. The sensed values include bird roll angle, bird roll angular velocity (roll rate), the wing angles, and the static pressure of the water. These values are typically delivered to the central processor unit **54** at a sample rate of at least 10 Hz. The following values may be transmitted from the local control system **36** to the global control system **22** using the RS485 communication unit **76**: the measured roll angle, the measured roll rate, the measured wing angles, the measured water pressure, the calculated depth, and the calculated wing forces.

The system has been designed with a redundant communication system to increase its overall reliability. The bird **18** will typically have a backup communications channel, such as by overlaying a backup control signal on top of the power line current. This backup communications channel is particularly important because in the event of loss of communications to the bird **18** there would otherwise be no method for instructing the bird **18** to bring the streamer **12** to surface so the defective communications equipment can be repaired or replaced.

In contrast to previous streamer position device control systems, the present control system converts the desired horizontal force **42** and the desired vertical force **44** into a desired roll angle ϕ and a desired common wing angle α by deterministic calculations, rather than using an "incremental change/measured response/further incremental change based on measured response" type of feedback control circuit. The desired roll angle ϕ can be calculated in the manner discussed in the text describing FIG. **3** above. The magnitude of the force F imparted by the wings **28** along the force axis **48** can, for instance, be deterministically calculated using the following formula:

$$F = \frac{1}{2}\rho * A * C_L(v_{tow}\cos(\alpha) - v_{current}\sin(\alpha))^2$$

where:

ρ=water density

A=wing area

C_L=wing lift coefficient

α=common wing angle

V_{tow}=towing velocity

$V_{current}$=crosscurrent velocity

A similar deterministic calculation could be made using a calculated coefficient that incorporates the towing velocity of the bird **18**. A gain factor GF, for instance, could be calculated as follows:

$$GF = \frac{1}{2}\rho * A * C_L(v_{tow})^2$$

which could be simply multiplied by $\cos(\alpha)^2$ to estimate the force that would be applied for a given common angle.

One of the beneficial elements of the inventive control system is that the desired change in the orientation of the wing **28** is calculated using an estimate of the velocity of the bird **18** rather than simply relying on a feedback-loop type of control system that operates in the same manner regardless of the vessel speed. Because the force produced by wing **28** is proportional to the velocity of the device squared, a much mere precise calculation of the desired change in the wing orientation can be made by using an estimate of the device velocity.

The inventive control system is based on shared responsibilities between the global control system **22** located on the seismic survey vessel **10** and the local control system **36** located on the bird **18**. The global control system **22** is tasked with monitoring the positions of the streamers **12** and providing desired forces or desired position information to the local control system **36**. The local control system **36** within each bird **18** is responsible for adjusting the wing splay angle to rotate the bird to the proper position and for adjusting the wing common angle to produce the magnitude of total desired force required.

The inventive control system will primarily operate in two different control modes: a feather angle control mode and a turn control mode. In the feather angle control mode, the global control system **22** attempts to keep each streamer in a straight line offset from the towing direction by a certain feather angle. The feather angle could be input either manually, through use of a current meter, or through use of an estimated value based on the average horizontal bird forces. Only when the crosscurrent velocity is very small will the feather angle be set to zero and the desired streamer positions be in precise alignment with the towing direction.

The turn control mode is used when ending one pass and beginning another pass during a 3D seismic survey, sometimes referred to as a "line change". The turn control mode consists of two phases. In the first part of the turn, every bird **18** tries to "throw out" the streamer **12** by generating a force in the opposite direction of the turn. In the last part of the turn, the birds **18** are directed to go to the position defined by the feather angle control mode. By doing this, a tighter turn can be achieved and the turn time of the vessel and equipment reduced. Typically during the turn mode adjacent streamers will be depth separated to avoid possible entanglement during the turn and will be returned to a common depth as soon as possible after the completion of the turn. The vessel navigation system will typically notify the global control system **22** when to start throwing the streamers **12** out, and when to start straightening the streamers.

In extreme weather conditions, the inventive control system may also operate in a streamer separation control mode that attempts to minimize the risk of entanglement of the streamers. In this control mode, the global control system **22** attempts to maximize the distance between adjacent streamers. The streamers **12** will typically be separated in depth and the outermost streamers will be positioned as far away from each other as possible. The inner streamers will then be regularly spaced between these outermost streamers, i.e. each bird **18** will receive desired horizontal forces **42** or desired horizontal position information that will direct the bird **18** to the midpoint position between its adjacent streamers.

While the embodiment of the inventive control system described above is shown in connection with a "bird" type of streamer positioning device, it will be readily understood that the control system method and apparatus may also be used in connection with streamer positioning devices that are characterized as "deflectors" or steerable "tail buoys" because they are attached to either the front end or the back end of the streamer **12**.

The present invention includes any novel feature or novel combination of features disclosed herein, either explicitly or implicitly.

The invention claimed is:

1. A method comprising:

(a) towing an a array of streamers each having a plurality of streamer positioning devices there along;

(b) predicting positions of at least some of the streamer positioning devices;

(c) using the predicted positions to calculate desired changes in position of one or more of the streamer positioning devices; and

(d) implementing at least some of the desired changes.

2. A method as claimed in claim **1**, comprising estimating velocity of at least some of the streamer positioning devices, wherein said estimated velocity is calculated using a vessel speed received from a navigation system on said seismic survey vessel.

3. A method as claimed in claim **2**, in which said estimated velocity is a water referenced towing velocity that compensates for the speed and heading of marine currents acting on said streamer positioning devices.

4. A method as claimed in claim **3**, in which said estimated velocity is compensated for relative movement between said seismic survey vessel and said streamer positioning devices.

5. A method as claimed in claim **2**, in which said step of using the predicted positions to calculate desired changes in position of one or more of the streamer positioning devices further uses an estimate of the crosscurrent velocity at the respective streamer positioning device.

6. A method as claimed in claim **5**, in which said step of using the predicted positions to calculate desired changes in position of one or more of the streamer positioning devices is regulated to prevent the positioning device from stalling.

7. A method as claimed in claim **6**, in which said step of using the predicted positions to calculate desired changes in position of one or more of the streamer positioning devices is regulated by a global control system located on or near a seismic survey vessel that is configured into a feather angle mode, wherein said global control system attempts to direct the streamer positioning devices to maintain each of said streamers in a straight line offset from the towing direction of said marine seismic vessel by a certain feather angle, and into a turn control mode, wherein said global control system directs said streamer positioning devices to generate a force in the opposite direction of a turn at the beginning of the turn.

8. A method as claimed in claim **7**, in which said global control system is further configured into a streamer separation mode, wherein said global control system attempts to direct said streamer positioning device to maintain a minimum separation distance between adjacent streamers.

9. A method as claimed in claim **8**, further including the step of displaying the position of said streamer positioning devices on said seismic survey vessel.

10. A method as claimed in claim **9**, in which each streamer positioning device is attached to and unable rotate with respect to its streamer and further comprising the step of monitoring twist in said marine seismic streamers and calculating a desired change in the orientation of hydrodynamic deflecting surfaces of the streamer positioning devices to reduce said twist.

11. A method as claimed in claim **10**, further including the step of obtaining the desired positions of at least some of the streamer positioning devices.

12. A method as claimed in claim **11**, wherein the prediction of position of a streamer positioning device and the desired position of that same streamer positioning device are used to produce a desired force to be applied to its streamer by that streamer positioning device.

13. A method as claimed in claim **12**, in which said desired force is projected onto a current force axis and orientation of hydrodynamic deflecting surfaces of the streamer positioning device is calculated that will produce said projected force at said estimated velocity.

14. A method as claimed in claim **13**, in which the streamer positioning device is rotated to align the current force axis with said desired force and its hydrodynamic deflecting surface orientation is changed as the current force axis becomes more closely aligned with said desired force.

15. An array of seismic streamers towed by a towing vessel comprising:

(a) a plurality of streamer positioning devices on or inline with each streamer;

(b) a prediction unit adapted to predict positions of at least some of the streamer positioning devices; and

(c) a control unit adapted to use the predicted positions to calculate desired changes in positions of one or more of the streamer positioning devices.

16. Apparatus as claimed in claim **15**, in which each streamer positioning device has a first hydrodynamic deflecting surface and a second hydrodynamic deflecting surface, said first deflecting surface and said second deflecting surface being independently moveable to steer the streamer positioning device laterally and vertically.

17. Apparatus as claimed in claim **16**, wherein each streamer positioning device is rigidly attached to and unable to rotate with respect to its streamer.

18. Apparatus as claimed in claim **17**, further including means for determining the angular velocity of each streamer positioning device.

19. Apparatus as claimed in claim **18**, wherein a global control system is located on or near said seismic vessel and a respective local control system is located within or near each streamer positioning device and said global control system and said local control systems communicate using a respective communication line passing through each streamer.

20. Apparatus as claimed in claim **19**, in which input values for said local control systems are downloaded over said communication lines.

21. Apparatus as claimed in claim **20**, further including a respective backup communications channel in each streamer between the global control system and the local control systems of the streamer positioning devices of the streamer.

22. Apparatus as claimed in claim **21**, in which each local control system has a cycle rate that is at least 10 times greater than the data transfer rate of said communication line.

23. Apparatus as claimed in claim **22**, in which each local control system comprises a microprocessor programmed to monitor the current orientation of the wing of its streamer positioning device and to calculate desired changes to the orientation of said wing based on inputs from said global control system.

24. Apparatus as claimed in claim **23**, further including means for producing a weight function filtered depth value.

25. A method of controlling position of a seismic streamer comprising:

(a) calculating magnitude and direction of a desired total force or displacement to apply to the seismic streamer;

(b) adjusting, based on forces exerted on the streamer by hydrodynamic deflecting surfaces in a force axis, the calculated magnitude of total force or displacement to form an intermediate desired total force;

(c) adjusting a common angle between hydrodynamic deflecting surfaces to produce the intermediate desired total force along the force axis; and

(d) introducing a splay angle in to the hydrodynamic deflecting surfaces to produce a rotational movement in a body of the streamer positioning device to align the force axis with the direction of the desired total force.

* * * * *

Exhibit C

US007162967B2

(12) **United States Patent**
Hillesund et al.

(10) **Patent No.: US 7,162,967 B2**
(45) **Date of Patent: Jan. 16, 2007**

(54) **CONTROL SYSTEM FOR POSITIONING OF MARINE SEISMIC STREAMERS**

(75) Inventors: **Oyvind Hillesund**, Histon (GB); **Simon Hastings Bittleston**, Bury St Edmunds (GB)

(73) Assignee: **Westerngeco, L.L.C.**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/454,352**

(22) Filed: **Jun. 16, 2006**

(65) **Prior Publication Data**

US 2006/0260529 A1 Nov. 23, 2006

Related U.S. Application Data

(63) Continuation of application No. 09/787,723, filed as application No. PCT/IB99/01590 on Sep. 28, 1999, now Pat. No. 6,932,017.

(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**
B60P 3/10 (2006.01)
G01V 1/00 (2006.01)

(52) **U.S. Cl.** **114/344**; 367/19

(58) **Field of Classification Search** 114/162, 114/163, 242, 244–246, 253
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,404,664 A * 9/1983 Zachariadis 367/19
4,709,355 A * 11/1987 Woods et al. 367/16
5,790,472 A * 8/1998 Workman et al. 367/19

* cited by examiner

Primary Examiner—Jesús D. Sotelo
(74) *Attorney, Agent, or Firm*—WesternGeco, L.L.C.

(57) **ABSTRACT**

A method of controlling a streamer positioning device (**18**) configured to be attached to a marine seismic streamer (**12**) and towed by seismic survey vessel (**10**) and having a wing and a wing motor for changing the orientation of the wing. The method includes the steps of: obtaining an estimated velocity of the streamer positioning device, calculating a desired change in the orientation of the wing using the estimated velocity of the streamer positioning device, and actuating the wing motor to produce the desired change in the orientation of the wing. The invention also involves an apparatus for controlling a streamer positioning device including means for obtaining an estimated velocity of the streamer positioning device, means for calculating a desired change in the orientation of the wing using the estimated velocity of the streamer positioning device, and means for actuating the wing motor to produce the desired change in the orientation of the wing.

28 Claims, 3 Drawing Sheets

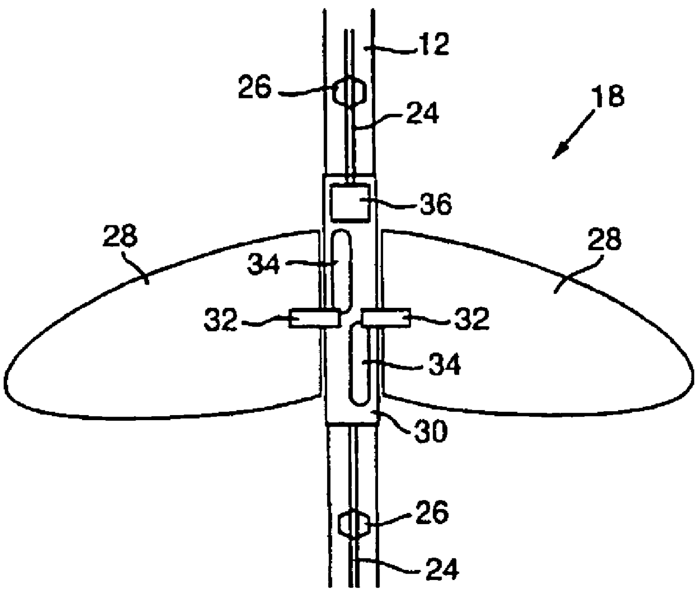

Fig.1.

Prior Art

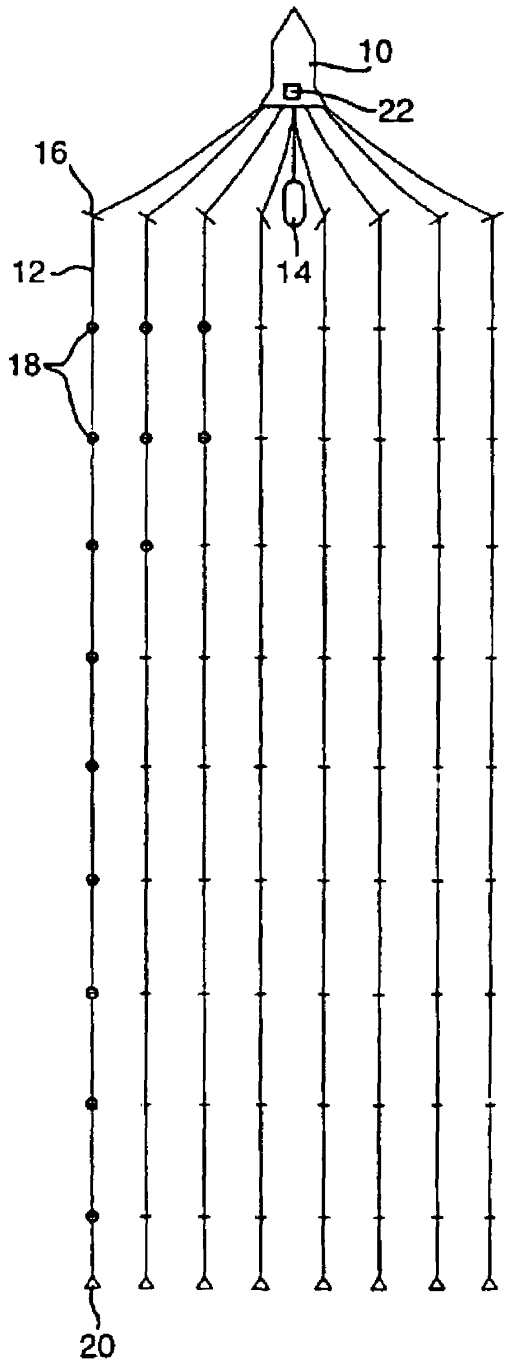

Fig.2.

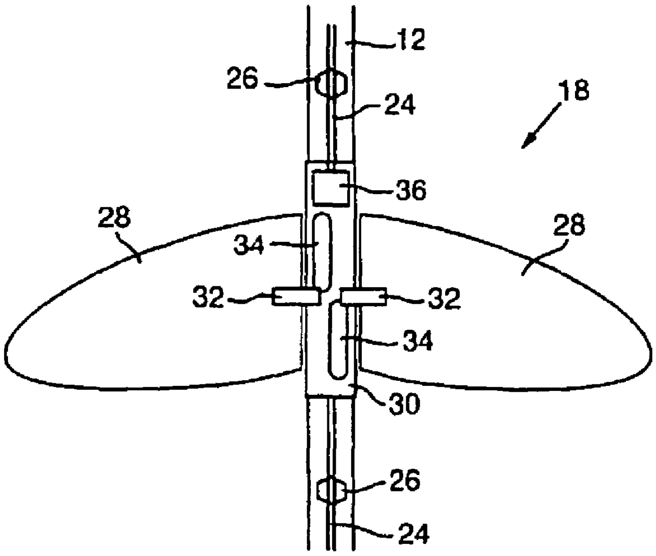
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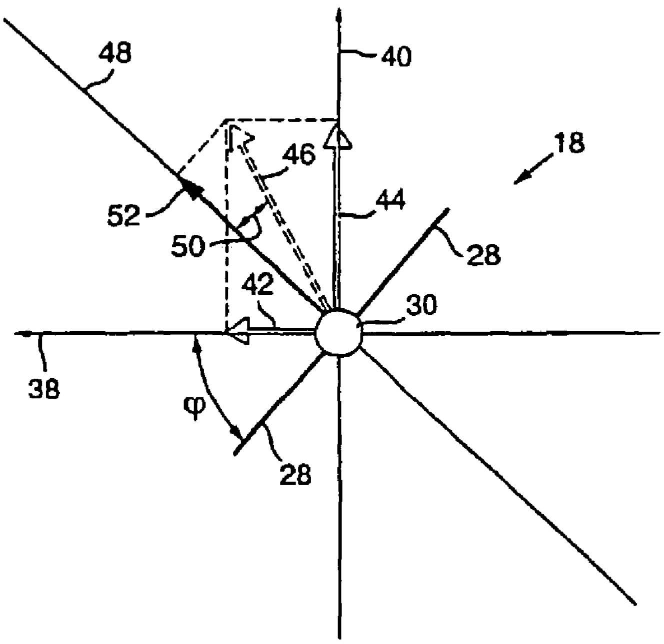
Fig.3.


48
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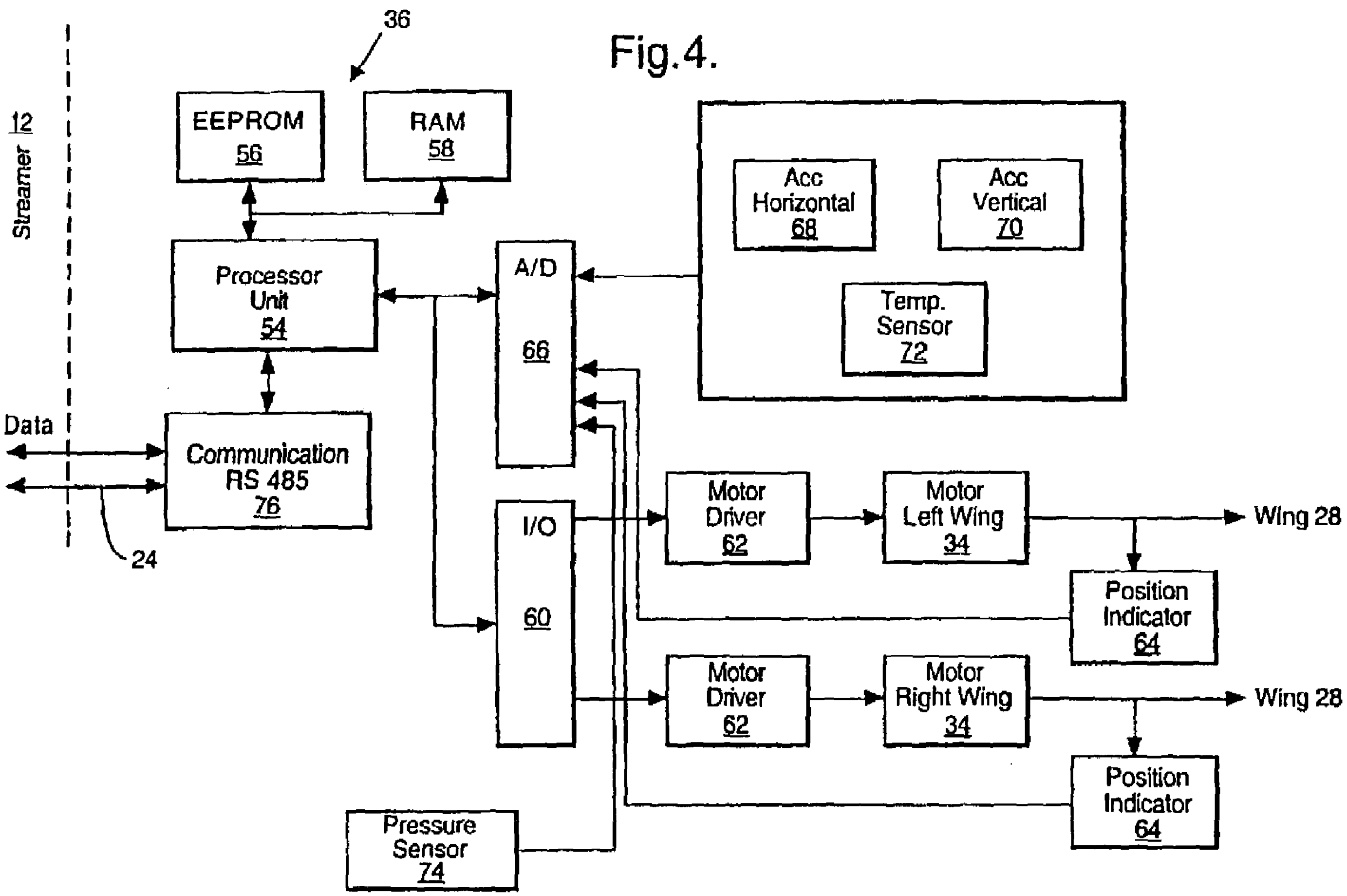
φ
28

Fig.4.


36
EEPROM 56
RAM 58
Streamer 12
Processor Unit 54
A/D 66
Acc Horizontal 68
Acc Vertical 70
Temp. Sensor 72
Data
Communication RS 485 76
24
I/O 60
Motor Driver 62
Motor Left Wing 34
Wing 28
Position Indicator 64
Motor Driver 62
Motor Right Wing 34
Wing 28
Position Indicator 64
Pressure Sensor 74

CONTROL SYSTEM FOR POSITIONING OF MARINE SEISMIC STREAMERS

CROSS-REFERENCE TO RELATED APPLICATIONS

Applicant claims priority under 35 U.S.C. § 120 from Ser. No. 11/070,614, filed Mar. 2, 2005, now U.S. Pat. No. 7,080,607, which was a continuation of parent application Ser. No. 09/787,723, filed Jul. 2, 2001, now U.S. Pat. No. 6,932,017, which was a 35 U.S.C. § 371 national stage filing from Patent Cooperation Treaty application number PCT/IB99/01590, filed Sep. 28, 1999, which in turn claimed priority from Great Britain patent application number 9821277.3, filed Oct. 1, 1998, from which Applicant claims foreign priority under 35 U.S.C. § 119, all of which are incorporated herein by reference. This application is also related to application Ser. Nos. 11/454,349 and 11/455,042, both filed simultaneously herewith, which also are both incorporated herein by reference.

BACKGROUND OF THE INVENTION

This invention relates generally to systems for controlling seismic data acquisition equipment and particularly to a system for controlling a marine seismic streamer positioning device.

A marine seismic streamer is an elongate cable-like structure, typically up to several thousand meters long, which contains arrays of seismic sensors, known as hydrophones, and associated electronic equipment along its length, and which is used in marine seismic surveying. In order to perform a 3D marine seismic survey, a plurality of such streamers are towed at about 5 knots behind a seismic survey vessel, which also tows one or more seismic sources, typically air guns. Acoustic signals produced by the seismic sources are directed down through the water into the earth beneath, where they are reflected from the various strata. The reflected signals are received by the hydrophones, and then digitized and processed to build up a representation of the subsurface geology.

The horizontal positions of the streamers are typically controlled by a deflector, located at the front end or "head" of the streamer, and a tail buoy, located at the back end or "tail" of the streamer. These devices create tension forces on the streamer which constrain the movement of the streamer and cause it to assume a roughly linear shape. Cross currents and transient forces cause the streamer to bow and undulate, thereby introducing deviations into this desired linear shape.

The streamers are typically towed at a constant depth of approximately ten meters, in order to facilitate the removal of undesired "ghost" reflections from the surface of the water. To keep the streamers at this constant depth, control devices known as "birds", are typically attached at various points along each streamer between the deflector and the tail buoy, with the spacing between the birds generally varying between 200 and 400 meters. The birds have hydrodynamic deflecting surfaces, referred to as wings, that allow the position of the streamer to be controlled as it is towed through the water. When a bird is used for depth control purposes only, it is possible for the bird to regularly sense its depth using an integrated pressure sensor and for a local controller within the bird to adjust the wing angles to maintain the streamer near the desired depth using only a desired depth value received from a central control system.

While the majority of birds used thus far have only controlled the depth of the streamers, additional benefits can be obtained by using properly controlled horizontally steerable birds, particularly by using the types of horizontally and vertically steerable birds disclosed in our published PCT International Application No. WO 98/28636. The benefits that can be obtained by using properly controlled horizontally steerable birds can include reducing horizontal out-of-position conditions that necessitate reacquiring seismic data in a particular area (i.e. in-fill shooting), reducing the chance of tangling adjacent streamers, and reducing the time required to turn the seismic acquisition vessel when ending one pass and beginning another pass during a 3D seismic survey.

It is estimated that horizontal out-of-position conditions reduce the efficiency of current 3D seismic survey operations by between 5 and 10%, depending on weather and current conditions. While incidents of tangling adjacent streamers are relatively rare, when they do occur they invariably result in prolonged vessel downtime. The loss of efficiency associated with turning the seismic survey vessel will depend in large part on the seismic survey layout, but typical estimates range from 5 to 10%. Simulations have concluded that properly controlled horizontally steerable birds can be expected to reduce these types of costs by approximately 30%.

One system for controlling a horizontally steerable bird, as disclosed in UK Patent GB 2093610 B, is to utilize a manually-operated central control system to transmit the magnitudes and directions of any required wing angle changes to the birds. While this method greatly simplifies the circuitry needed within the bird itself, it is virtually impossible for this type of system to closely regulate the horizontal positions of the birds because it requires manual input and supervision. This becomes a particularly significant issue when a substantial number of streamers are deployed simultaneously and the number of birds that must be controlled goes up accordingly.

Another system for controlling a horizontally steerable bird is disclosed in our published PCT International Application No. WO 98/28636. Using this type of control system, the desired horizontal positions and the actual horizontal positions are received from a remote control system and are then used by a local control system within the birds to adjust the wing angles. The actual horizontal positions of the birds may be determined every 5 to 10 seconds and there may be a 5 second delay between the taking of measurements and the determination of actual streamer positions. While this type of system allows for more automatic adjustment of the bird wing angles, the delay period and the relatively long cycle time between position measurements prevents this type of control system from rapidly and efficiently controlling the horizontal position of the bird. A more deterministic system for controlling this type of streamer positioning device is therefore desired.

It is therefore an object of the present invention to provide for an improved method and apparatus for controlling a streamer positioning device.

An advantage of the present invention is that the position of the streamer may be better controlled, thereby reducing the need for in-fill shooting, reducing the chance of streamer tangling, and reducing the time needed to turn the seismic survey vessel.

Another advantage of the present invention is that noise in marine seismic data associated with streamer position overcorrection and streamer positioning errors can be significantly reduced.

SUMMARY OF THE INVENTION

The present invention provides methods and apparatus for controlling the positions of marine seismic streamers in an array of such streamers being towed by a seismic survey vessel, the streamers having respective streamer positioning devices disposed therealong and each streamer positioning device having a wing and a wing motor for changing the orientation of the wing so as to steer the streamer positioning device laterally, said methods and apparatus involving (a) obtaining an estimated velocity of the streamer positioning devices, (b) for at least some of the streamer positioning devices, calculating desired changes in the orientation of their wings using said estimated velocity, and (c) actuating the wing motors to produce said desired changes in wing orientation.

The invention and its benefits will be better understood with reference to the detailed description below and the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of a seismic survey vessel and associated seismic data acquisition equipment;

FIG. **2** is a schematic horizontal cross-sectional view through a marine seismic streamer and an attached streamer positioning device;

FIG. **3** is a schematic vertical cross-sectional view through the streamer positioning device from FIG. **2**; and

FIG. **4** is a schematic diagram of the local control system architecture of the streamer positioning device from FIG. **2**.

DETAILED DESCRIPTION OF THE INVENTION

In FIG. **1**, a seismic survey vessel **10** is shown towing eight marine seismic streamers **12** that may, for instance, each be 3000 meters in length. The outermost streamers **12** in the array could be 700 meters apart, resulting in a horizontal separation between the streamers of 100 meters in the regular horizontal spacing configuration shown. A seismic source **14**, typically an airgun or an array of airguns, is also shown being towed by the seismic survey vessel **10**. At the front of each streamer **12** is shown a deflector **16** and at the rear of every streamer is shown a tail buoy **20**. The deflector **16** is used to horizontally position the end of the streamer nearest the seismic survey vessel **10** and the tail buoy **20** creates drag at the end of the streamer farthest from the seismic survey vessel **10**. The tension created on the seismic streamer by the deflector **16** and the tail buoy **20** results in the roughly linear shape of the seismic streamer **12** shown in FIG. **1**.

Located between the deflector **16** and the tail buoy **20** are a plurality of streamer positioning devices known as birds **18**. Preferably the birds **18** are both vertically and horizontally steerable. These birds **18** may, for instance, be located at regular intervals along the streamer, such as every 200 to 400 meters. The vertically and horizontally steerable birds **18** can be used to constrain the shape of the seismic streamer **12** between the deflector **16** and the tail buoy **20** in both the vertical (depth) and horizontal directions.

In the preferred embodiment of the present invention, the control system for the birds **18** is distributed between a global control system **22** located on or near the seismic survey vessel **10** and a local control system located within or near the birds **18**. The global control system **22** is typically connected to the seismic survey vessel's navigation system and obtains estimates of system wide parameters, such as the vessel's towing direction and velocity and current direction and velocity, from the vessel's navigation system.

The most important requirement for the control system is to prevent the streamers **12** from tangling. This requirement becomes more and more important as the complexity and the total value of the towed equipment increases. The trend in the industry is to put more streamers **12** on each seismic survey vessel **10** and to decrease the horizontal separation between them. To get better control of the streamers **12**, horizontal steering becomes necessary. If the birds **18** are not properly controlled, horizontal steering can increase, rather than decrease, the likelihood of tangling adjacent streamers. Localized current fluctuations can dramatically influence the magnitude of the side control required to properly position the streamers. To compensate for these localized current fluctuations, the inventive control system utilizes a distributed processing control architecture and behavior-predictive model-based control logic to properly control the streamer positioning devices.

In the preferred embodiment of the present invention, the global control system **22** monitors the actual positions of each of the birds **18** and is programmed with the desired positions of or the desired minimum separations between the seismic streamers **12**. The horizontal positions of the birds **18** can be derived, for instance, using the types of acoustic positioning systems described in our U.S. Pat. No. 4,992,990 or in our PCT International Patent Application No. WO 98/21163. Alternatively, or additionally, satellite-based global positioning system equipment can be used to determine the positions of the equipment. The vertical positions of the birds **18** are typically monitored using pressure sensors attached to the birds, as discussed below.

The global control system **22** preferably maintains a dynamic model of each of the seismic streamers **12** and utilizes the desired and actual positions of the birds **18** to regularly calculate updated desired vertical and horizontal forces the birds should impart on the seismic streamers **12** to move them from their actual positions to their desired positions. Because the movement of the seismic streamer **12** causes acoustic noise (both from seawater flow past the bird wing structures as well as cross current flow across the streamer skin itself), it is important that the streamer movements be restrained and kept to the minimum correction required to properly position the streamers. Any streamer positioning device control system that consistently overestimates the type of correction required and causes the bird to overshoot its intended position introduces undesirable noise into the seismic data being acquired by the streamer. In current systems, this type of over-correction noise is often balanced against the "noise" or "smearing" caused when the seismic sensors in the streamers **12** are displaced from their desired positions.

The global control system **22** preferably calculates the desired vertical and horizontal forces based on the behavior of each streamer and also takes into account the behavior of the complete streamer array. Due to the relatively low sample rate and time delay associated with the horizontal position determination system, the global control system **22** runs position predictor software to estimate the actual locations of each of the birds **18**. The global control system **22** also checks the data received from the vessel's navigation system and the data will be filled in if it is missing. The interface between the global control system **22** and the local control system will typically operate with a sampling frequency of at least 0.1 Hz. The global control system **22** will typically acquire the following parameters from the vessel's navigation system: vessel speed (m/s), vessel heading (degrees), current speed (m/s), current heading (degrees), and the location of each of the birds in the horizontal plane in a vessel fixed coordinate system. Current speed and heading can also be estimated based on the average forces acting on the streamers **12** by the birds **18**. The global control system **22** will preferably send the following values to the local bird controller: demanded vertical force, demanded horizontal force, towing velocity, and crosscurrent velocity.

The towing velocity and crosscurrent velocity are preferably "water-referenced" values that are calculated from the vessel speed and heading values and the current speed and heading values, as well as any relative movement between the seismic survey vessel **10** and the bird **18** (such as while the vessel is turning), to produce relative velocities of the bird **18** with respect to the water in both the "in-line" and the "cross-line" directions. Alternatively, the global control system **22** could provide the local control system with the horizontal velocity and water in-flow angle. The force and velocity values are delivered by the global control system **22** as separate values for each bird **18** on each streamer **12** continuously during operation of the control system.

The "water-referenced" towing velocity and crosscurrent velocity could alternatively be determined using flowmeters or other types of water velocity sensors attached directly to the birds **18**. Although these types of sensors are typically quite expensive, one advantage of this type of velocity determination system is that the sensed in-line and cross-line velocities will be inherently compensated for the speed and heading of marine currents acting on said streamer positioning device and for relative movements between the vessel **10** and the bird **18**.

FIG. **2** shows a type of bird **18** that is capable of controlling the position of seismic streamers **12** in both the vertical and horizontal directions. A bird **18** of this type is also disclosed in our PCT International Application No. WO 98/28636. While a number of alternative designs for the vertically and horizontally steerable birds **18** are possible, including those utilizing one full-moving wing with ailerons, three full-moving wings, and four full-moving wings, the independent two-wing principal is, conceptually, the simplest and most robust design.

In FIG. **2**, a portion of the seismic streamer **12** is shown with an attached bird **18**. A communication line **24**, which may consist of a bundle of fiber optic data transmission cables and power transmission wires, passes along the length of the seismic streamer **12** and is connected to the seismic sensors, hydrophones **26**, that are distributed along the length of the streamer, and to the bird **18**. The bird **18** preferably has a pair of independently moveable wings **28** that are connected to rotatable shafts **32** that are rotated by wing motors **34** and that allow the orientation of the wings **28** with respect to the bird body **30** to be changed. When the shafts **32** of the bird **18** are not horizontal, this rotation causes the horizontal orientation of the wings **28** to change and thereby changes the horizontal forces that are applied to the streamer **12** by the bird.

The motors **34** can consist of any type of device that is capable of changing the orientation of the wings **28**, and they are preferably either electric motors or hydraulic actuators. The local control system **36** controls the movement of the wings **28** by calculating a desired change in the angle of the wings and then selectively driving the motors **34** to effectuate this change. While the preferred embodiment depicted utilizes a separate motor **34** for each wing **28**, it would be also be possible to independently move the wings **28** using a single motor **34** and a selectively actuatable transmission mechanism.

When the bird **18** uses two wings **28** to produce the horizontal and vertical forces on the streamer **12**, the required outputs of the local control system **36** are relatively simple, the directions and magnitudes of the wing movements required for each of the wings **28**, or equivalently the magnitude and direction the motors **34** need to be driven to produce this wing movement. While the required outputs of the local control system **36** for such a two full moving wing design is quite simple, the structure and operation of the overall system required to coordinate control of the device is relatively complicated.

FIG. **3** shows a schematic vertical cross-sectional view through the streamer positioning device shown in FIG. **2** that will allow the operation of the inventive control system to be described in more detail. The components of the bird **18** shown in FIG. **3** include the wings **28** and the body **30**. Also shown in FIG. **3** are a horizontal coordinate axis **38** and a vertical coordinate axis **40**. During operation of the streamer positioning control system, the global control system **22** preferably transmits, at regular intervals (such as every five seconds) a desired horizontal force **42** and a desired vertical force **44** to the local control system **36**.

The desired horizontal force **42** and the desired vertical force **44** are combined within the local control system **36** to calculate the magnitude and direction of the desired total force **46** that the global control system **22** has instructed the local control system to apply to the streamer **12**. The global control system **22** could alternatively provide the magnitude and direction of the desired total force **46** to the local control system **36** instead of the desired horizontal force **42** and the desired vertical force **44**.

While the desired horizontal force **42** and the desired vertical force **44** are preferably calculated by the global control system **22**, it is also possible for the local control system **36** in the inventive control system to calculate one or both of these forces using a localized displacement/force conversion program. This type of localized conversion program may, for instance, use a look-up table or conversion routine that associates certain magnitudes and directions of vertical or horizontal displacements with certain magnitudes and directions of changes in the vertical or horizontal forces required. Using this type of embodiment, the global control system **22** can transmit location information to the local control system **36** instead of force information. Instead of the desired vertical force **44**, the global control system **22** can transmit a desired vertical depth and the local control system **36** can calculate the magnitude and direction of the deviation between the desired depth and the actual depth. Similarly, instead of transmitting a desired horizontal force **42**, the global control system **22** can transmit the magnitude and direction of the displacement between the actual horizontal position and the desired horizontal position of the bird **18**. One advantage to this alternative type of system is that the required vertical force can be rapidly updated as the local control system receives updated depth information from the integrated pressure sensor. Other advantages of this type of alternative system include reducing communication traffic on the communication line **24** and simplifying the programming needed to convert the measured vertical and/or horizontal displacements into corresponding forces to be applied by the birds **18**.

When the local control system **36** has a new desired horizontal force **42** and desired vertical force **44** to be applied, the wings **28** will typically not be in the proper orientation to provide the direction of the desired total force **46** required. As can be seen in FIG. **3**, the wings **28** introduce a force into the streamer **12** along an axis perpendicular to the rotational axis of the wings **28** and perpendicular to the streamer. This force axis **48** is typically not properly aligned with the desired total force **46** when new desired horizontal and vertical force values are received from the global control system **22** or determined by the local control system **36** and some rotation of the bird **18** is required before the bird can produce this desired total force **46**. As can be seen, the force axis **48** is directly related to the bird roll angle, designated in FIG. **3** as ϕ.

The local control system **36** optimizes the control process by projecting the desired total force **46** onto the force axis **48** (i.e. multiplying the magnitude of the desired total force by the cosine of the deviation angle **50**) to produce an intermediate desired force **52** and then adjusting the wing common angle α (the angle of the wings with respect to the bird body **30**, or the average angle if there is a non-zero splay angle) to produce this magnitude of force along the force axis. The calculated desired common wing angle is compared to the current common wing angle to calculate a desired change in the common wing angle and the wing motors **34** are actuated to produce this desired change in the orientation of the wings.

A splay angle is then introduced into the wings **28** to produce a rotational movement in the bird body **30** (i.e. to rotate the force axis **48** to be aligned with the desired total force **46**). The splay angle is the difference between the angles of the wings **28** with respect to the bird body **30**. As the bird body **30** rotates and the force axis **48** becomes more closely aligned with the desired total force **46**, the bird roll angle and the bird roll angular velocity are monitored, the splay angle is incrementally reduced, and the common angle is incrementally increased until the intermediate desired force **52** is in the same direction and of the same magnitude as the desired total force. The local control system **36** carefully regulates the splay angle to ensure that the streamer is stable in roll degree of freedom. The calculated common wing angle and the splay angle are also regulated by the local control system **36** to prevent the wings **28** from stalling and to ensure that the splay angle is prioritized.

When using the type of birds described in our published PCT International Application No. WO 98/28636, where the bird **18** is rigidly attached, and cannot rotate with respect, to the streamer **12**, it is important for the control system to take the streamer twist into account. If this is not taken into account, the bird **18** can use all of its available splay angle to counter the twist in the streamer **12**. The bird **18** will then be unable to reach the demanded roll angle and the generated force will decrease. The inventive control system incorporates two functions for addressing this situation; the anti-twist function and the untwist function.

In the anti-twist function, the streamer twist is estimated by weightfunction filtering the splay angle measurements instead of simply averaging the splay angle measurements to improve the bandwidth of the estimation. The anti-twist function engages when the estimated twist has reached a critical value and it then overrides the normal shortest path control of the calculated roll angle. The anti-twist function forces the bird **18** to rotate in the opposite direction of the twist by adding +/−180 degrees to the demanded roll angle. Once the twist has been reduced to an acceptable value, the anti-twist function disengages and the normal shortest path calculation is continued.

The untwist function is implemented by the global control system **22** which monitors the splay angle for all of the birds **18** in each streamer **12**. At regular intervals or when the splay angle has reached a critical value, the global control system **22** instructs each local control system **36** to rotate each bird **18** in the opposite direction of the twist. The number of revolutions done by each bird **18** is monitored and the untwist function is disengaged once the twist has reached an acceptable level. FIG. **4** is a schematic diagram of the architecture of the local control system **36** for the bird **18**. The local control system **36** consists of a central processor unit **54**, having EEPROM 56 and RAM **58** memory, an input/output subsystem **60** that is connected to a pair of motor drivers **62**, and an analog to digital conversion unit **66**. The motor drivers **62** are connected to and actuate the wing motors **34** to produce the desired change the orientation of the wings **28** with respect to the bird body **30**.

The wing motor **34**/wing **28** units are also connected to wing position indicators **64** that sense the relative positions of the wings and provide measurements to the analog to digital conversion unit **66** which converts the analog wing position indicator **64** measurements into digital format and conveys these digital values to the central processor unit **54**. Various types of wing position indicators **64** can be used, including resistive angle or displacement sensors inductive sensors, capacitive sensors, hall sensors, or magneto-restrictive sensors.

A horizontal accelerometer **68** and a vertical accelerometer **70**, placed at right angles with respect to one another, are also connected to the analog to digital conversion unit **66** and these accelerometers convey measurements that allow the central processor unit **54** to determine the roll angle and roll rate of the bird **18**. An angular velocity vibrating rate gyro (rategyro) can also be used to measure the roll rate of the bird **18**. A temperature sensor **72** is connected to the analog to digital conversion unit **66** to provide temperature measurements that allow the horizontal accelerometer **68** and the vertical accelerometer **70** to be calibrated.

A pressure sensor **74** is also connected to the analog to digital conversion unit **66** to provide the central processor unit **54** with measurements of the water pressure at the bird **18**. To calculate an appropriate depth value, the measured pressure values must be filtered to limit the disturbance from waves. This is done in the inventive control system with a weightfunction filter that avoids the large phase displacements caused by mean value filters. Instead of using an instantaneous depth value or simply calculating an average depth value over a given period of time (and thereby incorporating a large phase displacement into the depth value), the inventive control system uses a differentially weighted pressure filtering scheme. First the pressure values are transformed into depth values by dividing the pressure sensor reading by the seawater density and gravitational acceleration. These depth values are then filtered using a weight function filter. Typical incremental weighting functions values range from 0.96 to 0.90 (sample weights of 1.0, 0.9, 0.81, 0.729, etc.) and the filter will typically process depth values received over a period of at least 100 seconds.

The central processor unit **54** is also connected to a RS485 communications unit **76** that allows information to be exchanged between the local control system **36** and the global control system **22** over the communication line **24** that passes through the streamer **12**. The RS485 bus may, for instance, utilize Neuron chips that communicate using a Local Operating Network protocol to control the data transfer.

Preferably, the central processor unit **54** and associated components comprise a MicroChip 17C756 processor. This type of microprocessor has very low power requirements, a dual UART on-chip, 12-channel, 10 bit ADC on-chip, 908×8 RAM, 16 k×16 ROM, and 50 digital I/O channels. The software running on the central processor unit **54** will typically consist of two units, the local control unit and the hardware control unit. It is typically not possible to pre-load both of these program units into the EEPROM 56 and it is possible to update these program units without having to open the bird **18**. The on-chip memory may thus only initially contain a boot-routine that enables the loading of software units into the external memory via the RS485 communication unit **76**. The external program memory (EEPROM 56) will typically be a non-volatile memory so that these program units do not have to be re-loaded after every power down.

The central processor unit **54** must be able to run the local control system software fast enough to secure the sampling frequency needed for effective local bird control. This may mean, for instance, a sample rate of 10 Hz, which may be 10 to 100 times faster than the sample rate of the communications between the global control system **22** and the local control system **36**. As discussed above, the central processor unit **54** will also receive data from sensors attached to the bird **18**. The sensed values include bird roll angle, bird roll angular velocity (roll rate), the wing angles, and the static pressure of the water. These values are typically delivered to the central processor unit **54** at a sample rate of at least 10 Hz. The following values may be transmitted from the local control system **36** to the global control system **22** using the RS485 communication unit **76**: the measured roll angle, the measured roll rate, the measured wing angles, the measured water pressure, the calculated depth, and the calculated wing forces.

The system has been designed with a redundant communication system to increase its overall reliability. The bird **18** will typically have a backup communications channel, such as by overlaying a backup control signal on top of the power line current. This backup communications channel is particularly important because in the event of loss of communications to the bird **18** there would otherwise be no method for instructing the bird **18** to bring the streamer **12** to surface so the defective communications equipment can be repaired or replaced.

In contrast to previous streamer position device control systems, the present control system converts the desired horizontal force **42** and the desired vertical force **44** into a desired roll angle ϕ and a desired common wing angle α by deterministic calculations, rather than using an "incremental change/measured response/further incremental change based on measured response" type of feedback control circuit. The desired roll angle ϕ can be calculated in the manner discussed in the text describing FIG. **3** above. The magnitude of the force F imparted by the wings **28** along the force axis **48** can, for instance, be deterministically calculated using the following formula:

$$F=0.5\rho AC_L(V_{tow}\cos(\alpha)-V_{current}\sin(\alpha))^2$$

where: ρ=water density;

A=wing area;

C_L=wing lift coefficient;

α=common wing angle;

V_{tow}=towing velocity; and

$V_{current}$=crosscurrent velocity.

A similar deterministic calculation could be made using a calculated coefficient that incorporates the towing velocity of the bird **18**. A gain factor GF, for instance, could be calculated as follows:

$$GF=0.5\rho AC_L(V_{tow})^2$$

which could be simply multiplied by $\cos(\alpha)^2$ to estimate the force that would be applied for a given common angle.

One of the beneficial elements of the inventive control system is that the desired change in the orientation of the wing **28** is calculated using an estimate of the velocity of the bird **18** rather than simply relying on a feedback-loop type of control system that operates in the same manner regardless of the vessel speed. Because the force produced by wing **28** is proportional to the velocity of the device squared, a much more precise calculation of the desired change in the wing orientation can be made by using an estimate of the device velocity.

The inventive control system is based on shared responsibilities between the global control system **22** located on the seismic survey vessel **10** and the local control system **36** located on the bird **18**. The global control system **22** is tasked with monitoring the positions of the streamers **12** and providing desired forces or desired position information to the local control system **36**. The local control system **36** within each bird **18** is responsible for adjusting the wing splay angle to rotate the bird to the proper position and for adjusting the wing common angle to produce the magnitude of total desired force required.

The inventive control system will primarily operate in two different control modes: a feather angle control mode and a turn control mode. In the feather angle control mode, the global control system **22** attempts to keep each streamer in a straight line offset from the towing direction by a certain feather angle. The feather angle could be input either manually, through use of a current meter, or through use of an estimated value based on the average horizontal bird forces. Only when the crosscurrent velocity is very small will the feather angle be set to zero and the desired streamer positions be in precise alignment with the towing direction.

The turn control mode is used when ending one pass and beginning another pass during a 3D seismic survey, sometimes referred to as a "line change". The turn control mode consists of two phases. In the first part of the turn, every bird **18** tries to "throw out" the streamer **12** by generating a force in the opposite direction of the turn. In the last part of the turn, the birds **18** are directed to go to the position defined by the feather angle control mode. By doing this, a tighter turn can be achieved and the turn time of the vessel and equipment can be substantially reduced. Typically during the turn mode adjacent streamers will be depth separated to avoid possible entanglement during the turn and will be returned to a common depth as soon as possible after the completion of the turn. The vessel navigation system will typically notify the global control system **22** when to start throwing the streamers **12** out, and when to start straightening the streamers.

In extreme weather conditions, the inventive control system may also operate in a streamer separation control mode that attempts to minimize the risk of entanglement of the streamers. In this control mode, the global control system **22** attempts to maximize the distance between adjacent streamers. The streamers **12** will typically be separated in depth and the outermost streamers will be positioned as far away from each other as possible. The inner streamers will then be regularly spaced between these outermost streamers, i.e. each bird **18** will receive desired horizontal forces **42** or desired horizontal position information that will direct the bird **18** to the midpoint position between its adjacent streamers.

While the embodiment of the inventive control system described above is shown in connection with a "bird" type of streamer positioning device, it will be readily understood that the control system method and apparatus may also be used in connection with streamer positioning devices that are characterized as "deflectors" or steerable "tail buoys" because they are attached to either the front end or the back end of the streamer **12**.

The present invention includes any novel feature or novel combination of features disclosed herein, either explicitly or implicitly.

What is claimed is:

1. A method comprising:

(a) towing an array of streamers each having a plurality of streamer positioning devices there along, at least one of the streamer positioning devices having a wing;

(b) transmitting from a global control system location information to at least one local control system on the at least one streamer positioning devices having a wing; and

(c) adjusting the wing using the local control system.

2. The method of claim **1** wherein the adjusting comprises calculating, with the at least one local control system, a desired force on the at least one streamer positioning device using the location information, the desired force selected from a desired horizontal force, a desired vertical force, and both.

3. The method as claimed in claim **2** wherein the calculating comprises a localized conversion program that associates magnitude and direction of vertical displacement, horizontal displacement, or both displacements with magnitude and direction of the desired vertical force, the desired horizontal force, or both forces.

4. The method as claimed in claim **1**, wherein the global control system transmits a desired vertical depth for the at least one streamer positioning device and the local control system calculates magnitude and direction of the deviation between the desired vertical depth and actual depth.

5. The method as claimed in claim **1**, wherein the global control system transmits a desired horizontal displacement for the at least one streamer positioning device and the local control system calculates magnitude and direction of the deviation between the desired horizontal displacement and actual horizontal displacement.

6. The method as claimed in claim **1**, comprising calculating velocity of at least one of the streamer positioning devices, wherein the calculating velocity comprises at least one of a) using a vessel speed received from a navigation system on a seismic survey vessel; b) compensating for the speed and heading of marine currents acting on the at least one streamer positioning device; and c) compensating for relative movement between the seismic survey vessel and the at least one streamer positioning device.

7. The method as claimed in claim **6**, in which said step of adjusting the wing using the local control system is regulated to prevent the positioning device from stalling.

8. The method as claimed in claim **7**, in which said step of using the location information to calculate desired forces on the at least one streamer positioning device is regulated by the global control system located on or near a seismic survey vessel that is configured into a feather angle mode, wherein the global control system attempts to direct the streamer positioning devices to maintain each of the streamers in a straight line offset from the towing direction of the marine seismic vessel by a certain feather angle, and into a turn control mode, wherein the global control system directs the streamer positioning devices to generate a force in the opposite direction of a turn at the beginning of the turn.

9. The method as claimed in claim **8**, which said global control system is further configured into a streamer separation mode, wherein said global control system attempts to direct said streamer positioning device to maintain a minimum separation distance between adjacent streamers.

10. The method as claimed in claim **9**, further including the step of displaying the position of said streamer positioning devices on said seismic survey vessel.

11. The method as claimed in claim **10**, in which each streamer positioning device is attached to and unable rotate with respect to its streamer and further comprising the step of monitoring twist in said marine seismic streamers and calculating a desired change in the orientation of hydrodynamic deflecting surfaces of the streamer positioning devices to reduce said twist.

12. The method as claimed in claim **11**, further including the step of obtaining the desired positions of at least some of the streamer positioning devices.

13. The method as claimed in claim **12**, in which said desired force is projected onto a current force axis and orientation of hydrodynamic deflecting surfaces of the streamer positioning device is calculated that will produce said projected force at said calculated velocity.

14. The method as claimed in claim **13**, in which the streamer positioning device is rotated to align the current force axis with said desired force and its hydrodynamic deflecting surface orientation is changed as the current force axis becomes more closely aligned with said desired force.

15. An array of seismic streamers towed by a towing vessel comprising:

(a) a plurality of streamer positioning devices on or inline with each streamer, at least one of the streamer positioning devices having a wing;

(b) a global control system transmitting location information to at least one local control system on the at least one streamer positioning device having a wing, the local control system adjusting the wing.

16. The apparatus of claim **15** wherein the local control system calculates forces selected from a desired horizontal force, a desired vertical force, and both, on the at least one streamer positioning device using the location information.

17. The apparatus of claim **16** wherein local control system comprises a localized conversion program that associates magnitude and direction of vertical displacement, horizontal displacement, or both displacements with magnitude and direction of the desired vertical force, the desired horizontal force, or both forces.

18. The apparatus as claimed in claim **16**, wherein the global control system transmits a desired vertical depth for the at least one streamer positioning device and the local control system calculates magnitude and direction of the deviation between the desired vertical depth and actual depth.

19. The apparatus as claimed in claim **16**, wherein the global control system transmits a desired horizontal displacement for the at least one streamer positioning device and the local control system calculates magnitude and direction of the deviation between the desired horizontal displacement and actual horizontal displacement.

20. The apparatus as claimed in claim **16**, comprising means for calculating velocity of at least one of the streamer positioning devices, wherein the means for calculating velocity comprises means selected from at least one of a) a navigation system on a seismic survey vessel calculating vessel speed; b) a current meter compensating for the speed and heading of marine currents acting on the at least one streamer positioning device; and c) a unit measuring relative movement between the seismic survey vessel and the at least one streamer positioning device.

21. The apparatus as claimed in claim **20**, wherein the local control system adjusting the wing includes a regulator to prevent the positioning device from stalling.

22. The apparatus as claimed in claim **21**, wherein use of the location information to calculate desired forces on the at least one streamer positioning device is regulated by the global control system located on or near a seismic survey vessel that is configured into a feather angle mode, wherein the global control system attempts to direct the streamer positioning devices to maintain each of the streamers in a straight line offset from the towing direction of the marine seismic vessel by a certain feather angle, and into a turn control mode, wherein the global control system directs the streamer positioning devices to generate a force in the opposite direction of a turn at the beginning of the turn.

23. The apparatus as claimed in claim **22**, in which the global control system is further configured into a streamer separation mode, wherein said global control system attempts to direct said streamer positioning device to maintain a minimum separation distance between adjacent streamers.

24. The apparatus as claimed in claim **23**, comprising a display of the position of said streamer positioning devices on said seismic survey vessel.

25. The apparatus as claimed in claim **24**, in which each streamer positioning device is attached to and unable rotate with respect to its streamer, and further comprising a monitoring component to monitor twist in said marine seismic streamers and a calculating unit for calculating a desired change in the orientation of hydrodynamic deflecting surfaces of the streamer positioning devices to reduce said twist.

26. The apparatus as claimed in claim **25**, further including the step of obtaining the desired positions of at least some of the streamer positioning devices.

27. The apparatus as claimed in claim **26**, in which said desired force is projected onto a current force axis and orientation of hydrodynamic deflecting surfaces of the streamer positioning device is calculated that will produce said projected force at said calculated velocity.

28. The apparatus as claimed in claim **27**, in which the streamer positioning device is rotated to align the current force axis with said desired force and its hydrodynamic deflecting surface orientation is changed as the current force axis becomes more closely aligned with said desired force.

* * * * *

Exhibit D

US006691038B2

(12) **United States Patent**
Zajac

(10) **Patent No.: US 6,691,038 B2**
(45) **Date of Patent: Feb. 10, 2004**

(54) **ACTIVE SEPARATION TRACKING AND POSITIONING SYSTEM FOR TOWED SEISMIC ARRAYS**

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(73) Assignee: **WesternGeco L.L.C.**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 174 days.

(21) Appl. No.: **09/882,952**

(22) Filed: **Jun. 15, 2001**

(65) **Prior Publication Data**

US 2003/0208320 A1 Nov. 6, 2003

(51) **Int. Cl.**[7] **G01V 1/38**
(52) **U.S. Cl.** **702/14**; 367/20
(58) **Field of Search** 702/14, 16; 367/16, 367/72, 20, 19, 17; 114/244, 245, 246

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,676,183	A	*	6/1987	Conboy	114/245
4,729,333	A	*	3/1988	Kirby et al.	114/244
4,890,568	A	*	1/1990	Dolengowski	114/246
5,771,202	A		6/1998	Bale et al.	367/20
5,784,335	A	*	7/1998	Deplante et al.	367/72
5,790,472	A		8/1998	Workman et al.	367/19
5,920,828	A	*	7/1999	Norris et al.	702/14
6,011,752	A		1/2000	Ambs et al.	367/17
6,028,817	A		2/2000	Ambs	367/16
6,418,378	B1	*	7/2002	Nyland	702/14

FOREIGN PATENT DOCUMENTS

EP	0613025 A1 *	8/1994		G01V/1/38
EP	0909701 A2	4/1999		G01V/1/38
GB	2122562 A *	1/1984		B63B/21/66
GB	WO 98/28636	7/1998		G01V/1/38
WO	WO 00/20895	4/2000		G01V/1/38
WO	WO 01/16623	3/2001		G01V/1/38

OTHER PUBLICATIONS

Morice et al., SPE 63136: 4D–Ready Towed–Streamer Data and the Foinaven Benchmark, Oct. 2000, pp. 1–7.

Marine Lateral Steering Advance Unveiled, Petroleum Engineer International, Hart Publications, US, vol. 73, No. 8, Aug. 2000, p. 113.

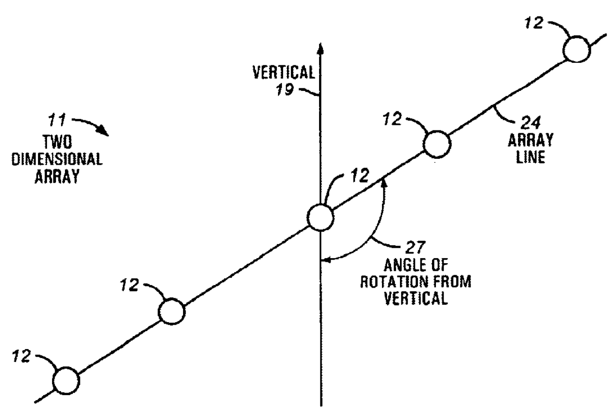
* cited by examiner

Primary Examiner—John Barlow
Assistant Examiner—Victor J. Taylor
(74) *Attorney, Agent, or Firm*—Madan, Mossman & Sriram, P.C.

(57) **ABSTRACT**

A method and apparatus comprising an active control system for a towed seismic streamer array that enables any relative positional control of any number of towed seismic streamers. The streamer positions are controlled horizontally and vertically using active control units positioned within the seismic array. The three component (x, y, z) position of each streamer element, relative to the vessel and relative to each other is controlled, tracked and stored during a seismic data acquisition run. The present invention enables a seismic array to be maneuvered as the towing vessel maintains course, enables maintenance of specific array position and geometry in the presence of variable environmental factors and facilitates four-dimensional seismic data acquisition by sensing and storing the position of the array and each array element with respect to time.

50 Claims, 6 Drawing Sheets



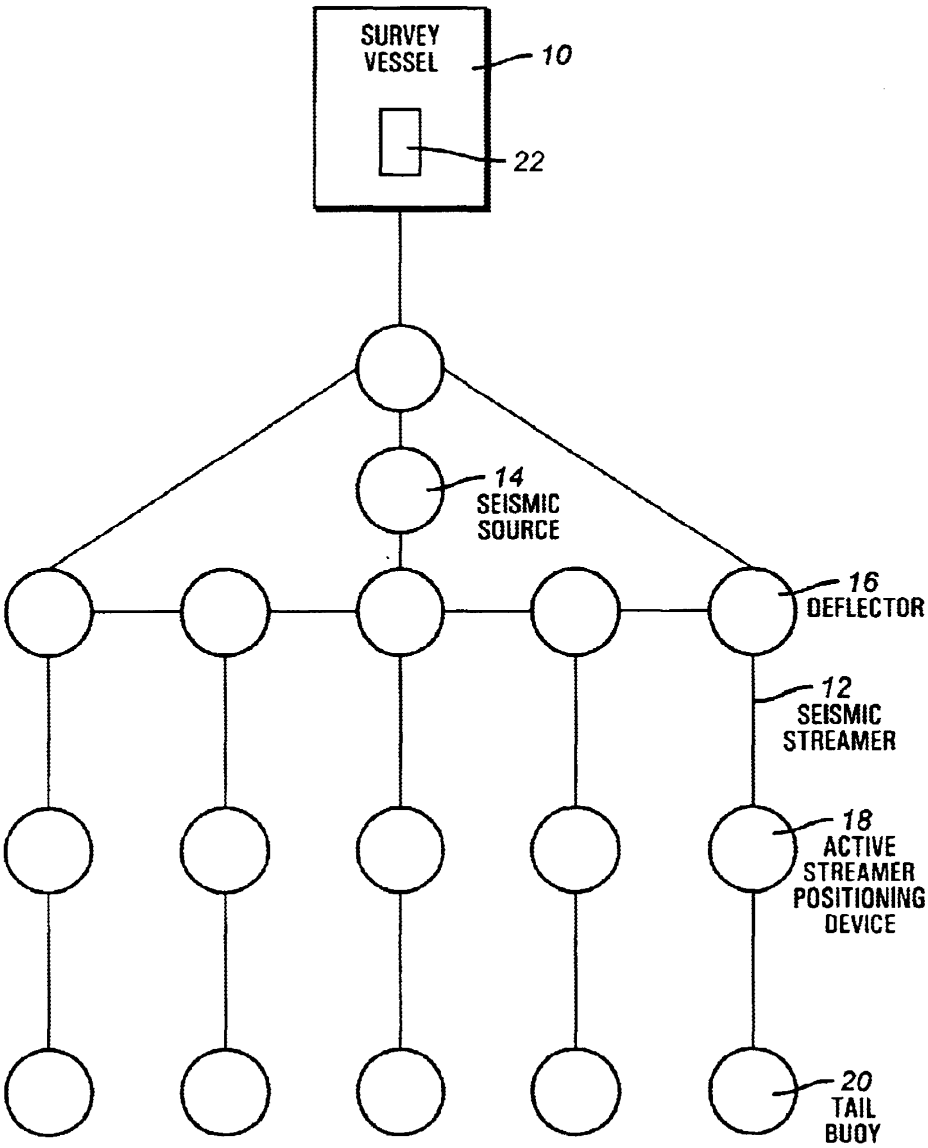

SURVEY VESSEL
10
22
14
SEISMIC SOURCE
16
DEFLECTOR
12
SEISMIC STREAMER
18
ACTIVE STREAMER POSITIONING DEVICE
20
TAIL BUOY

FIG. 1

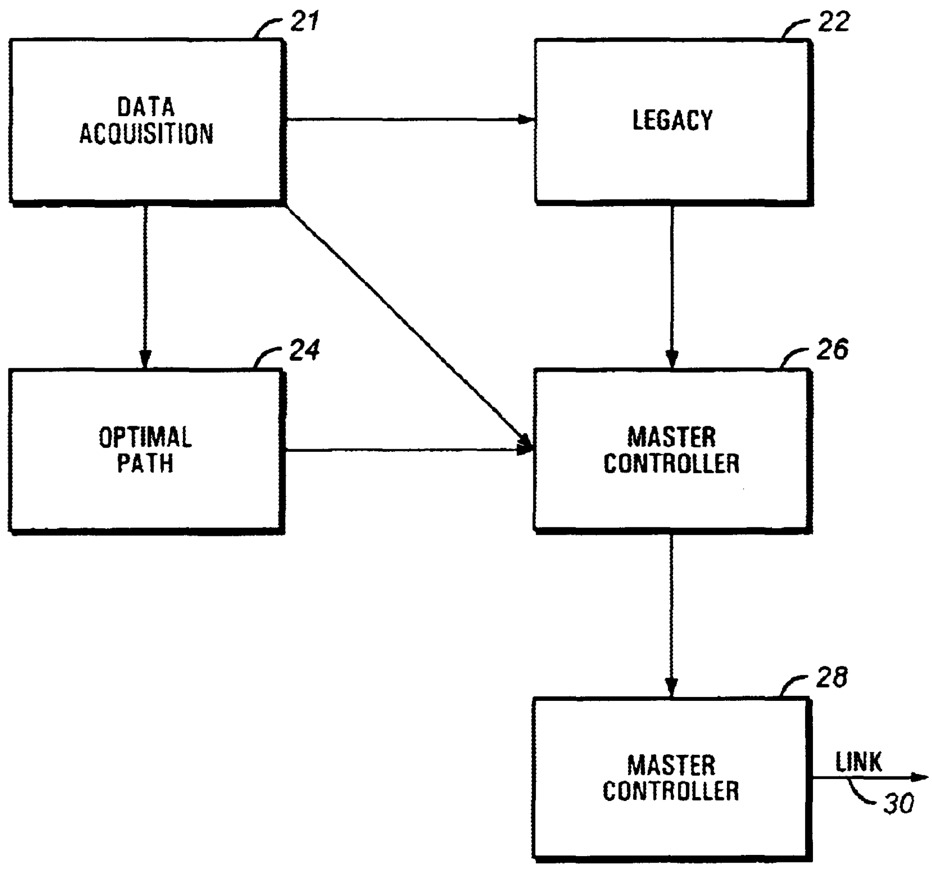

21
DATA ACQUISITION
22
LEGACY
24
OPTIMAL PATH
26
MASTER CONTROLLER
28
MASTER CONTROLLER
LINK
30

FIG. 2

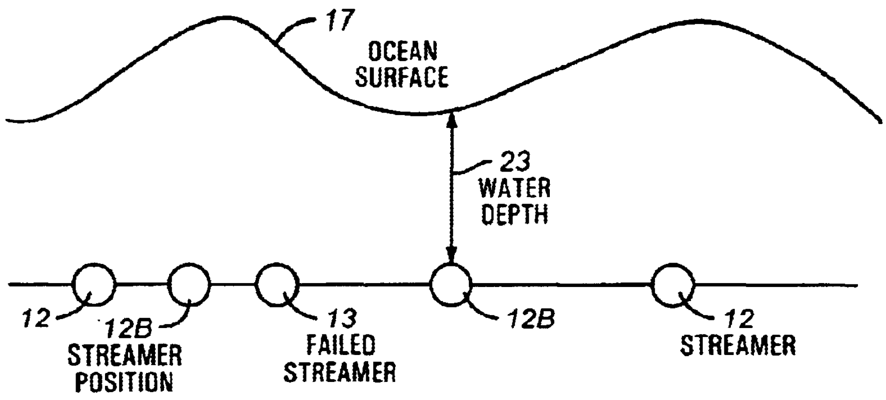

17
OCEAN
SURFACE
23
WATER
DEPTH
12
12B
STREAMER
POSITION
13
FAILED
STREAMER
12B
12
STREAMER

FIG. 3A

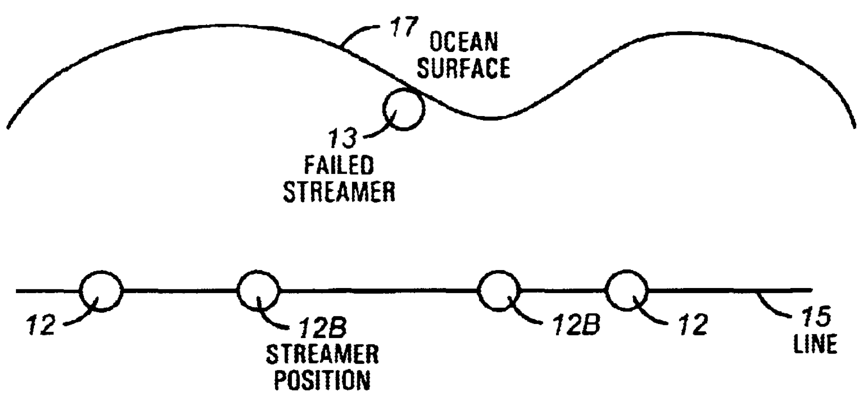
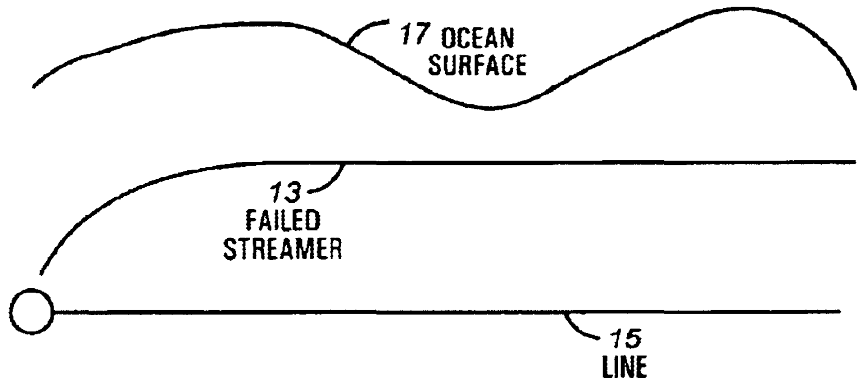
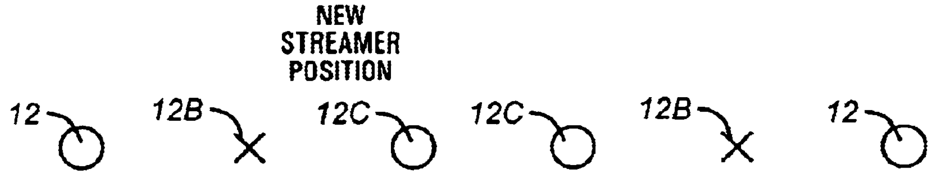

17
OCEAN
SURFACE
13
FAILED
STREAMER
12
12B
STREAMER
POSITION
12B
12
15
LINE

FIG. 3B



17 OCEAN SURFACE
13 FAILED STREAMER
15 LINE

FIG. 3C



NEW STREAMER POSITION
12
12B
12C
12C
12B
12

FIG. 3D

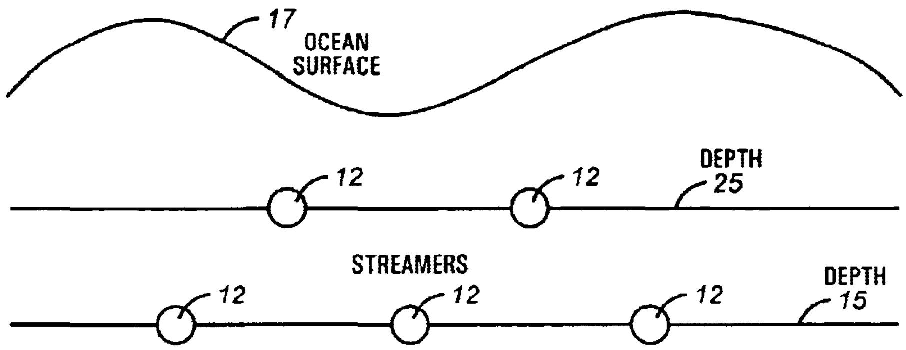

17
OCEAN
SURFACE
12
12
DEPTH
25
STREAMERS
12
12
12
DEPTH
15

FIG. 4

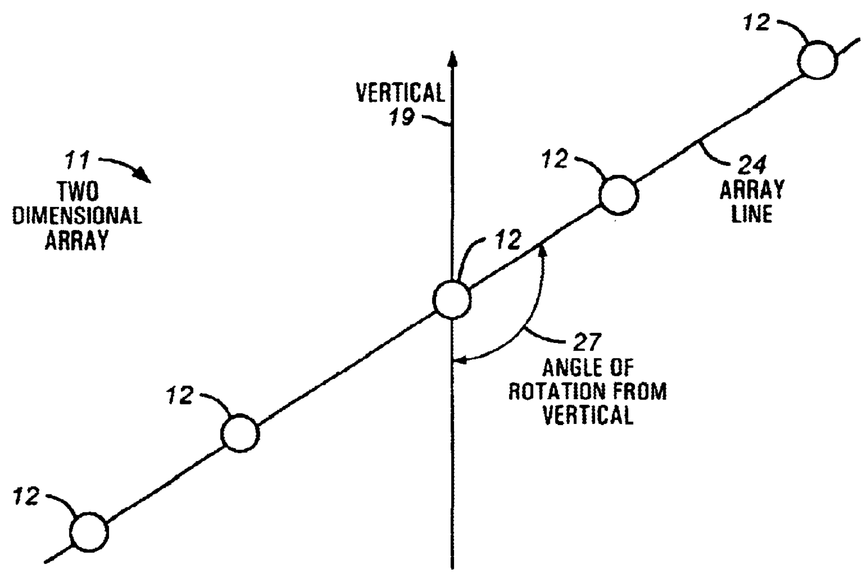

12
VERTICAL
19
11
TWO
DIMENSIONAL
ARRAY
12
24
ARRAY
LINE
12
27
ANGLE OF
ROTATION FROM
VERTICAL
12
12

FIG. 5

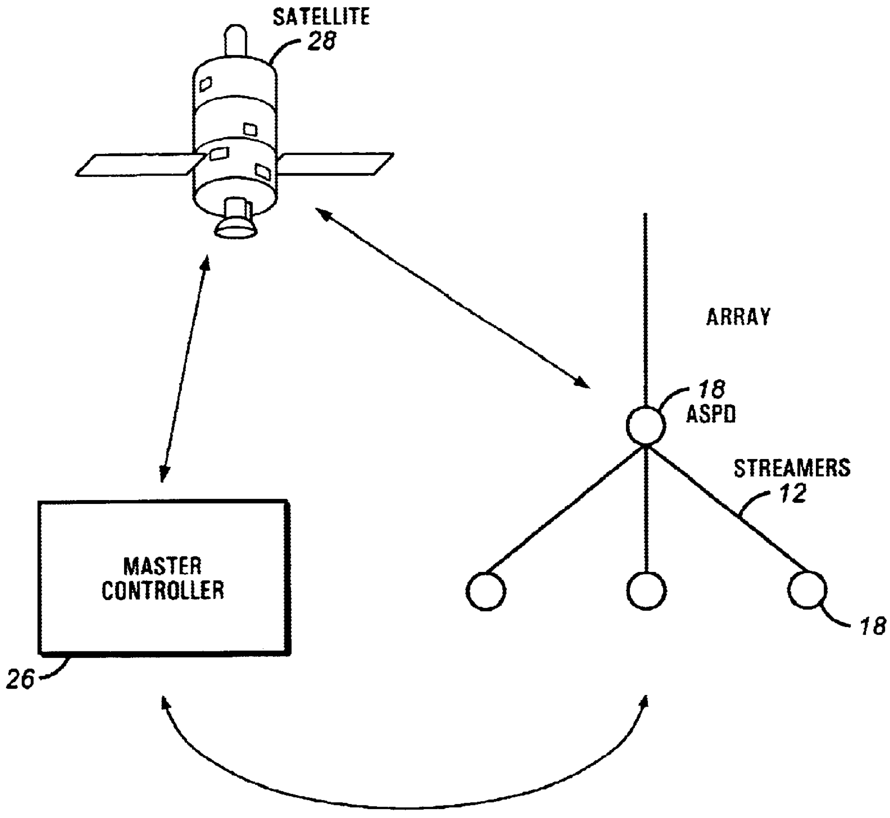

SATELLITE
28
ARRAY
18
ASPD
STREAMERS
12
MASTER
CONTROLLER
26
18

FIG. 6

ACTIVE SEPARATION TRACKING AND POSITIONING SYSTEM FOR TOWED SEISMIC ARRAYS

CROSS REFERENCE TO RELATED APPLICATIONS

This is related to U.S. patent application Ser. No. 09/603,068, filed on Jun. 26, 2000 entitled "Optimal Paths for Marine Data Collection" which is hereby incorporated herein by reference. This is related to U.S. patent application Ser. No. 09/658,846, filed on Nov. 11, 2000 entitled "Neural Network Prediction of Seismic Streamer Shape" which is hereby incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates generally to a method and apparatus for controlling sea borne seismic data acquisition systems comprising an array of streamers, and in particular to the relative vertical and horizontal positioning of seismic streamers forming a seismic array towed behind a sea borne towing vessel.

DESCRIPTION OF THE RELATED ART

The related art discloses a wide variety of towed marine seismic tracking and positioning systems and methods typically comprising one or more seismic streamers and/or one or more seismic sources. Some these seismic tracking and positioning systems and methods utilize a main or host vessel and/or other-associated unmanned vessels or vehicles to tow the seismic array. Typically towing is controlled or guided by a central control system. The known marine seismic tow tracking and positioning systems and methods are comprised of apparatuses such as seismic hydrophone streamers and attached floats, paravanes, and/or buoyant members. Typically each streamer and control apparatus is connected to the host vessel by a line, cable or tether. Considerable towing power is required of a host vessel to tow existing seismic streamer systems, cables and interconnecting sensing devices. A typical host vessel is capable of towing a plurality of tow vessels and/or carrying a plurality of seismic streamers or arrays and associated support apparatus on the vessel's deck awaiting deployment.

One such tracking and positioning system for positioning and control of marine seismic streamers is taught in the international application published under the Patent Cooperation Treaty (PCT), International Publication Number WO 00/20895, international publication date Apr. 13, 2000. A marine seismic system with independently power tow vehicles is taught by U.S. Pat. No. 6,028,817. A control device for controlling the position of a marine seismic streamer is taught in the international application published under the Patent Cooperation Treaty (PCT), International Publication Number WO 98/28636, international publication date Jul. 2, 1998.

With known seismic cable tracking and positioning systems, the location and spacing of system components is limited by the type, size, and length of cables used and by the characteristics of the towing vehicles and other control devices utilized by the known seismic tracking and positioning systems. Typically, the plurality of towed seismic streamers form an array which is towed behind the host vessel. Typically, changing the configuration of such a towed streamer array, comprised of known components is a complex, cumbersome, time-consuming operation and can often become somewhat unwieldy. Moreover, the spatial and

temporal positioning capability of known towing and tracking and positioning systems is limited.

There is no known seismic tracking and positioning system that enables independent and relative positioning of individual seismic streamer array elements, for example "birds", seismic streamers, comprising sensors, sources and depth and position controls, for example to configure, manipulate and/or maintain a desired geometry of and within a towed seismic streamer array. There is also no known seismic tracking and positioning system that enables relative positioning and manipulation of an entire seismic streamer array. There is also no known tracking and positioning system that enables specification of a plurality of diverse acquisition and ancillary non-acquisition array geometries that facilitates run-time maintenance, retrieval and deployment of a towed seismic array. Moreover, there is no known seismic tracking and positioning system that tracks the geometry of the seismic streamer array and the relative positions of the individual streamers comprising array elements with respect to time and with respect to the earth's latitude and longitude so that towed seismic array data acquisition runs are repeatable, thereby enabling acquisition of four-dimensional geophysical data (x, y, z, time).

Thus, there is a need for a seismic acquisition tracking and positioning system that overcomes the above-mentioned shortcomings of known seismic data acquisition tracking and positioning systems. There has been a long-felt need for an efficient and effective towed marine seismic tracking and positioning system having system components that are easily and reliably tracked, controlled and positioned. There has also been a long-felt need for seismic data acquisition towing, tracking and positioning systems to provide sufficient positioning flexibility to enable efficient, accurate, and repeatable control of the relative and absolute horizontal and vertical positions of towed arrays and the streamers, sensors and sources within a towed array during seismic data acquisition.

SUMMARY OF THE INVENTION

The present position invention provides a method and apparatus for an active tracking and positioning system for a towed seismic streamer array. The present invention recognizes and addresses the previously mentioned shortcomings, problems and long-felt needs associated with known towed seismic tracking and positioning systems. The present invention provides a solution to the aforementioned problems and provides satisfactory meeting of those needs in its various embodiments and equivalents thereof.

The active tracking and positioning system of the present invention provides a method and apparatus that enables relative positional control of any number of towed seismic streamers. The present invention controls streamer positions horizontally and vertically using active control units positioned on each streamer within the seismic array. The three component (x, y, z) position of each streamer element, relative to the vessel, relative to each other and relative Earth coordinate latitude and longitude is controlled, tracked and stored with respect to time during each seismic data acquisition run. This stored data is referred to as legacy data. Environmental factors (wind speed, currents, temperature, salinity, etc), and maneuverability data for the streamers and geometry of the towed array (cable diameter, array type, deployed configuration, vessel type, device type, etc.) for the seismic data acquisition run are also sensed with respect to time and stored as legacy data. The acquisition of legacy data enables repetition of seismic data acquisition runs.

The present invention provides active streamer positioning devices (ASPDs) as control elements, which are installed on individual streamers comprising an array, alternatively at the diverter position, streamer head, along the length of the streamer or at the tail of the streamer. One or more ASPD is employed on each seismic array. The active control elements are also installed at the head tow point of an array, at the head or tail of one or more streamers comprising an array, and/or along any streamer comprising an element of an array. The control elements attached at the streamer head are alternatively detachably connected to the front of the array to facilitate detachment and removal of a single streamer element from the array during a data acquisition run.

The apparatus and method of the present invention enables a seismic array to be maneuvered as the towing vessel maintains it desired course or as the towing vessel maneuvers to assist in the repositioning of the array during a seismic data acquisition run. The present invention may alternatively employ methods such as force vectoring, active wings, or other known means of changing the spatial or temporal, that is the vertical or z-depth position of the streamer elements comprising the array. In addition to enabling change in the spatial and temporal positions of individual array elements, the tracking and positioning system enables maintenance of specific array position and geometry in the presence of variable environmental factors. In this mode, the control system of the present invention adjusts the lifting force of the streamer to accommodate variations in the tide, real-time current velocity and direction, water depth, towed speed, cable maneuverability, towed direction and water salinity, and salinity variations, all of which may affect the buoyancy and position of the towed seismic array. The salinity of the water in which the array is towed may vary abruptly when a salt water towing operation passes by the mouth of a fresh water supply such as a river. The salinity may diminish considerably in the fresh water region near the mouth of a river, thereby requiring adjustment of the array towing forces to maintain desired array geometry and depth.

The present invention enables repeatable, four-dimensional seismic data acquisition by sensing and storing environmental data, temperature sensitive array maneuverability data and positional tracking data for a towed array and each individual element of the towed array with respect to time. The relative horizontal and vertical positioning of each seismic cable and energy source independent of the streamer attached to the array or streamer is controlled, monitored and stored, along with real-time environmental data during a seismic data acquisition operation. The composite stored data comprises legacy data for the data acquisition run. Thus, a seismic data acquisition run can be duplicated at a later date to reproduce the same array geometry and path during subsequent data acquisition runs, in the presence of varying environmental and maneuverability conditions. That is, a particular seismic data acquisition operation is repeatable based on the legacy data, thereby enabling repeatable four-dimensional data (x, y, z, time) gathering for multiple runs over a seismic target area. The present invention also enables implementation of non-acquisition ancillary array configurations such as augmented array geometry for collapsing or expanding an array during deployment or retrieval. The present invention also enables raising a single array element for retrieval from a deployed array during acquisition.

One array section or one streamer of an array section can be deflected out of the array geometry during a data acquisition run and vertically to the surface for detachment, retrieval and/or maintenance. The present invention also enables compensation for a failed or missing streamer. Streamers adjacent a failed or missing/removed streamer can be moved closer together to compensate for the failed or missing streamer array element with or without removal of the element. This enables repair and/or removal and replacement of such a failed array element during a seismic data acquisition run without interruption of the data acquisition run to repair and or replace the disabled streamer. Runtime removal of streamers and compensation for failed streamers enables continuation of data acquisition without causing the vessel and/or array to deviate from its planned data acquisition path.

It is time consuming, difficult and expensive to interrupt the towing vessel during a data acquisition run. Interruption for replacement or repair a streamer element in a data acquisition array and a subsequent attempt to duplicate array geometry and reposition the array and necessitates starting the vessel and array again at the exact location and array geometry where the run data acquisition run was interrupted. This process is difficult and time consuming, if not impossible. The present invention enables compensation for an array element and continuation of a data acquisition run during repair and replacement of the array streamer element.

The instant invention also enables configuring the towed array geometry to compensate for changing environmental and operational conditions that affect maneuverability. The array geometry can also be configured to increase or decrease the temporal resolution and spacing of the array to avoid ghost notching. Deployment and ancillary configurations are also provided wherein, for example, the width of an array may be increased to reduce chances of streamer tangling during deployment. The present invention also enhances in fill shooting where an optimal path has been selected. The present invention enables movement of the array in conjunction with movement of the vessel along an optimal in fill shooting path. The present invention individually controls positioning of the vessel and positioning of the array. Thus, the present invention also enables the towing vessel to account for a portion of the positioning along the selected optimal in fill path or data acquisition path and positioning of the array to account for the remainder of the positioning along the path. This division of positioning movements between the vessel and the array provides a more flexible and efficient positioning system for use during in fill shooting and/or other data acquisition positioning maneuvers.

In one aspect of the invention a seismic streamer array tracking and positioning system is presented comprising a towing vessel for towing a seismic array; an array comprising a plurality of seismic streamers; an active streamer positioning device (ASPD) attached to at least one seismic streamer for positioning the seismic streamer relative to other seismic streamers within the array; and a master controller for issuing positioning commands to each ASPD for maintaining a specified array geometry. In another aspect of the invention the apparatus further comprises an environmental sensor for sensing environmental factors which influence the path of the towed array. In another aspect of the invention the apparatus further comprises a tracking system for tracking the streamer positions versus time during a seismic data acquisition run and storing the positions versus time in a legacy database for repeating the positions versus time in a subsequent data acquisition; and an array geometry tracking system for tracking the array geometry versus time during a seismic data acquisition run and storing the array geometry versus time in a legacy database for repeating the array geometry versus time in a subsequent data acquisition run.

In another aspect of the invention the apparatus further comprises a master controller which compares the positions of the streamers versus time and the array geometry versus time to a desired streamer position and array geometry versus time and issues positioning commands to the ASPDs to maintain the desired streamer position and array geometry versus time. In another aspect of the invention the apparatus further comprises a master controller that factors in environmental factors into the positioning commands to compensate for environmental influences on the positioning of the streamers and the array geometry.

In another aspect of the invention the apparatus further comprises a master controller which compensates for maneuverability in the positioning commands to compensate for maneuverability influences on the positioning of the streamers and the array geometry. In another aspect of the invention the apparatus further comprises a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to compensate for a failed streamer. In another aspect of the invention the apparatus further comprises a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to move a failed streamer out of the array. In another aspect of the invention the apparatus further comprises a monitor for determining the status of each streamer, wherein the master controller detaches a failed streamer from the array. In another aspect of the invention the apparatus further comprises an array geometry which comprises a plurality of streamers positioned at a uniform depth. In another aspect of the invention the apparatus further comprises array geometry comprising a plurality of streamers positioned at a plurality of depths for varying temporal resolution of the array.

In another aspect of the invention the apparatus further comprises an array geometry comprising a plurality of streamers positioned along a plane, wherein the plane is rotated at an angel theta with respect to the longitudinal axis of the array. In another aspect of the invention the apparatus further comprises an apparatus wherein the array geometry is tracked via satellite and communicated to the master controller.

In another aspect of the invention a method is provided for tracking and positioning a seismic streamer array comprising a towing vessel for towing a seismic array; providing a seismic streamer array comprising a plurality of seismic streamers; providing an active streamer positioning device (ASPD) attached to each seismic streamer for positioning each seismic streamer; providing a master controller for issuing positioning commands to each ASPD and to the towing vessel for maintaining an optimal path, wherein the master controller further comprises a processor for calculating an optimal path for the seismic array for optimal coverage during seismic data acquisition over a seismic field, and a streamer behavior prediction processor which predicts array behavior, wherein the master controller compensates for predicted streamer behavior in issuing positioning commands to the towing vessel and the ASPDs for positioning the array along the optimal path, wherein the master controller compensates for environmental and maneuverability factors in the positioning commands.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the invention will become apparent upon reading the following detailed description and upon reference to the accompanying drawings in which:

FIG. **1** is a schematic diagram of a seismic survey vessel and associated seismic data acquisition tracking and positioning system;

FIG. **2** is a schematic diagram for the preferred array geometry tracking and positioning system showing real-time and legacy data storage and acquisition;

FIGS. **3**A, **3**B, **3**C and **3**D illustrate a schematic diagram of a towed seismic streamer array showing deflection of a failed streamer to the surface and compensation for the failed streamer by adjacent streamers;

FIG. **4** is a schematic diagram of a towed seismic streamer array showing a alternative array geometry for increasing temporal resolution of the towed array;

FIG. **5** is a schematic diagram of a towed seismic streamer array showing rotation of the array about the longitudinal axis of the array; and

FIG. **6** is a schematic diagram showing the tracking and positioning communication path provided by the present invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

To one skilled in this art who has the benefit of this invention's realizations, teachings, disclosures, and suggestions, other purposes and advantages will be appreciated from the following description of preferred embodiments, given for the purpose of disclosure, when taken in conjunction with the accompanying drawings. The detail in these descriptions is not intended to thwart this patent's object to claim this invention no matter how others may later disguise it by variations in form or additions of further improvements.

Turning now to FIG. **1**, a seismic survey vessel **10** is shown towing a plurality of marine seismic streamers **12** that may, for instance be 3000 meters in length. The outermost streamers **12** in the array can be as much as 400 meters apart, resulting in a horizontal displacement between each streamer of 100 meters, in an equally-spaced array configuration. A seismic source **14**, typically an airgun or one or more array of airguns, is also shown towed behind the seismic survey vessel **10**.

As shown in FIG. **1**, at the front of each streamer **12** is shown a detachable deflector **16** and at the rear of every streamer is shown a detachable tail buoy **20**. In a preferred embodiment, a detachable, active streamer positioning device **18** (ASPD) can be supplemented or substituted for the deflector **16** and/or tail buoy **20**. The detachable deflector **16** is used to horizontally position the front end of the streamer nearest to the seismic survey vessel **10**. The tail buoy **20** creates drag at the backend of the streamer farthest away from the seismic vessel **10** and provides a platform for absolute positioning or relative positioning at the tail of the streamer. The tension created on the seismic streamer by the deflector **16** and the tail buoy **20** results in the roughly rectilinear shape of the seismic streamer **12** shown in FIG. **1**.

The rectilinear shape of the streamer can be maintained by the present invention to overcome side currents and tides which may affect the shape of the towed cable and cause it to deviate from a preferred rectilinear shape. A rectilinear shape is preferred to maintain array geometry for accurate and repeatable seismic data acquisition runs. Deviation from a rectilinear cable shape can cause undesirable variations in the data gathered from the array. The present invention enables sensing and correction of deviations is the preferred shape of a towed streamer array.

Located between the deflector **16** and the tail buoy **20** are a plurality of ASPDs **18**. Preferably the ASPDs **18** are both vertically and horizontally steerable. These ASPDs **18** may, for instance, be located at regular intervals along the individual streamers, such as every 200 to 400 meters. The vertically and horizontally steerable ASPDs **18** can be used to constrain and configure the shape of the seismic streamer **12** between deflector **16** and the tail buoy **20** in the vertical (z or depth) and horizontal (x, y) directions. The ASPDs **18** can be placed at the head end of a streamer, at the tail end of the streamer or at any place along the streamer in between the streamer head end and streamer tail end.

Turning now to FIG. **2**, in a preferred embodiment of the present invention, the control system for the ASPD **18** may be distributed between a master controller **26** located remotely on the towing vessel (or at any other location on land, sea or satellite) and a group of one or more separate controllers **18** built into one or more ASPDs **18**, which is positioned on streamer **12** within the seismic array. The master controller **26** may be located remotely and communicate via satellite or other communication means as shown in FIG. **6**. The master controller receives data representing individual position of at least one point on the array, but preferably one or more points on each streamer element. These streamer positions from individual ASPDs **18**, are processed, compared to the desired positions and commands are transmitted to the individual ASPD **18**. The link between the active controllers on ASPD **18** and the main controller **26** can be accomplished by any suitable electronic cable, such as coaxial or fiber-optic cable attached to the towed array, via point to point communications or RF communications facilitated by a transceiver attached to the towed array. As shown in FIG. **6**, the tracking information from a plurality of points on individual streamers comprising the seismic array can be obtained and transmitted to the master controller **26** via satellite or radio frequency or any other means of communication.

The master controller may be connected via an electronic data bus, via any other suitable physical data interface, or via a wireless communication data interface to collect inputs from environmental sensors associated with vessel **10**. Sensed environmental data comprises wind speed and direction; tidal currents velocity and direction; ocean bottom depth/angle; local current velocity and direction; wave height and direction; ocean bottom depth/angle; and water temperature and salinity.

Turning now to FIG. **2**, the master controller **26** of the present invention receives the three component position of each active controller in the array, as shown in FIG. **6**. Thus, the present invention enables tracking with respect to time, of each individual ASPD and the streamer cable with which the ASPD is associated. Each active controller element is also equipped with a receiver for receipt of commands generated and formatted by the master control **26** and transmitted by active position commander **28**. The commands are sent to the ASPDs **18**, to instruct each of the ASPDs regarding commands for changing the position of each individual streamer to maintain desired array geometry and overall position. The positioning commands can be absolute commands or represent changes in position from the last command to the particular ASPD. The flexibility of the individual ASPD **18** enables precise positioning of each individual ASPD and associated streamer within the towed streamer array. The present invention enables control of the horizontal, vertical and depth position of the entire array geometry comprising the individual streamers, individual streamers and attached ASPDs, with respect to time.

The array, streamer and individual ASPD three-component (x, y, z) position data with respect to time is stored along with real time environmental data. Environmental data is received via cable or radio from sensors deployed from the vessel or the array. The stored position and environmental data is stored as legacy data in the legacy data storage **22**. Optimal path data, is generated by Optimal path processor **24**, which may be generated by a neural network or some other methodology such as human input or mathematical formulae, is input to master controller **26**. Optimal path data may be provided as a desired seismic acquisition path during primary seismic data acquisition or during in fill shooting. Optimal path data steering is preferably divided between an optimal path for the tow vessel **10** and an optimal path for the towed array. During seismic data acquisition utilizing an optimal path **24**, vessel, array, array element and ASPD positions are sensed along with environmental data are transmitted to and received by the data acquisition unit **21**. The data acquisition unit **21** stores these inputs with respect to time as legacy data in the legacy data storage **22**. The data acquisition unit **21** also passes the array and environmental tracking data to the master controller **26**. The maneuverability of the particular cable, ASPD and vessel under the particular sensed environmental conditions are also factored into the active positioning commands. For example, a cable that becomes stiffer in colder water or more buoyant in higher salinity receives an augmented steering command depending on the sensed environmental data. Master controller **26** compares the current vessel and array position data with the desired position or optimal vessel and array path position. The master controller **26** then determines, in light of the current environmental conditions and the maneuverability of the vessel, ASPDs and towed streamers comprising the array, the timing and magnitude of positioning commands to be sent to the ASPDs on the array. The positioning commands are formatted and transmitted by active position commander **28** over link **30**. Link **30** may be hardwired or wireless via satellite, laser or radio link.

In a preferred embodiment optimal path processor **24** collects real-time positioning data for the seismic array and for the towing vessel along with environmental data and maneuverability data for the array and towing vessel. The optimal path processor **24** computes predictions for the array behavior and computes the optimal path through the seismic survey area during a data acquisition run. The master control receives the predicted array behavior and takes it into account in generating and issuing positioning commands to the array ASPDs and the towing vessel. The division of the steering commands between the towing vessel and the ASPDs provides additional flexibility and control over the array along the optimal path. The additional flexibility and control of the array long the optimal path reduces the amount of in fill shooting required after a primary data acquisition run and reduces the amount of decision making required of a navigator striving to properly steer the towing vessel during a data acquisition run.

In a preferred embodiment of the present invention, the master controller monitors the actual position of each ASPD to determine the position of the streamers and the composite array geometry comprising the streamers and control elements are tracked and stored as legacy data. The actual positions of vessel, streamers, ASPDs and array geometry are compared to the desired vessel/streamers/ASPD positions and array geometry and corrective position commands are sent to the control elements to move the vessel/streamers/ASPDs to the desired position and array geometry. Tracking data and positioning commands are transmitted between the master controller and active positioners via a cable connecting the master controller and the active positioners or via wireless communications.

The horizontal positions of the ASPDs **18** and/or active controllers can be derived using acoustic position systems as described in U.S. Pat. No. 4,992,990. In the alternative, satellite-based global positioning systems may be utilized separately or in conjunction to determine the positions of the array and the active controllers and streamers comprising the array. The depth of the arrays, and of the individual streamers and individual streamer elements can be determined using pressure sensors.

In calculating desired or necessary movements by vessel, streamers/array and individual ASPDs, to maintain the desired array geometry and position and the relative position of the array elements as well as the desired array position and geometry during four-dimensional data acquisition, the master controller **26** takes into account environmental factors including but not limited to water salinity, current velocity and direction as well as legacy tracking data to adjust the positioning commands provided to the active controller. The master controller also factors in the maneuverability of the streamer cable and streamer array based on the cable diameter and cable type. The master controller sends position correction commands to the active controller either as a desired position or as a force vector comprising the vertical deflection, horizontal deflection, towing velocity and cross current velocity.

The vessel towing velocity and cross current velocity may be calculated from the vessel speed and heading values and the current speed and heading values to determine the relative velocities of the streamers, active controllers and the array. In an alternative embodiment, the towing velocity and/or cross current velocity can be determined using flow meters or other commercially available water velocity meters. Thus, the present invention enables dynamic adaptive geometric configuration, tracking and control to compensate for changes in local currents, tides and salinity of the water during seismic data acquisition.

In an alternative embodiment, a neural network is provided to model and predict cable and array behavior in the presence of changing currents, tides and salinity, or other environmental factors such as wave height, wind, water temperature, etc. The present invention may also factor in compensation for streamer buoyancy, streamer diameter, maneuverability of the cable with respect to the current temperature, streamer and vessel maneuverability and combined streamer/ASPD positioning maneuverability as well as particular array geometry and spacing. The neural network is preferably trained to compensate for changes in such environmental factors in combination with the vessel and streamer/ASPD positioning maneuverability. The present invention thereby enables repeatable and consistent array geometry and positioning for collection of four-dimensional data on separate seismic data acquisition runs using different streamers having different streamer/ASPD maneuverability and under different environmental conditions.

For example, a first data acquisition run may occur during the summer when the water temperature, salinity, tides, winds and currents comprise a first set of data for a first streamer system having a first maneuverability. A second data acquisition run may occur during the winter, years later, when the water temperature, salinity, tides, winds and currents comprise a second set of data for a second streamer/ASPD system possessing a second maneuverability. In order to replicate the first data acquisition run and obtain four-dimensional data during the second data acquisition run; the present invention compensates for the differences between the environmental factors and the differences in vessel/streamers/ASPD maneuverability of the first and second run to accurately repeat the array positioning and geometry during the second run, thereby enabling repeatable seismic acquisition runs and the acquisition of four-dimensional data. The difference maneuverability of the first and second vessels is also considered by the master controller in selecting ASPD positioning commands.

The present invention enable precise maneuvering the individual streamers, the array position and the array geometry, thereby reducing in fill shooting caused by array geometry that is either too broad, too narrow or simply out of position. The present invention also determines and corrects for inappropriately shaped arrays, for example, elements in the array which become non symmetric are adjusted and moved into position so that array geometry errors in x, y, and z space are corrected and compensated by the present invention. The present invention also enables placement of streamers in close proximity without entanglement.

Turning now to FIG. **3**A, a cross section is illustrated, taken perpendicular to the longitudinal axis of the towed array of streamers **12** shown in FIG. **1**. In FIG. **3**A, the array of streamers **12** is positioned at the same water depth **23**, along line **15** at depth **23**, and beneath the ocean surface **17**. A failed streamer **13** originally positioned along line **15** is detected as failed by the master controller. The master controller issues a positioning command to the ASPD on the failed streamer **13**. As shown FIG. **3**B, the failed streamer cable **13** is maneuvered and lifted above line **15** to the surface of the water and out of the array geometry for replacement and or repair during a data acquisition run. A side view of failed streamer **13**, is shown in the raised position in FIG. **3**C. As shown in FIG. **3**D, array geometry can also be altered by the present invention to alter the beam pattern and/or coverage of the array by moving the streamers adjacent the failed streamer to replace and compensate for failed streamer cable **13**. As shown in FIG. **3**D, the streamers in position **12**B adjacent streamer **13** are moved closer together, from position **12**B to position **12**C, to compensate for streamer **13** which has been removed from the array. In a preferred embodiment, all streamers including streamer **13** are detachably connected to the streamer array so that each streamer can be easily removed during seismic data acquisition operations. The master controller **26** detects the failed streamer **13**, commands the ASPD attached to failed streamer **13** to raise streamer **13** to the surface **17**. Once on or near the surface, or simply physically displaced from the array, a manned or unmanned support vehicle can retrieve and or remove and replace streamer **13**. The master controller issues positioning commands to adjust the position of streamers adjacent streamer **13** without interrupting the seismic data acquisition run.

Thus, the present invention senses a failed streamer cable in an array geometry and adjusts the position of adjacent streamer cables so that the beam pattern of the sensing array covers the area covered by the failed streamer. The compensation for a failed array streamer and associated compensation array geometry are noted and stored by the present invention so that post processing analysis compensates for variations in the data caused by the compensation array geometry.

Turning now to FIG. **4**, a three-dimensional array of streamers **12** is shown. The three-dimensional array of FIG. **4** positions the streamers **12** at varying depths **15** and **25**, rather than along a single line at a uniform depth. The varying depths of the streamers increases the temporal resolution of the streamer and substantially eliminates ghost notching. The depths can vary between two or more depths.

Turning now to FIG. **5**, a two-dimensional array **11**, positioned along line **24**, is shown rotated at an angel theta **27** rotated theta degrees from vertical **19**. The ability to rotate the array enables maneuvering the array in shallow water near a steep ocean bottom **14** inclined at angle theta.

The foregoing description is for purposes of example only and not intended to limit the scope of the present invention which is defined by the following claims.

What is claimed is:

1. A seismic streamer array tracking and positioning system comprising:

a towing vessel for towing a seismic array;

an array comprising a plurality of seismic streamers;

an active streamer positioning device (ASPD) attached to at least one seismic streamer for positioning the seismic streamer relative to other seismic streamers within the array; and

a master controller for issuing positioning commands to each ASPD to adjust a vertical and horizontal position of a first streamer relative to a second streamer within the array for maintaining a specified array geometry.

2. The apparatus of claim **1** further comprising:

an environmental sensor for sensing environmental factors which influence the path of the towed array.

3. The apparatus of claim **1** further comprising:

a tracking system for tracking the streamer positions versus time during a seismic data acquisition run and storing the positions versus time in a legacy database for repeating the positions versus time in a subsequent data acquisition; and

an array geometry tracking system for tracking the array geometry versus time during a seismic data acquisition run and storing the array geometry versus time in a legacy database for repeating the array geometry versus time in a subsequent data acquisition run.

4. The apparatus of claim **3** wherein the master controller compares the positions of the streamers versus time and the array geometry versus time to a desired streamer position and array geometry versus time and issues positioning commands to the ASPDs to maintain the desired streamer position and array geometry versus time.

5. The apparatus of claim **4** wherein the master controller factors in environmental factors into the positioning commands to compensate for environmental influences on the positioning of the streamers and the array geometry.

6. The apparatus of claim **4** wherein the master controller compensates for maneuverability in the positioning commands to compensate for maneuverability influences on the positioning of the streamers and the array geometry.

7. The apparatus of claim **1** further comprising:

a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to compensate for a failed streamer.

8. The apparatus of claim **1** further comprising:

a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to move a failed streamer out of the array.

9. The apparatus of claim **1** further comprising:

a monitor for determining the status of each streamer, wherein the master controller detaches a failed streamer from the array.

10. The apparatus of claim **1** wherein the array geometry comprises a plurality of streamers positioned at a uniform depth.

11. The apparatus of claim **1** wherein the array geometry comprises a plurality of streamers positioned at a plurality of depths for varying temporal resolution of the array.

12. The apparatus of claim **1** wherein the array geometry comprises a plurality of streamers positioned along a plane, wherein the plane is rotated at an angel theta with respect to the longitudinal axis of the array.

13. The apparatus of claim **4** wherein the array geometry is tracked via satellite and communicated to the master controller.

14. A seismic streamer array tracking and positioning system comprising:

a towing vessel for towing a seismic array;

a seismic streamer array comprising a plurality of seismic streamers;

an active streamer positioning device (ASPD) attached to each seismic streamer for positioning each seismic streamer;

a master controller for issuing vertical and horizontal positioning commands to each ASPD for maintaining a specified array geometry;

an environmental sensor for sensing environmental factors which influence the towed path of the towed array;

a tracking system for tracking the streamer horizontal and vertical positions versus time during a seismic data acquisition run;

an array geometry tracking system for tracking the array geometry versus time during a seismic data acquisition run, wherein the master controller compares the vertical and horizontal positions of the streamers versus time and the array geometry versus time to desired streamer positions and array geometry versus time and issues positioning commands to the ASPDs to maintain the desired streamer positions and array geometry versus time.

15. The apparatus of claim **14** wherein the master controller factors in environmental measurements into the positioning commands to compensate for environmental influences on the positions of the streamers and the array geometry.

16. The apparatus of claim **14** wherein the master controller compensates for maneuverability in the positioning commands to compensate for maneuverability influences on the positioning of the streamers and the array geometry.

17. The apparatus of claim **14** further comprising:

a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to compensate for a failed streamer.

18. The apparatus of claim **14** further comprising:

a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to move the failed streamer out of the array.

19. A seismic streamer array tracking and positioning system comprising:

a towing vessel for towing a seismic array;

a seismic streamer array comprising a plurality of seismic streamers;

an active streamer positioning device (ASPD) attached to each seismic streamer for vertically and horizontally positioning each seismic streamer relative to the array;

a master controller for issuing positioning commands to each ASPD for maintaining a specified array geometry;

an environmental sensor for sensing environmental factors which influence the path of the towed array;

a tracking system for tracking the streamer positions versus time during a seismic data acquisition run;

an array geometry tracking system for tracking the array geometry versus time during a seismic data acquisition run, wherein the master controller compares the positions of the streamers versus time and the array geometry versus time to a desired position and array geometry versus time and issues positioning commands to the ASPDs to maintain the desired position and array geometry versus time, wherein the master controller factors in environmental and maneuverability factors into the positioning commands to compensate for environmental and maneuverability influences on the position of the streamers and the array geometry; and

a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to compensate for a failed streamer and removes the failed streamer from the array.

20. A seismic streamer array tracking and positioning system comprising:

a towing vessel for towing a seismic array;

a seismic streamer array comprising a plurality of seismic streamers;

an active streamer positioning device (ASPD) attached to each seismic streamer for vertically and horizontally positioning each seismic streamer relative to the array; and

a master controller for issuing positioning commands to each ASPD for maintaining a specified array path.

21. The apparatus of claim **20** wherein the master controller issues positioning commands to the towing vessel for maintaining a specified array path.

22. The apparatus of claim **20** further comprising:

a processor for calculating an optimal path for the seismic array for optimal coverage during seismic data acquisition over a seismic field;

a streamer behavior prediction processor which predicts array behavior; and

wherein the master controller compensates for predicted streamer behavior in issuing vertical and horizontal positioning commands to the towing vessel and the ASPDs for positioning the array along the optimal path.

23. The apparatus of claim **22** wherein the master controller compensates for environmental factors in the positioning commands.

24. The apparatus of claim **23** wherein the master controller compensates for maneuverability factors in the positioning commands.

25. A seismic streamer array tracking and positioning system comprising:

a towing vessel for towing a seismic array;

a seismic streamer array comprising a plurality of seismic streamers;

an active streamer positioning device (ASPD) attached to each seismic streamer for vertically and horizontally positioning each seismic streamer relative to the array;

a master controller for issuing positioning commands to each ASPD and to the towing vessel for maintaining an optimal path, wherein the master controller further comprises a processor for calculating an optimal path for the seismic array for optimal coverage during seismic data acquisition over a seismic field, and a streamer behavior prediction processor which predicts array behavior, wherein the master controller compensates for predicted streamer behavior in issuing positioning commands to the towing vessel and the ASPDs for positioning the array along the optimal path, wherein the master controller compensates for environmental and maneuverability factors in the positioning commands.

26. A method for tracking and positioning a seismic streamer array comprising:

for towing a seismic array comprising a plurality of seismic streamers;

attaching an active streamer positioning device (ASPD) each seismic streamer for positioning the seismic streamer relative to other seismic streamers within the array; and

issuing vertical and horizontal positioning commands to each ASPD for maintaining a specified array geometry.

27. The method of claim **26** further comprising:

providing an environmental sensor for sensing environmental factors which influence the path of the towed array.

28. The method of claim **26** further comprising:

providing a tracking system for tracking the streamer positions versus time during a seismic data acquisition run and storing the positions versus time in a legacy database for repeating the positions versus time in a subsequent data acquisition; and

providing an array geometry tracking system for tracking the array geometry versus time during a seismic data acquisition run and storing the array geometry versus time in a legacy database for repeating the array geometry versus time in a subsequent data acquisition run.

29. The method of claim **28** wherein the master controller compares the positions of the streamers versus time and the array geometry versus time to a desired streamer position and array geometry versus time and issues positioning commands to the ASPDs to maintain the desired streamer position and array geometry versus time.

30. The method of claim **29** wherein the master controller factors in environmental factors into the positioning commands to compensate for environmental influences on the positioning of the streamers and the array geometry.

31. The method of claim **30** wherein the master controller compensates for maneuverability in the positioning commands to compensate for maneuverability influences on the positioning of the streamers and the array geometry.

32. The method of claim **26** further comprising:

providing a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to compensate for a failed streamer.

33. The method of claim **26** further comprising:

providing a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to move a failed streamer out of the array.

34. The method of claim **26** further comprising:

providing a monitor for determining the status of each streamer, wherein the master controller detaches a failed streamer from the array.

35. The method of claim **26** wherein the array geometry comprises a plurality of streamers positioned at a uniform depth.

36. The method of claim **26** wherein the array geometry comprises a plurality of streamers positioned at a plurality of depths for varying temporal resolution of the array.

37. The method of claim **26** wherein the array geometry comprises a plurality of streamers positioned along a plane, wherein the plane is rotated at an angel theta with respect to the longitudinal axis of the array.

38. The method of claim **29** wherein the array geometry is tracked via satellite and communicated to the master controller.

39. A method for tracking and positioning a seismic streamer array comprising:

towing a seismic array comprising a plurality of seismic streamers from a towing vessel;

attaching an active streamer positioning device (ASPD) to each seismic streamer for positioning each seismic streamer;

issuing positioning commands from a master controller to each ASPD to adjust vertical and horizontal position of a first streamer relative to a second streamer in the array for maintaining a specified array geometry;

sensing environmental factors which influence the towed path of the towed array;

tracking the streamer positions versus time during a seismic data acquisition run;

tracking the array geometry versus time during a seismic data acquisition run, wherein the master controller compares the positions of the streamers versus time and the array geometry versus time to desired streamer positions and array geometry versus time and issues positioning commands to the ASPDs to maintain the desired streamer positions and array geometry versus time.

40. The method of claim **39** wherein the master controller factors in environmental measurements into the positioning commands to compensate for environmental influences on the positions of the streamers and the array geometry.

41. The method of claim **39** wherein the master controller compensates for maneuverability in the positioning commands to compensate for maneuverability influences on the positioning of the streamers and the array geometry.

42. The method of claim **39** further comprising:

determining the status of each streamer, wherein the master controller adjusts the array geometry to compensate for a failed streamer.

43. The method of claim **39** further comprising:

providing a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to move the failed streamer out of the array.

44. A method for tracking and positioning a seismic streamer array comprising:

towing a seismic array comprising a plurality of seismic streamers from a towing vessel;

issuing vertical and horizontal positioning commands to each ASPD for maintaining a specified array geometry;

sensing environmental factors which influence the path of the towed array;

tracking the streamer positions versus time during a seismic data acquisition run;

tracking the array geometry versus time during a seismic data acquisition run, wherein the master controller compares the positions of the streamers versus time and the array geometry versus time to a desired position and array geometry versus time and issues positioning commands to the ASPDs to maintain the desired position and array geometry versus time, wherein the master controller factors in environmental and maneuverability factors into the positioning commands to compensate for environmental and maneuverability influences on the position of the streamers and the array geometry; and

determining the status of each streamer, wherein the master controller adjusts the array geometry to compensate for a failed streamer and removes the failed streamer from the array.

45. A method for tracking and positioning seismic streamer array comprising:

towing a seismic array comprising a plurality of seismic streamers;

attaching an active streamer positioning device (ASPD) attached to each seismic streamer for positioning each seismic streamer; and

issuing vertical and horizontal positioning commands to each ASPD for maintaining a specified array path.

46. The method of claim **45** wherein a master controller issues positioning commands to the towing vessel for maintaining a specified array path.

47. The method of claim **45** further comprising:

calculating an optimal path for the seismic array for optimal coverage during seismic data acquisition over a seismic field;

predicting array behavior; and

compensating for predicted streamer behavior in issuing positioning commands to the towing vessel and the ASPDs for positioning the array along the optimal path.

48. The method of claim **47** wherein the master controller compensates for environmental factors in the positioning commands.

49. The method of claim **48** wherein the master controller compensates for maneuverability factors in the positioning commands.

50. A method for tracking and positioning a seismic streamer array comprising:

towing a seismic array comprising a plurality of seismic streamers;

attaching an active streamer positioning device (ASPD) attached to each seismic streamer for positioning each seismic streamer;

issuing horizontal and vertical positioning commands to each ASPD and to the towing vessel for maintaining an optimal path, calculating an optimal path for the seismic array for optimal coverage during seismic data acquisition over a seismic field, and a behavior prediction processor which predicting array behavior, wherein the master controller compensates for predicted streamer behavior in issuing positioning commands to the towing vessel and the ASPDs for positioning the array along the optimal path, wherein the master controller compensates for environmental and maneuverability factors in the positioning commands.

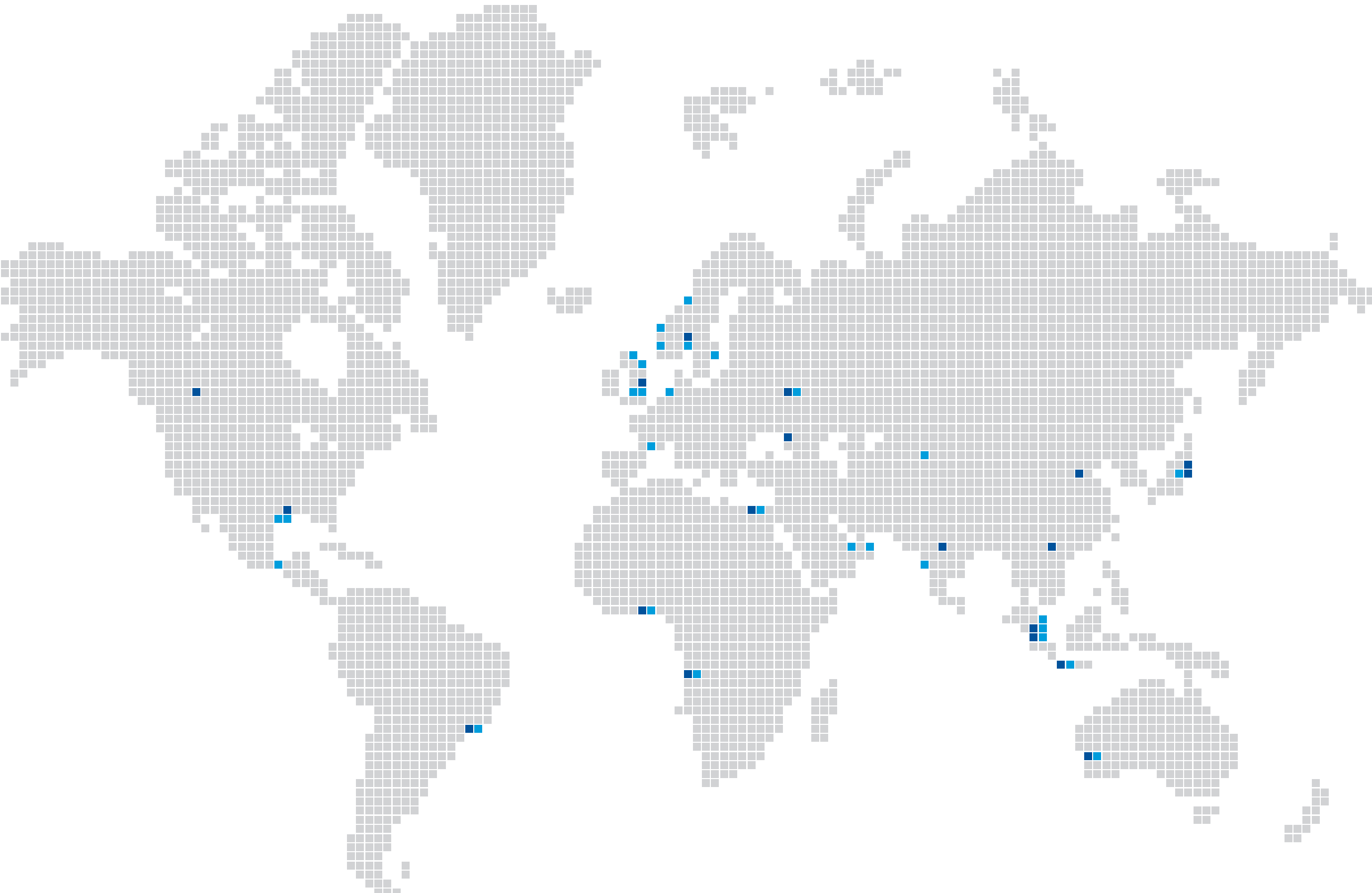
* * * * *

Exhibit E

Petroleum Geo-Services ASA

ANNUAL REPORT 2009

WORLD WIDE OFFICES



■ Marine ■ Data Processing and Technology

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- ■ ■ USA, Houston

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ROBUST PERFORMANCE THROUGH THE CYCLE

«PGS PROVIDES A BROAD RANGE OF GEOPHYSICAL AND RESERVOIR SERVICES WORLDWIDE»

Petroleum Geo-Services ASA (PGS or the Company) is a focused marine geophysical company. Noted for technological innovation, PGS ranks among the world's three largest marine seismic survey, data processing, reservoir analysis, and MultiClient library suppliers. After the sale of the Onshore business the Company's operations are organized within Marine and Data Processing & Technology.

PGS provides a broad range of geophysical and reservoir services worldwide. Key market niches are seismic and electromagnetic data acquisition, survey data processing, reservoir interpretation, and field evaluation. PGS operates through the business units: Marine and Data Processing & Technology. In 2009, the Company sold its Onshore business activities to US-based Geokinetics Inc. (Geokinetics) for a total amount of $205 million. The sale provides consolidation in a fragmented Onshore market. PGS Onshore is a good industrial fit for Geokinetics in terms of skills, technology, and geographical presence. The combined company constitutes the second largest provider of onshore seismic data acquisition services in the world in terms of crew count and the largest such enterprise based in the Western Hemisphere. PGS will continue its presence as a significant Geokinetics shareholder. The larger and more comprehensive Geokinetics enterprise offers a broad range of technologies that includes marine transition zone surveys, ocean-bottom cable and land vibroseis data acquisition. Acquiring PGS' Onshore operations enables Geokinetics to compete even more effectively across the entire onshore seismic value chain of planning, acquisition, processing and interpretation services.

As a marine geophysical company, PGS can concentrate its resources on further developing its Marine business segment. The business model is to acquire and market seismic data worldwide to oil and natural gas companies and governments. Customers use the data to identify hydrocarbons, to determine the size and structure of reservoirs, and to optimize reservoir production. A highly efficient seismic fleet and acquisition technologies are key competitive advantages of PGS.

PGS acquires and processes seismic data under exclusive contracts with individual customers or, alternatively, for PGS' library of MultiClient field surveys. PGS invests in MultiClient seismic surveys, and the processed data sets and imaging are marketed to multiple customers on a non-exclusive basis. MultiClient has two revenue sources: customers who are pre-funding surveys and so-called late sales from its MultiClient library of acquired and processed data.

Data Processing & Technology (DP&T) is managed as a separate organization, because of its distinctive specializations. However, DP&T activities are included in the financial reporting of PGS' Marine business segment. DP&T has four departments: DATA PROCESSING provides a full range of processing, advanced imaging, and reservoir-related processing services to a global exploration and production customer base — and to PGS' MultiClient library and regional MegaSurveys. GEOSCIENCE & ENGINEERING constitutes the Company's R&D unit. Core activities are GeoStreamer® dual-sensor streamer technology, survey fleet efficiency, high-end imaging and automation, electromagnetic (EM) acquisition research, and Reservoir Services consulting. Reservoir Services' industry-leading team of subsurface and production geoscientists provides interpretation and reservoir characterization expertise to PGS and external customers. COMMERCIALIZATION & NEW VENTURES focuses on introducing new technology and products to the marketplace. The department is also the process owner of the PGS innovation value chain, established to ensure maximum return on technology investments, such as optoSeis®, PGS' fiber optic monitoring system that is permanently installed on the seabed. The fourth department is PGS EM where the Company manages its EM activities.

PGS History
Petroleum Geo-Services was established in 1991 through the merger of Geoteam and Nopec. PGS was listed on the Oslo Stock Exchange in 1992 and on NASDAQ in 1993. In 1997, the Company transferred trade in its American Depository Shares (ADS) to the New York Stock Exchange. Today, PGS is listed on the Oslo Stock Exchange while ADS trade is quoted on the US Pink Sheets. During 1995 to 1999, PGS designed, built, and deployed six Ramform survey vessels and grew to become one of the worldwide leaders in developing and industrializing 3D Marine seismic acquisition.

In 1998 PGS acquired Golar-Nor, and the acquisition gave the Company a foothold in the Floating Production Storage and Offloading (FPSO) market. As the year 2000 approached, PGS' financial situation deteriorated. Aggressive growth in a declining market strained the Company's liquidity. Sale of shares in the subsidiary Spinnaker Exploration, a Gulf of Mexico oil company, and sale of PGS' global Petrobank Data Management business and related software provided some relief.

In an attempt to secure maximum utilization of its FPSO fleet, PGS bought a 70-percent license interest in the Varg field in the North Sea from Norsk Hydro and Statoil in 2001 and established the exploration and production company Pertra. PGS' liquidity situation remained challenging and the Company tried to sell another non-core asset, the exploration and production company Atlantis. While trying to sell Atlantis, PGS management discussed a possible merger with Veritas DGC. One of the conditions Veritas DGC set forth in the proposed merger agreement was that Atlantis had to be sold prior to the merger. The protracted effort to sell Atlantis remained unsuccessful, and the merger negotiations ceased. Finally, in early 2003, PGS and Sinochem reached an agreement, but at a significantly lower price than PGS' original asking price. The low Atlantis sale price at a time when the seismic market was weak, and an inability to meet debt installment payments left PGS with no alternative other than to voluntarily file for reorganization under Chapter 11 of the US Bankruptcy Code in July 2003. PGS emerged from Chapter 11 four months later.

In March 2005, the exploration and production company Pertra was sold to Talisman and PGS became a dedicated oil services company. Divestments continued. In 2006, PGS demerged its floating production unit Petrojarl. In late 2009, an agreement was entered into to sell PGS' Onshore seismic business to Houston-based Geokinetics. PGS is now a focused marine geophysical company; competitive advantages include advanced data processing and imaging capabilities and the Company's Ramform seismic fleet, offering proven operational capabilities, superior efficiency, and leading technologies. PGS holds the industry record of towing and handling the greatest number of streamers. The deployment of newly built *Ramform Sovereign* in March 2008 and *Ramform Sterling* in June 2009 enhanced fleet capacity and efficiency. The two Ramform S-class vessels are the world's most advanced seismic vessels, capable of towing 22 streamers at a record-wide streamer spread of 1.3 kilometers.

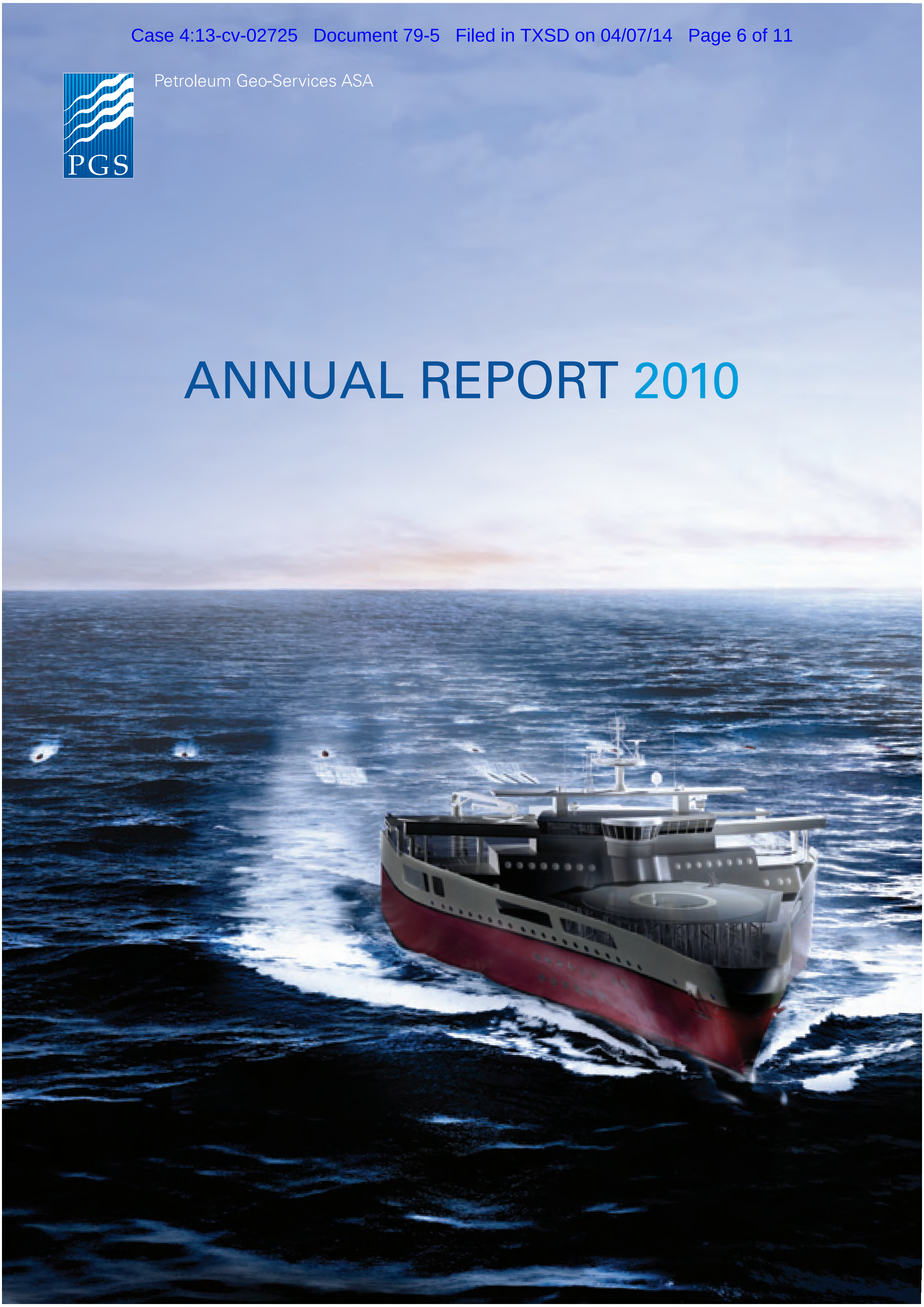
«THE TWO RAMFORM S-CLASS VESSELS ARE THE WORLD'S MOST ADVANCED SEISMIC VESSELS»

PGS Key Figures
In 2009, PGS proved its ability to deliver robust performance through the industry cycle and maintained acceptable revenues from continuing operations and earnings despite a challenging market. Revenues from continuing operations in 2009 were $1.35 billion. Earnings before interest, tax, depreciation, and amortization (EBITDA) in 2009 amounted to $672 million, and operating profit (EBIT), excluding special items, was $387 million. EBITDA was down 25 percent, compared with 2008 and EBIT decreased 44 percent from 2008. The average EBIT margin for marine contract acquisition work in 2009 was 39 percent, compared with 49 percent in 2008.

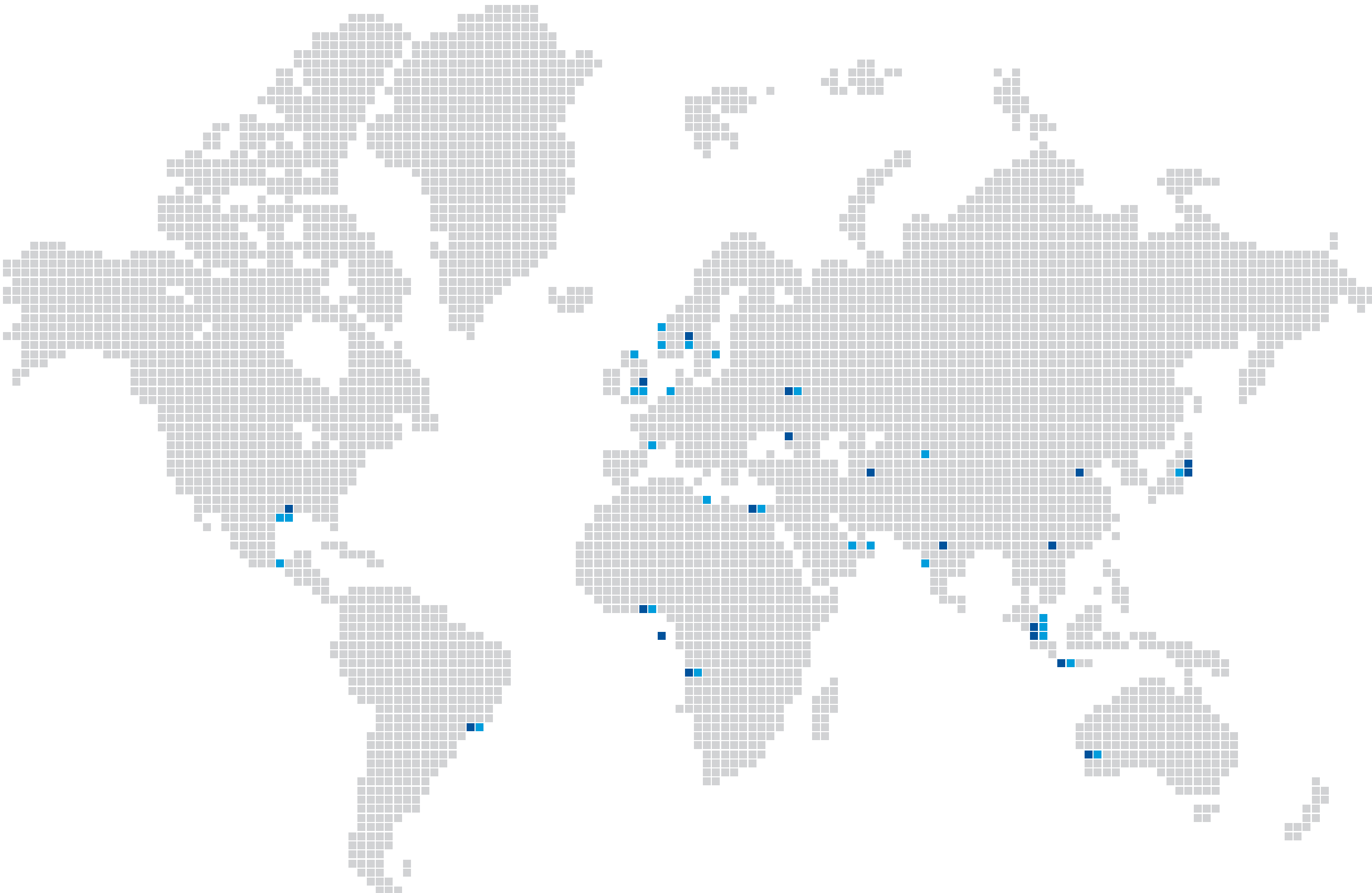
PGS headquarters are located at Lysaker (Oslo), Norway. The Company is represented in 24 countries around the world, with larger regional offices in London, Houston, and Singapore. At year-end 2009, PGS had approximately 2,100 full time employees in continuing operations.

Petroleum Geo-Services ASA

ANNUAL REPORT 2010



WORLD WIDE OFFICES



Marine   Data Processing

NORTH AMERICA
- USA, Austin
- USA, Houston

CENTRAL AMERICA
- Mexico, Villahermosa

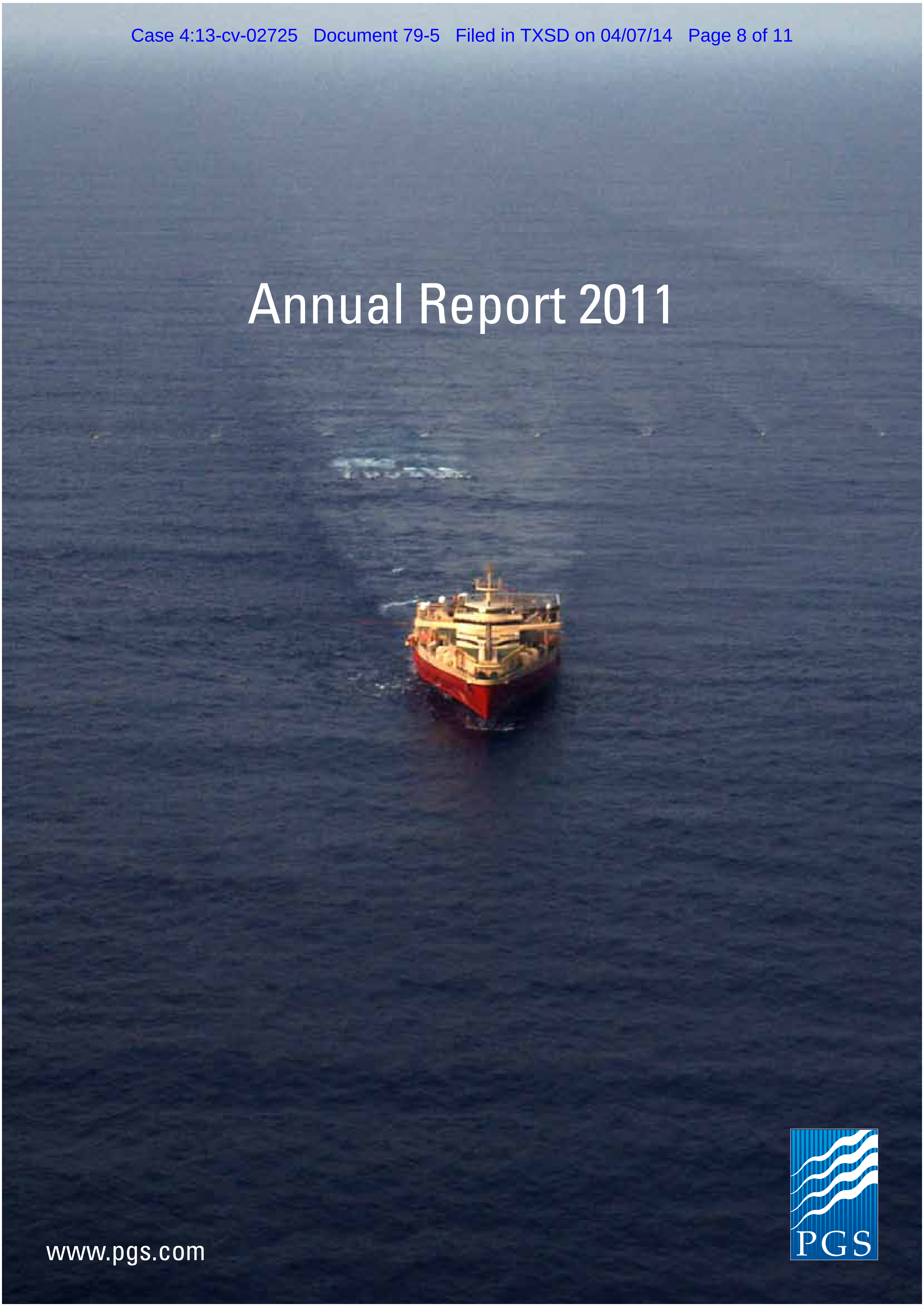
SOUTH AMERICA
- Brazil, Rio de Janeiro

EUROPE
- France, Pau
- Netherlands, Leiden
- Norway, Bergen
- Norway, Lysaker
- Norway, Stavanger
- Norway, Trondheim
- Russia, Moscow
- Russia, Gelendjik
- Sweden, Stockholm
- UK, Edinburgh
- UK, Maidenhead
- UK, Weybridge

AFRICA
- Angola, Luanda
- Egypt, Cairo
- Libya, Tripoli
- Nigeria, Lagos
- Sao Tome

ASIA
- China, Bejing
- India, Mumbai
- India, New Dehli
- Indonesia, Jakarta
- Japan, Makuhari
- Japan, Tokyo
- Kazakhstan, Almaty
- Malaysia, Kuala Lumpur
- Malaysia, Cyberjaya
- Oman, Muscat
- United Arab Emirates, Abu Dhabi
- Singapore
- Turkmenistan, Ashgabat
- Vietnam, Hanoi

AUSTRALIA
- Australia, Perth



Annual Report 2011

www.pgs.com

PGS

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Luanda Office

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Perth Office

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Rio Office

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Cairo - Maadi Office
Cairo - Nasr City Office

FRANCE
Pau Office

INDIA
Mumbai Office
New Delhi Office

INDONESIA
Jakarta Office

JAPAN
Makuhari Office
Nagasaki
Tokyo - Toranomon Office
Tokyo - Uchisaiwai Office

KAZAKHSTAN
Almaty Office

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Tripoli Office

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Muscat Office

RUSSIA
Gelendjik Office
Moscow Office

SAO TOME & PRINCIPE
Sao Tome Office

SINGAPORE
Singapore Office

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Stockholm Office

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Ashgabat Office

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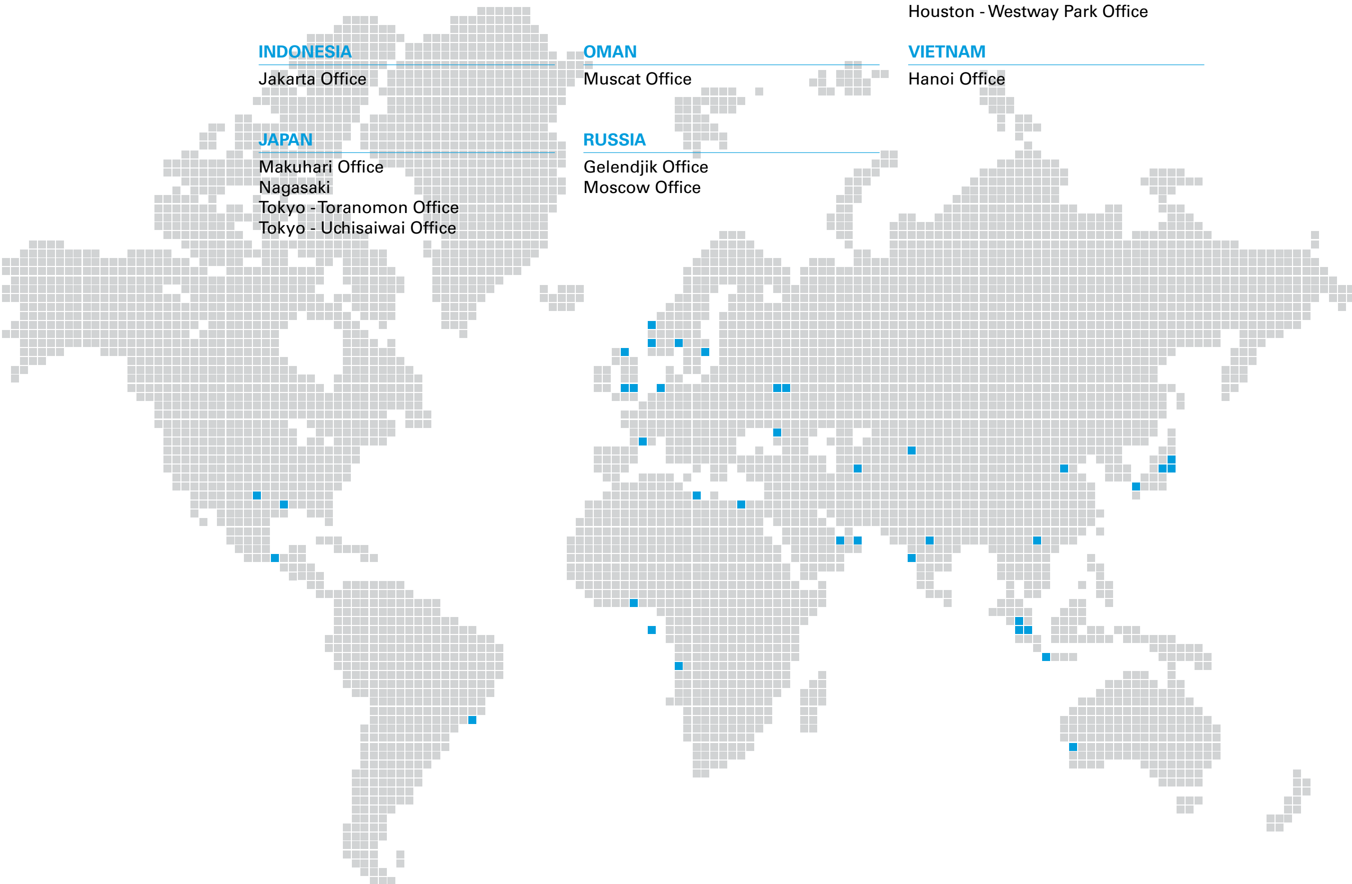
Maidenhead Office
Weybridge Office

UNITED ARAB EMIRATES
Abu Dhabi Office

USA
Austin Office
Houston - AGS Office
Houston - Memorial Office
Houston - Park Row 10 Office
Houston - Westway Park Office

VIETNAM
Hanoi Office



ANNUAL REPORT 2012

www.pgs.com

WORLDWIDE OFFICES

ANGOLA
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Cairo - Nasr City Office

INDIA
Mumbai Office
New Delhi Office

INDONESIA
Jakarta Office

JAPAN
Makuhari Office
Nagasaki
Tokyo - Toranomon Office
Tokyo - Uchisaiwai Office

KAZAKHSTAN
Almaty Office

MALAYSIA
Cyberjaya Office
Kuala Lumpur Office

MEXICO
Villahermosa Office

NETHERLAND
Leiden Office

NIGERIA
Lagos Office

NORWAY
Bergen Office
Lysaker Office (Headquarter)
Stavanger Office

RUSSIA
Gelendjik Office
Moscow Office

SINGAPORE
Singapore Office

SWEDEN
Stockholm Office

TURKMENISTAN
Ashgabat Office

UK
Edinburgh Office
Maidenhead Office
Weybridge Office

UNITED ARAB EMIRATE
Abu Dhabi Office

USA
Austin Office
Houston - AGS Office
Houston - Memorial Office
Houston - Park Row 10 Office
Houston - Westway Park Office

VIETNAM
Hanoi Office

Exhibit F

As filed with the Securities and Exchange Commission on May 21, 2007

Registration No. 333-______

UNITED STATES
SECURITIES AND EXCHANGE COMMISSION
Washington, D.C. 20549

FORM S-8

REGISTRATION STATEMENT
UNDER
THE SECURITIES ACT OF 1933

PETROLEUM GEO-SERVICES ASA

(Exact name of registrant as specified in its charter)

Kingdom of Norway (State or other jurisdiction of incorporation or organization)	**N/A** (I.R.S. Employer Identification No.)
Strandveien 4 **N-1366 Lysaker, Norway** (Address of principal executive offices)	**N/A** (Zip code)

2006 STOCK OPTION PLAN
(Full title of the plan)

James E. Brasher
Vice President and Senior Legal Counsel
Petroleum Geo-Services, Inc.
15150 Memorial Drive
Houston, Texas 77079
(Name and address of agent for service)

(281) 509-8000
(Telephone number, including area code, of agent for service)

CALCULATION OF REGISTRATION FEE

Title of Securities to be Registered (1)	Amount to be Registered (2)	Proposed Maximum Offering Price Per Share (3)	Proposed Maximum Aggregate Offering Price (3)	Amount of Registration Fee

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As filed with the Securities and Exchange Commission on July 20, 2007

Registration No. 333 -

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SECURITIES AND EXCHANGE COMMISSION
Washington, D.C. 20549

FORM F-6
REGISTRATION STATEMENT
UNDER
THE SECURITIES ACT OF 1933 FOR AMERICAN DEPOSITARY SHARES EVIDENCED BY
AMERICAN DEPOSITARY RECEIPTS

PETROLEUM GEO-SERVICES ASA
(Exact name of issuer of deposited securities as specified in its charter)

[N/A]
(Translation of issuer's name into English)

Kingdom of Norway
(Jurisdiction of incorporation or organization of issuer)

CITIBANK, N.A.
(Exact name of depositary as specified in its charter)

----

399 Park Avenue
New York, New York 10043
(212) 816-6690
(Address, including zip code, and telephone number, including area code,
of depositary's principal executive offices)

James E. Brasher
Vice President and Senior Legal Counsel
Petroleum Geo-Services, Inc.
15150 Memorial Drive
Houston, Texas 77079

(281) 509-8000
(Address, including zip code, and telephone number, including area code,
of agent for service)

Copies to:

Gottfred Langseth
Senior Vice President and
Chief Financial Officer
Petroleum Geo-Services ASA
Strandveien 4
N-1366 Lysaker
Norway

Joe S. Poff
Baker Botts L.L.P.
One Shell Plaza
910 Louisiana
Houston, Texas 77002

Patricia Brigantic, Esq.
Citibank, N.A.
388 Greenwich Street,
17th Floor
New York, New York 10013

It is proposed that this filing become effective under Rule 466:
|X| immediately upon filing.
|_| on (Date) at (Time).

If a separate registration statement has been filed to register the deposited shares, check the following box : |_|

CALCULATION OF REGISTRATION FEE

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Title of Each Class of Securities to be Registered	Amount to be Registered	Proposed Maximum Aggregate Price Per Unit (1)(2)	Proposed Maximum Aggregate Offering Price (2)	Amount of Registration Fee
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American Depositary Shares ("ADSs") evidenced by American Depositary Receipts ("ADRs"), each ADS representing one (1) ordinary share, nominal value NOK 3 per share, of Petroleum Geo-Services ASA.	100,000,000	$5.00	$5,000,000.00	$153.50

</TABLE>

(1) For purposes of this table only, the term "unit" is defined as 100 American Depositary Shares.
(2) Estimated solely for the purpose of calculating the registration fee. Pursuant to Rule 457(k) under the Securities Act of 1933, as amended, such estimate is computed on the basis of the maximum aggregate fees or charges

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As filed with the Securities and Exchange Commission on February 29, 2008

Registration No. 333-144741

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SECURITIES AND EXCHANGE COMMISSION
Washington, D.C. 20549

POST-EFFECTIVE AMENDMENT NO. 1
TO
FORM F-6
REGISTRATION STATEMENT
UNDER
THE SECURITIES ACT OF 1933 FOR AMERICAN DEPOSITARY SHARES EVIDENCED BY
AMERICAN DEPOSITARY RECEIPTS

PETROLEUM GEO-SERVICES ASA
(Exact name of issuer of deposited securities as specified in its charter)

N/A
(Translation of issuer's name into English)

Kingdom of Norway
(Jurisdiction of incorporation or organization of issuer)

CITIBANK, N.A.
(Exact name of depositary as specified in its charter)

----

399 Park Avenue
New York, New York 10043
(212) 816-6690
(Address, including zip code, and telephone number,
including area code, of depositary's principal executive offices)

James E. Brasher
Vice President and Senior Legal Counsel
Petroleum Geo-Services, Inc.

15150 Memorial Drive
Houston, Texas 77079
(281) 509-8000
(Address, including zip code, and telephone number,
including area code, of agent for service)

Copies to:

<TABLE>
<S> <C> <C>

Gottfred Langseth Senior Vice President and Chief Financial Officer Petroleum Geo-Services ASA Strandveien 4 N-1366 Lysaker Norway	Joe S. Poff Baker Botts L.L.P. One Shell Plaza 910 Louisiana Houston, Texas 77002	Herman H. Raspe, Esq. Patterson Belknap Webb & Tyler LLP 1133 Avenue of the Americas New York, New York 10036

</TABLE>

It is proposed that this filing become effective under Rule 466:
|_| immediately upon filing.
|_| on (Date) at (Time).

If a separate registration statement has been filed to register the deposited shares, check the following box : |_|

The Registrant hereby amends this Post-Effective Amendment No. 1 to Registration Statement on such date or dates as may be necessary to delay its effective date until the Registrant shall file a further amendment which specifically states that this Post-Effective Amendment No. 1 to Registration Statement shall thereafter become effective in accordance with Section 8(a) of the Securities Act of 1933, or until this Post-Effective Amendment No. 1 to Registration Statement shall become effective on such date as the Commission, acting pursuant to said Section 8(a), may determine.

<PAGE>

This Post-Effective Amendment No. 1 to Registration Statement may be executed in any number of counterparts, each of which shall be deemed an original, and all of such counterparts together shall constitute one and the same instrument.

<PAGE>

PART I

INFORMATION REQUIRED IN PROSPECTUS

F-6 1 e610709_f6-petroleum.htm

As filed with the United States Securities and Exchange Commission on March 15, 2013

UNITED STATES
SECURITIES AND EXCHANGE COMMISSION
Washington, D.C. 20549

FORM F-6

REGISTRATION STATEMENT
UNDER
THE SECURITIES ACT OF 1933 FOR AMERICAN DEPOSITARY SHARES EVIDENCED BY AMERICAN DEPOSITARY RECEIPTS

Petroleum Geo-Services ASA

(Exact name of issuer of deposited securities as specified in its charter)

N/A
(Translation of issuer's name into English)

Norway
(Jurisdiction of incorporation or organization of issuer)

DEUTSCHE BANK TRUST COMPANY AMERICAS
(Exact name of depositary as specified in its charter)

60 Wall Street
New York, New York 10005
(212) 250-9100
(Address, including zip code, and telephone number, including area code, of depositary's principal executive offices)

Petroleum Geo-Services, Inc.
15150 Memorial Drive
Houston, Texas 77079
(281) 509-8000
(Address, including zip code, and telephone number, including area code, of agent for service)

Copies to:

Deutsche Bank Trust Company Americas
60 Wall Street
New York, New York 10005
(212) 250-9100

It is proposed that this filing become effective under Rule 466: ☐ immediately upon filing.
☐ on (Date) at (Time)

If a separate registration statement has been filed to register the deposited shares, check the following box: ☐

CALCULATION OF REGISTRATION FEE

Title of Each Class of Securities to be Registered	Amount to be Registered	Proposed Maximum Aggregate Price Per Unit*	Proposed Maximum Aggregate Offering Price**	Amount of Registration Fee

Exhibit G

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UNITED STATES
SECURITIES AND EXCHANGE COMMISSION
Washington, D.C. 20549

FORM 6-K

REPORT OF FOREIGN PRIVATE ISSUER

Pursuant to Rule 13a-16 or 15d-16 of
The Securities Exchange Act of 1934

January 8, 2007

PETROLEUM GEO-SERVICES ASA
(Exact name of registrant as specified in its charter)

STRANDVEIEN 4, N-1325 LYSAKER, NORWAY
(Address of principal executive offices)

001-14614
(Commission File Number)

Indicate by check mark whether the registrant files or will file annual reports under cover of Form 20-F or Form 40-F:

Form 20-F [X]   Form 40-F [ ]

Indicate by check mark whether the registrant by furnishing the information contained in this form is also thereby furnishing the information to the Commission pursuant to Rule 12g3-2(b) under the Securities Exchange Act of 1934.

Yes [ ]   No [X]

<PAGE>

[PGS GRAPHIC OMITTED]   NEWS RELEASE

FOR DETAILS, CONTACT: FOR IMMEDIATE RELEASE

OLA BOSTERUD January 4, 2007
Phone: +47 67 52 64 00
Cellular: +47 90 95 47 43
CHRISTOPHER MOLLERLOKKEN
Phone: +47 67 52 64 00
Cellular: +47 90 27 63 55

US INVESTOR SERVICES
Katrina Green
Phone: +1 281 509 8000

Vessel Allocation Fourth Quarter 2006

JANUARY 4, 2007: OSLO, NORWAY, Petroleum Geo-Services ASA ("PGS" or the "Company") (OSE and NYSE: PGS) announced today that its seismic vessel fleet used approximately 80% of its total time to acquire marine contract and multi-client seismic in the fourth quarter of 2006. This compares to 83% in the third quarter of 2006 and 78% in the fourth quarter of 2005.

PGS routinely releases information about vessel utilization around the end of each quarter.

Summary of vessel utilization:

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Approximate allocation of PGS total towed streamer capacity	Quarter ended December 31, 2006	Quarter ended December 31, 2005	Quarter ended September 30, 2006
Contract seismic	61%	75%	50%
Multi-client seismic	19%	3%	33%
Steaming	18%	16%	10%
Yard	2%	6%	7%

</TABLE>

6-K 1 c96293.htm

UNITED STATES
SECURITIES AND EXCHANGE COMMISSION

Washington, D.C. 20549

FORM 6-K

Report of Foreign Private Issuer

Pursuant to Rule 13a-16 or 15d-16 of the Securities Exchange Act of 1934

April 23, 2007

PETROLEUM GEO-SERVICES ASA

(Exact name of registrant as specified in its charter)

Strandveien 4, N-1325 Lysaker, Norway
(Address of principal executive offices)

001-14614
(Commissin File Number)

Indicate by check mark whether the registrant files or will file annual reports under cover Form 20-F or Form 40-F.

Form 20-F ☑ Form 40-F ☐

Indicate by check mark whether the registrant by furnishing the information contained in this form is also thereby furnishing the information to the Commission pursuant to Rule 12g3-2(b) under the Securities Exchange Act of 1934.

Yes ☐ No ☑

PGS Unaudited IFRS Transition Report and Change of 2006 Norwegian GAAP Financial Statements

April 20, 2007: Oslo, Norway, Petroleum Geo-Services ASA ('PGS' or the 'Company') (OSE and NYSE: PGS) released today its IFRS Transition Report. PGS is required to use International Financial Reporting Standards (IFRS) for its primary financial reporting effective from, and including, the first quarter 2007. The Company has historically, through December 31, 2006, presented its primary financial statements on the basis of US GAAP.

The purpose of the IFRS Transition Report is to prepare users of the Company's financial statements for the change to IFRS. The document contains a description of the Company's IFRS accounting policies, reconciliation from US GAAP to IFRS of selected unaudited 2006 financial information, and a description of significant differences between its reporting based on IFRS and US GAAP.

In connection with the Company's completion of the IFRS Transition Report, the Company's Board of Directors have resolved to change the reporting of Income from discontinued operations in the Company's 2006 financial statements based on Norwegian GAAP. The change does not impact the Company's financial information previously released based on US GAAP which is the Company's primary basis for reporting to the market.

Compared to the unaudited Norwegian GAAP financial information included in the supporting tables in the Company's earnings release dated February 26, 2007, the change will reduce the reported Income from discontinued operations, net of tax, by USD 47.5 million. The change relates to the reported gain on the sale of 20% of the shares in Petrojarl and is a reclassification in the Norwegian GAAP financial statements of consolidated net assets of Petrojarl between distribution to shareholders and cost of shares sold. The change does not impact reported earnings from continuing operations, statement of cash flows or balance sheets under Norwegian GAAP.

****

Petroleum Geo-Services is a focused geophysical company providing a broad range of seismic and reservoir services, including acquisition, processing, interpretation, and field evaluation. The company also possesses the world's most extensive multi-client data library. PGS operates on a worldwide basis with headquarters at Lysaker, Norway.

For more information on Petroleum Geo-Services visit www.pgs.com.

****

The information included herein contains certain forward-looking statements within the meaning of Section 27A of the Securities Act of 1933 and Section 21E of the Securities Exchange Act of 1934. These statements are based on various assumptions made by the Company, which are beyond its control and are subject to certain additional risks and uncertainties as disclosed by the Company in its filings with the Securities and Exchange Commission including the Company's most recent Annual Report on Form 20-F for the year ended December 31, 2005. As a result of these factors, actual events may differ materially from those indicated in or implied by such forward-looking statements.

FOR DETAILS, CONTACT:

Ola Bøsterud
Phone +47 67 52 64 00
Mobile: +47 90 95 47 43
Christopher Møllerløkken
Phone: +47 67 51 43 16
Mobile: +47 90 27 63 55

US Investor Services
Katrina Parrott
Phone: +1 281 509 8000

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UNITED STATES
SECURITIES AND EXCHANGE COMMISSION
Washington, D.C. 20549

FORM 6-K

REPORT OF FOREIGN PRIVATE ISSUER

Pursuant to Rule 13a-16 or 15d-16 of
The Securities Exchange Act of 1934

July 17, 2007

PETROLEUM GEO-SERVICES ASA
(Exact name of registrant as specified in its charter)

STRANDVEIEN 4, N-1325 LYSAKER, NORWAY
(Address of principal executive offices)

001-14614
(Commission File Number)

Indicate by check mark whether the registrant files or will file annual reports under cover of Form 20-F or Form 40-F:

Form 20-F [X]   Form 40-F [ ]

Indicate by check mark whether the registrant by furnishing the information contained in this form is also thereby furnishing the information to the Commission pursuant to Rule 12g3-2(b) under the Securities Exchange Act of 1934.

Yes [ ]   No [X]

<PAGE>
PGS 2007 SECOND QUARTER RESULTS, WEBCAST AND CONFERENCE CALL CONTACT DETAILS

JULY 17, 2007: OSLO, NORWAY, Petroleum Geo-Services ASA ("PGS" or the Company) (OSE and NYSE: PGS) will as previously announced release its 2007 second quarter financial results on Thursday, July 26, 2007 at approximately 8:00 am Central

European Time (CET).

A presentation has been scheduled the same day at 9:00 am (CET) at PGS' Headquarters at Lysaker, Norway. A webcast and conference call have been scheduled the same day at 3:00 pm CET (9:00 am ET). The contact details for this service are detailed below.

The news release concerning the 2007 second quarter financial results and a corresponding slide presentation will be posted at Petroleum Geo-Services' web site at www.pgs.com. Interested parties can listen to the conference call over the Internet or by telephone.

To participate on the conference call over the Internet, please visit PGS' web site, www.pgs.com, at least 15 minutes early, to register and to download and install any necessary audio software.

Alternatively, to access the live broadcast of the conference call by telephone, please dial-in at the number provided below, corresponding to your location. The conference ID is 5691551.

LOCATION	DIAL-IN NUMBER
Norway (toll free)	800 19 395
International (toll)	+44 145 255 2510
UK (toll free)	0800 694 2370
US (toll free)	1866 966 9444

The telephone will be open for questions at the conclusion of management's remarks. For those that cannot listen to the live conference call, a replay of the webcast will be made available at PGS' website, www.pgs.com. Alternatively, a digital replay will be available shortly after the conclusion of the conference call, through Thursday, August 2, 2007. The access number is 5691551 followed by # (pound-sign). Please access the replay by dial-in at the number provided below.

LOCATION	DIAL-IN NUMBER
International (toll)	+44 145 255 0000
UK (toll free)	0800 953 1533
UK (local)	0845 245 5205
US (toll free)	1866 247 4222

<page>

****

Petroleum Geo-Services is a focused geophysical company providing a broad range of seismic and reservoir services, including acquisition, processing, interpretation, and field evaluation. The company also possesses the world's most extensive multi-client data library. PGS operates on a worldwide basis with headquarters at Lysaker, Norway.

For more information on Petroleum Geo-Services visit www.pgs.com.

****

The information included herein contains certain forward-looking statements within the meaning of Section 27A of the Securities Act of 1933 and Section 21E of the Securities Exchange Act of 1934. These statements are based on various assumptions made by the Company which are beyond its control and are subject to certain additional risks and uncertainties as disclosed by the Company in its filings with the Securities and Exchange Commission including the Company's most recent Annual Report on Form 20-F for the year ended December 31, 2006. As a result of these factors, actual events may differ materially from those indicated in or implied by such forward-looking statements.

--END--

FOR DETAILS, CONTACT:
OLA B0STERUD
Phone: +47 67 52 64 00
Cellular: +47 90 95 47 43

CHRISTOPHER M0LLERL0KKEN
Phone: +47 67 51 43 16
Cellular: +47 90 27 63 55

US INVESTOR SERVICES
Katrina Parrott
Phone: +1 281 509 8000

<PAGE>

SIGNATURES

Pursuant to the requirements of the Securities Act of 1934, the registrant has duly caused this report to be signed on its behalf by the undersigned thereunto duly authorized.

PETROLEUM GEO-SERVICES ASA

(Registrant)

July 17, 2007 /s/ CHRISTOPHER MOLLERLOKKEN
------------------------ ---
(Date) Christopher Mollerlokken
Investor Relations Manager

</TEXT>
</DOCUMENT>

Exhibit H

EXHIBIT A

Intellectual Property Agreement

Execution Copy

INTELLECTUAL PROPERTY AGREEMENT

This Intellectual Property Agreement ("***Agreement***"), effective as of February 12, 2010 ("***Effective Date***"), is made and entered into by and between Petroleum Geo-Services ASA, a Norwegian joint stock company ("***PGS***"), and Geokinetics Inc., a Delaware corporation ("***Geokinetics***"). In this Agreement, PGS and Geokinetics may also be referred to individually as a "***Party***" and collectively the "***Parties***."

Recitals

1. PGS and one or more of its Subsidiaries (as hereinafter defined) are in the process of developing certain marine vibrator technology.

2. PGS and Geokinetics, and several of their direct or indirect subsidiaries, have entered into a Purchase Agreement, dated December 3, 2009, pursuant to which Geokinetics and certain of its direct or indirect subsidiaries (collectively, the "***Purchasers***") have agreed to purchase, and PGS and certain of its direct or indirect subsidiaries (collectively, the "***Sellers***") have agree to sell, substantially all of PGS' onshore business segment (the "***Purchase Agreement***").

3. The Purchase Agreement provides in Section 6.5 that this Agreement will be delivered at the Closing of the transactions contemplated by the Purchase Agreement.

In consideration of the premises, agreements and covenants contained in this Agreement, the receipt and sufficiency of which are hereby acknowledged, the Parties agree as follows:

Section 1. Definitions

1.1 "***Effective Date***" means the date entered in the first paragraph of this Agreement.

1.2 "***Marine Vibrator***" means that certain marine vibrator being developed by PGS and its Subsidiaries as of the Effective Date for use in shallow water.

1.3 "***Marine Vibrator Documentation***" means all material documentation and drawings created as a result of or in connection with PGS' and its Subsidiaries' development of the Marine Vibrator, including standard processing flows used in processing Marine Vibrator data.

1.4 "***Marine Vibrator Patents***" means all patents owned by PGS and its Subsidiaries issuing from patent applications filed, invention disclosures executed or inventions made before the Effective Date that cover the operation or manufacture of the Marine Vibrator, and further including all reexaminations, reissues, continuations, and divisionals of any of the foregoing, and any foreign patents claiming priority therefrom.

1.5 "***New Development Work***" has the meaning set forth in Section 3.1.

1.6 ***"New Documentation*"** means all material documentation and drawings created as a result of New Development Work.

1.7 "***New Patents***" means all patents issued to, or acquired by, a Party or its Subsidiaries based on patent applications filed, invention disclosures executed or inventions made between the Effective Date and the fifth (5th) anniversary of the Effective Date that cover the operation or manufacture of the Marine Vibrator, and further including all reexaminations, reissues, continuations, and divisionals of any of the foregoing, and any foreign patents claiming priority therefrom.

1.8 "***Non-Streamer Field"*** means the field of acquiring seismic data by means other than the utilization of a Streamer.

1.9 "***Ocean Bed Seismic Field"*** means the field of acquiring seismic data utilizing sensors placed on the bed or floor of a body of water or otherwise maintained in a stationary position in a water-covered area or in a transition zone.

1.10 ***"Person"*** means an individual, a corporation, a limited liability company, a partnership, an association, a trust or any other entity or organization, including any governmental authority.

1.11 "***Purchased IP***" means all Intellectual Property (as defined in the Purchase Agreement) of a Business Owning Entity (as defined in the Purchase Agreement) that is acquired by Geokinetics pursuant to the Purchase Agreement, and further including all reexaminations, reissues, continuations, and divisionals of any of the foregoing, and any foreign patents claiming priority therefrom, but specifically excluding all trademarks and service marks.

1.12 "***Streamer***" means a casing, jacket or other structure containing or attaching one or more hydrophones or other sensors and designed to be towed through the water when acquiring seismic data.

1.13 "***Streamer Field***" means the field of acquiring seismic data utilizing, in whole or in part, a Streamer.

1.14 ***"Subsidiary"*** means, with respect to any Party, any corporation or other organization, whether incorporated or unincorporated, of which (i) at least a majority of the securities or other interests having by their terms voting power to elect a majority of the board of directors or others performing similar functions with respect to such corporation or other organization is directly or indirectly beneficially owned or controlled by such Party or by any one or more of its subsidiaries, or by such Party and one or more of its subsidiaries, or (ii) such Party or any Subsidiary of such Party is a general partner of a partnership or a manager of a limited liability company.

Section 2. License Grants

2.1 Patent License Grant. PGS hereby grants to Geokinetics a non-exclusive (except as limited herein), royalty-free, non-transferable (except as provided herein), worldwide license under the Marine Vibrator Patents in the Non-Streamer Field, including without limitation the

Ocean Bed Seismic Field. The foregoing license does not include the right to grant sublicenses, except to Geokinetics' Subsidiaries, but only for such time as any such entities are Subsidiaries, and to third Persons engaged solely to carry out work on behalf of Geokinetics.

2.2 Documentation License Grant. PGS hereby grants to Geokinetics a non-exclusive (except as limited herein), royalty-free, non-transferable (except as provided herein), worldwide license in the Non-Streamer Field, including without limitation the Ocean Bed Seismic Field, to use, copy, and create derivative works of the Marine Vibrator Documentation, and to use any trade secrets or know-how that are embodied therein. The foregoing license does not include the right to grant sublicenses, except to Geokinetics' Subsidiaries, but only for such time as any such entities are Subsidiaries, and to third Persons engaged solely to carry out work on behalf of Geokinetics. The rights granted hereunder are subject to the confidentiality obligations in Section 6.

2.3 IP Grant-Back License. Geokinetics hereby grants to PGS a non-exclusive, royalty-free, non-transferable (except as provided herein), worldwide license under the Purchased IP in the Streamer Field and the Ocean Bed Seismic Field, including a license to use, copy and create derivative works of any copyrighted materials whose copyrights are a part of the Purchased IP and to use any trade secrets or know-how that are a part of the Purchased IP. The foregoing license includes the right to grant sublicenses, except that PGS agrees that it will not grant sublicenses to non-Subsidiaries in the Non-Streamer Field for a period of ten (10) years after the Effective Date.

2.4 Limitation on Further Licenses and Disclosure. For a period of ten (10) years after the Effective Date, PGS shall not grant to any other Person a license under the Marine Vibrator Patents in the Non-Streamer Field. For a period of ten (10) years after the Effective Date, PGS shall only disclose the Marine Vibrator Documentation to third Persons who sign a confidentiality agreement and agree to limit their use of the Marine Vibrator Documentation, for other than PGS or its Subsidiaries to the Streamer Field.

2.5 Ownership. Geokinetics hereby acknowledges and agrees that, as between the Parties, PGS owns all right, title and interest in and to the Marine Vibrator Patents and the Marine Vibrator Documentation. Except as provided above, the licenses granted to Geokinetics under this Agreement in no way limit PGS from fully exploiting, including licensing or disclosing, the Marine Vibrator Patents or the Marine Vibrator Documentation. PGS hereby acknowledges and agrees that, as between the Parties, Geokinetics owns all right, title and interest in and to the Purchased IP. The license granted to PGS under this Agreement in no way limits Geokinetics from fully exploiting, including licensing or disclosing, the Purchased IP.

Section 3. New Developments

3.1 New Development Work. Each Party agrees that if it or any Subsidiary contemplates commencing further development of the Marine Vibrator, which would commence within ten (10) years after the Effective Date, then such Party shall provide written notice of such intention to the other Party and such Party may consider any request from the other Party to participate in such further development under mutually agreed terms. However, neither Party shall be under any obligation to participate with the other Party in any such further development.

For purposes of this Agreement, any further development of the Marine Vibrator commenced within ten (10) years after the Effective Date shall be "***New Development Work***," even if such development is completed after such ten-year period.

3.2 New Patents. PGS agrees to grant, and hereby does grant, to Geokinetics a non-exclusive, royalty-free, non-transferable (except as provided herein), worldwide license in the Non-Streamer Field, including without limitation the Ocean Bed Seismic Field, under any of its New Patents. Geokinetics agrees to grant, and hereby does grant, to PGS, a non-exclusive, royalty-free, non-transferable (except as provided herein), worldwide license in the Streamer Field under any of its New Patents. The foregoing licenses do not include the right to grant sublicenses, except to Subsidiaries of the licensee Party, but only for such time as any such entities are Subsidiaries, and to third Persons engaged solely to carry out work on behalf of the licensee Party.

3.3 New Documentation. PGS agrees to grant, and does hereby grant, to Geokinetics a non-exclusive, royalty-free, non-transferable (except as provided herein), worldwide license in the Non-Streamer Field, including without limitation the Ocean Bed Seismic Field, to use, copy, and create derivative works of all New Documentation of PGS, and to use any trade secrets or know-how that are embodied therein. Geokinetics agrees to grant, and does hereby grant, to PGS a non-exclusive, royalty-free, non-transferable (except as provided herein), worldwide license in the Streamer Field to use, copy, and create derivative works of all New Documentation, and to use any trade secrets or know-how that are embodied therein. The foregoing licenses do not include the right to grant sublicenses, except to Subsidiaries of the licensee Party, but only for such time as any such entities are Subsidiaries, and to third Persons engaged solely to carry out work on behalf of the licensee Party. The rights granted hereunder are subject to the confidentiality obligations in Section 6.

Section 4. Equipment and Documentation

4.1 Prototype. The prototypes of the Marine Vibrator that have been fabricated or partially fabricated before the Effective Date ("***Prototypes***") and ownership thereof shall be transferred to Geokinetics. Geokinetics agrees that it will arrange for and bear the cost of shipping and insurance.

4.2 Disclosure of Marine Vibrator Patents and Documentation. PGS agrees to advise Geokinetics upon the issuance of any patents that are a part of the Marine Vibrator Patents. PGS agrees to timely provide to Geokinetics copies of all Marine Vibrator Documentation as such documentation is finalized.

4.3 Disclosure of New Patents and New Documentation. The Parties agree to advise each other upon the issuance of any patents that are a part of the New Patents. For a period of five (5) years after the Effective Date, and for as long thereafter as any New Development Work is ongoing, the Parties shall meet with one another with reasonable regularity, but not less than once a year, unless such meetings are waived by both Parties in writing, at which time the Parties shall provide each other with a copy of their respective finalized New Documentation. Nothing herein contained is to be construed as requiring the Parties to transmit to each other information received from third Persons under any obligation of confidentiality and not otherwise lawfully known to or in the possession of the other Party.

Section 5. Disclaimers; Indemnity; Limitation of Liability

5.1 Disclaimer. THE PARTIES MAKE NO REPRESENTATION OR WARRANTY OF ANY KIND WITH RESPECT TO THE MARINE VIBRATOR PATENTS, THE MARINE VIBRATOR DOCUMENTATION, THE NEW PATENTS OR THE NEW DOCUMENTATION AND EXPRESSLY DISCLAIM ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING ANY WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, NON-INFRINGEMENT, OR ANY OTHER IMPLIED WARRANTIES WITH RESPECT TO THE MARINE VIBRATOR PATENTS, THE MARINE VIBRATOR DOCUMENTATION, THE NEW PATENTS AND THE NEW DOCUMENTATION.

5.2 Indemnification by PGS. PGS shall defend and indemnify Geokinetics, its officers, directors, employees, agents and representatives and any and all of Geokinetics' Subsidiaries from and against any and all claims, liabilities, suits, controversies, losses, costs and expenses (including, without limitation, claims for personal injury or death or property damage and including all court costs and reasonable attorneys' fees) (collectively, ***"Losses"***) to the extent arising out of, resulting from or attributable to PGS' exploitation of any Purchased IP, New Patents or New Documentation of Geokinetics that are licensed to PGS hereunder.

5.3 Indemnification by Geokinetics. Geokinetics shall defend and indemnify PGS, its officers, directors, employees, agents and representatives and any and all of PGS' Subsidiaries from and against any and all Losses to the extent arising out of, resulting from or attributable to Geokinetics' exploitation of the Marine Vibrator Patents, the Marine Vibrator Documentation, the Prototypes, or any New Patents or New Documentation of PGS that are licensed to Geokinetics hereunder.

5.4 Limitation of Liability. EXCEPT FOR A BREACH OF SECTION 6 (CONFIDENTIALITY), UNDER NO CIRCUMSTANCES WILL EITHER PARTY OR ITS SUBSIDIARIES BE LIABLE TO THE OTHER PARTY FOR ANY CONSEQUENTIAL, INDIRECT, EXEMPLARY, SPECIAL, PUNITIVE OR INCIDENTAL DAMAGES OR LOST PROFITS, WHETHER FORESEEABLE OR UNFORESEEABLE, EVEN IF SUCH PARTY HAS PREVIOUSLY BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES, ARISING OUT OF BREACH OR FAILURE OF EXPRESS OR IMPLIED WARRANTY, BREACH OF CONTRACT, MISREPRESENTATION, NEGLIGENCE, STRICT LIABILITY IN TORT OR OTHERWISE FROM DAMAGES ARISING UNDER THIS AGREEMENT.

Section 6. Confidentiality

6.1 Confidentiality Duty and Term of Duty. Each of the Parties recognizes that they may be exchanging confidential, proprietary and trade secret information under this Agreement, including the Marine Vibrator Documentation and the New Documentation (collectively hereinafter, "**Confidential Information**"). Each Party therefore agrees to maintain, and cause its Subsidiaries to maintain, any such material identified as being the Confidential Information of the other Party in confidence, and to refrain from using or disclosing such Confidential Information to any third Person, except as authorized by this Agreement, such obligation to be in effect for a period of fifteen (15) years after the Effective Date.

6.2 Exceptions to Duty. Notwithstanding the foregoing, the duties and obligations of this Section 6 shall not include information for which the receiving Party can demonstrate through documentary evidence: (a) is known to the receiving Party at the time of disclosure or becomes known to the receiving Party in its fully consolidated form as disclosed under this Agreement, all without breach of this Agreement; (b) is independently developed by the receiving Party without breach of this Agreement; (c) is or becomes publicly known through no wrongful act of the receiving Party, and so long as it becomes fully available and consolidated together in the public domain; (d) is rightfully received from a third Person without restriction on disclosure; or (e) is approved for release upon prior written consent of the disclosing Party.

6.3 Equitable / Injunctive Relief for Disclosure. If the receiving Party breaches any of its obligations with respect to confidentiality and unauthorized use of Confidential Information hereunder, the disclosing Party may be entitled to seek equitable relief to protect its interest therein, including but not limited to injunctive relief, as well as money damages, notwithstanding anything to the contrary contained herein.

6.4 Control. With respect to the subject matter of this Agreement, the terms and provisions of this Section 6 shall control over the terms and provisions of any pre-existing confidentiality agreement between the Parties.

Section 7. Termination

7.1 Term. Subject to the provisions of this Section 7, or unless otherwise negotiated and agreed to in writing by the Parties, the term of this Agreement will start as of the Effective Date and end upon the fifteenth (15th) anniversary of the Effective Date (such period herein referred to as the "Term"). Unless otherwise negotiated and agreed to in writing prior to the end of the Term, this Agreement will automatically terminate at the end of the Term.

7.2 Termination of Agreement for Cause. Either Party shall have the right to terminate this Agreement on the occurrence of any one or more of the following events:

(a) the insolvency of the other Party;

(b) the institution of any proceeding by the other Party under any bankruptcy, insolvency or moratorium law; or

(c) the material breach by the other Party of any term of this Agreement.

7.3 Exercise. The terminating Party may exercise its right of termination by giving the other Party, its trustees or receivers or assigns, forty-five (45) days prior written notice of the terminating Party's election to terminate, specifically setting forth the ground or grounds under Section 7.2 for such election. Upon the expiration of such period, this Agreement shall automatically terminate unless the breach or condition permitting termination has been previously cured, in which case this Agreement shall not terminate. Such notice and termination shall not prejudice any cause of action or claim of the terminating Party accrued or to accrue on account of any breach or default by the other Party.

7.4 Termination of Sublicenses. Each Party agrees to act promptly and reasonably to terminate any sublicenses granted by it pursuant to this Agreement in the event of: (a) the insolvency of the sublicensee; (b) the institution of any proceeding by the sublicensee under any bankruptcy, insolvency or moratorium law; or (c) any act of the sublicensee materially contrary to the obligations to be imposed on such sublicensee pursuant to this Agreement. The foregoing obligation may be made subject to any reasonable notice and cure period in the applicable sublicense.

7.5 Effect. Upon termination of this Agreement on the fifteenth (15th) anniversary of the Effective Date, any licenses granted hereunder shall survive. Upon earlier termination of this Agreement for cause, any licenses granted hereunder to the Party whose conduct or action was the basis for such termination shall terminate.

Section 8. Miscellaneous

8.1 Governing Law. This Agreement shall be construed, interpreted, and governed in accordance with the laws of the State of Texas, without reference to rules relating to conflicts of law.

8.2 Submission to Jurisdiction. Each Party consents to personal jurisdiction in any action arising out of or relating to this Agreement brought in the U.S. District Court for the Southern District of Texas, Houston Division, or any Texas state court in Harris County having subject matter jurisdiction as to a matter arising out of or relating to this Agreement (and the appropriate appellate courts), and each of the Parties agrees that any action instituted by it arising out of or relating to this Agreement will be instituted exclusively in one of the above specified courts. Each Party agrees that a final judgment in any dispute or action so brought will be conclusive and may be enforced by dispute or action on the judgment or in any other manner provided at law (common, statutory or other) or in equity. Each Party waives any defense of inconvenient forum to the maintenance of any dispute or action so brought.

8.3 Notice. All notices, statements and reports required or contemplated in this Agreement by one Party to the other shall be in writing and shall be deemed to have been given upon delivery in person or upon the expiration of five (5) days after deposit in a lawful mail depository in the country of residence of the Party giving the notice, registered or certified airmail postage prepaid, and addressed as follows:

If to PGS:

Petroleum Geo-Services, Inc.
10150 Memorial Drive
Houston, Texas 77024
Attention: Patent Counsel

with copy to:

Baker Botts L.L.P.
One Shell Plaza

Case 4:12-cv-04072 Document 29-1 Filed 03/16/13 Page 10 of 12

910 Louisiana Street
Houston, Texas 77002
Attention: Joe Poff

If to Geokinetics:

Geokinetics Inc.
1500 CityWest Blvd., Suite 800
Houston, Texas 77042
Attention: Scott McCurdy

with copy to:

Haynes and Boone, LLP
One Houston Center
1221 McKinney Street, Suite 2100
Houston, Texas 77010
Attention: Guy Young

A Party may change the address to which notices to such Party are to be sent by giving notice to the other Party at the address and in the manner provided above.

8.4 Assignment. Except as provided below, no Party may, directly or indirectly, in whole or in part, whether by operation of law or otherwise, assign or transfer this Agreement, without the other Party's prior written consent, and any attempted assignment, transfer or delegation without such prior written consent shall be void. Notwithstanding the foregoing, either Party may assign or transfer this Agreement as a whole without consent to a Subsidiary of such Party or to a Person that succeeds to all or substantially all of the business or assets of such Party relating to this Agreement. Without limiting the foregoing, this Agreement will be binding upon and inure to the benefit of the Parties and their permitted successors and assigns.

8.5 Entire Agreement. This Agreement constitutes the entire agreement between PGS and Geokinetics with respect to the subject matter hereof and shall not be modified, amended or terminated except as provided in this Agreement or except by another agreement in writing executed by the Parties.

8.6 Force Majeure. Neither Party will be liable to the other for any delay or failure to perform its obligations under this Agreement, if such delay or failure arises from any cause or causes beyond the reasonable control of the breaching Party, including, but not limited to, labor disputes, strikes, acts of God, acts of terrorism, floods, lightening, earthquakes or any other natural disasters, utility or communication failures, casualty, war, acts of the public enemy, riots, insurrections, embargoes, blockades or regulations or orders of governmental authorities. If a Party is delayed or prevented from performing their obligations pursuant to this Agreement due to any cause beyond that Party's reasonable control, such delay and period of performance will be excused during the continuance of such delay and the period of performance will be extended to the extent necessary to enable such Party to perform its obligations after the cause of such delay or prevention has been removed; provided, however, if such performance is delayed for

Case 1:12-cv-12472-DJC Doc 284-1 Filed 08/16/13 Page 10 of 11

ninety (90) or more days, the Party entitled to the benefit of such performance may elect to terminate this Agreement.

8.7 Severability. If for any reason any provision of this Agreement shall be invalid, illegal or unenforceable, then such provision shall be deemed to be severable from the other provisions of this Agreement, all of which shall remain in full force and effect and be binding on the Parties.

[Signature page follows]

PGS and Geokinetics have executed this Agreement on the Effective Date.

PETROLEUM GEO-SERVICES ASA

By:________________________________
Name:
Title:

GEOKINETICS INC.

By:________________________________
Name:
Title:

Exhibit I

PTO Form 1553 (Rev 9/2005)
OMB No. 0651-0054 (Exp. 09/30/2011)

Trademark/Service Mark Statement of Use
(15 U.S.C. Section 1051(d))

The table below presents the data as entered.

Input Field	Entered
SERIAL NUMBER	77334252
LAW OFFICE ASSIGNED	LAW OFFICE 113
EXTENSION OF USE	NO
MARK SECTION	
STANDARD CHARACTERS	YES
USPTO-GENERATED IMAGE	YES
LITERAL ELEMENT	GEOSTREAMER
OWNER SECTION (no change)	
ATTORNEY SECTION (no change)	
GOODS AND/OR SERVICES SECTION	
INTERNATIONAL CLASS	042
CURRENT IDENTIFICATION	geophysical exploration for oil and gas and other minerals
GOODS OR SERVICES	KEEP ALL LISTED
FIRST USE ANYWHERE DATE	05/19/2010
FIRST USE IN COMMERCE DATE	05/19/2010
SPECIMEN FILE NAME(S)	

ORIGINAL PDF FILE	SPN0-21622725050-170802294_._www.pgs.com_Geo-Svc_Marine_Tech_GS_Enhanced_Res.pdf
CONVERTED PDF FILE(S) (1 page)	\\TICRS\EXPORT10\IMAGEOUT10\773\342\77334252\xml1\SOU0002.JPG
ORIGINAL PDF FILE	SPN0-21622725050-170802294_._www.pgs.com_Geo-Svc_Marine_Tech_GS_Improved_Op.pdf
CONVERTED PDF FILE(S) (1 page)	\\TICRS\EXPORT10\IMAGEOUT10\773\342\77334252\xml1\SOU0003.JPG
SPECIMEN DESCRIPTION	print-outs of web pages
REQUEST TO DIVIDE	NO
PAYMENT SECTION	
NUMBER OF CLASSES IN USE	1
SUBTOTAL AMOUNT [ALLEGATION OF USE FEE]	100
TOTAL AMOUNT	100
SIGNATURE SECTION	
DECLARATION SIGNATURE	/E. Eugene Thigpen/
SIGNATORY'S NAME	E. Eugene Thigpen
SIGNATORY'S POSITION	Attorney of Record
DATE SIGNED	05/28/2010
FILING INFORMATION	
SUBMIT DATE	Thu Jun 03 12:41:46 EDT 2010
TEAS STAMP	USPTO/SOU-216.227.250.50-20100603124146216832-77334252-460c965873cf340502c2dbba9e65fcc-DA-9358-20100528170802294968

PTO Form 1553 (Rev 9/2005)
OMB No. 0651-0054 (Exp. 09/30/2011)

Trademark/Service Mark Statement of Use
(15 U.S.C. Section 1051(d))

To the Commissioner for Trademarks:

MARK: GEOSTREAMER
SERIAL NUMBER: 77334252

The applicant, Petroleum Geo-Services ASA, having an address of
Strandveien 4
Lysaker, N-1366
Norway
is submitting the following allegation of use information:

For International Class 042:
Current identification: geophysical exploration for oil and gas and other minerals

The mark is in use in commerce on or in connection with all goods or services listed in the application or Notice of Allowance or as subsequently modified for this specific class

The mark was first used by the applicant, or the applicant's related company, licensee, or predecessor in interest at least as early as 05/19/2010, and first used in commerce at least as early as 05/19/2010, and is now in use in such commerce. The applicant is submitting one specimen for the class showing the mark as used in commerce on or in connection with any item in the class, consisting of a(n) print-outs of web pages.

Original PDF file:
SPN0-21622725050-170802294_._www.pgs.com_Geo-Svc_Marine_Tech_GS_Enhanced_Res.pdf
Converted PDF file(s) (1 page)
Specimen File1
Original PDF file:
SPN0-21622725050-170802294_._www.pgs.com_Geo-Svc_Marine_Tech_GS_Improved_Op.pdf
Converted PDF file(s) (1 page)
Specimen File1

The applicant is not filing a Request to Divide with this Allegation of Use form.

The applicant(s) hereby appoint(s) E. Eugene Thigpen of PETROLEUM GEO-SERVICES

15150 MEMORIAL DR
HOUSTON, Texas 77079-4320
United States
to submit this Trademark/Service Mark Statement of Use on behalf of the applicant.

A fee payment in the amount of $100 will be submitted with the form, representing payment for the allegation of use for 1 class.

Declaration

Applicant requests registration of the above-identified trademark/service mark in the United States Patent and Trademark Office on the Principal Register established by the Act of July 5, 1946 (15 U.S.C. Section 1051 et seq., as amended). Applicant is the owner of the mark sought to be registered, and is using the mark in commerce on or in connection with the goods/services identified above, as evidenced by the attached specimen(s) showing the mark as used in commerce.

The undersigned, being hereby warned that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. Section 1001, and that such willful false statements may jeopardize the validity of the form or any resulting registration, declares that he/she is properly authorized to execute this form on behalf of the applicant; he/she believes the applicant to be the owner of the trademark/service mark sought to be registered, or, if the form is being filed under 15 U.S.C. Section 1126(d) or (e), he/she believes applicant to be entitled to use such mark in commerce; to the best of his/her knowledge and belief no other person, firm, corporation, or association has the right to use the mark in commerce, either in the identical form thereof or in such near resemblance thereto as to be likely, when used on or in connection with the goods/services of such other person, to cause confusion, or to cause mistake, or to deceive; and that all statements made of his/her own knowledge are true; and that all statements made on information and belief are believed to be true.

Signature: /E. Eugene Thigpen/ Date Signed: 05/28/2010
Signatory's Name: E. Eugene Thigpen
Signatory's Position: Attorney of Record

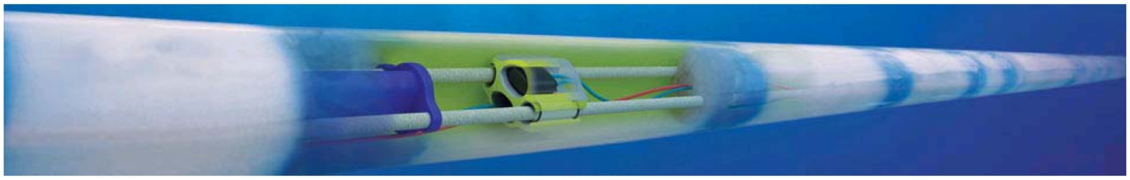
Mailing Address:
PETROLEUM GEO-SERVICES

15150 MEMORIAL DR
HOUSTON, Texas 77079-4320

RAM Sale Number: 9358
RAM Accounting Date: 06/03/2010

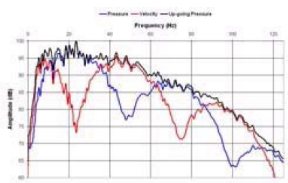
Serial Number: 77334252
Internet Transmission Date: Thu Jun 03 12:41:46 EDT 2010
TEAS Stamp: USPTO/SOU-216.227.250.50-201006031241462
16832-77334252-460c965873cf340502c2dbba9
e65fcc-DA-9358-20100528170802294968

Petroleum Geo-Services

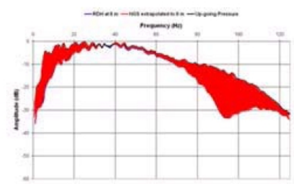


Enhanced Resolution

The new GeoStreamer service records both pressure and the vertical component of the particle velocity. Separation into up-going and down-going pressure and velocity wavefields is straightforward. Thus, the receiver ghost can be removed from the pressure wavefield, increasing resolution. Both the lower and higher frequency content is substantially boosted in comparison to conventional pressure-only streamer data. Significantly, the signal-to-noise ratio for all frequencies is also boosted, particularly for marginal conditions. Dual-sensor streamer data provide the optimum platform for spectral enhancement processing to recover high frequencies lost by natural attenuation in the earth, for inversion to acoustic and elastic impedance, for 4D survey matching, and for advanced noise and multiple removal.



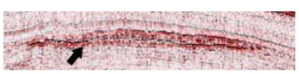
Superimposed amplitude spectra for pressure (blue), velocity (red), and the deghosted result (black).



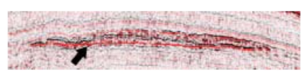
Improvement in frequency content for deghosted pressure data vs. total (conventional) pressure data.

ENHANCED RESOLUTION - ACCURATE RESERVOIR DESCRIPTION

The benefits are also realised for reservoir characterization as we see in the example below. A line of legacy data shot over a large gas field is compared to the GeoStreamer data. The flat spot as well as the internal architecture of this structure are significantly better defined by the enhanced resolution of the deghosted data. It results in a much better understanding of the reservoir, which in turn reduces field development risks.



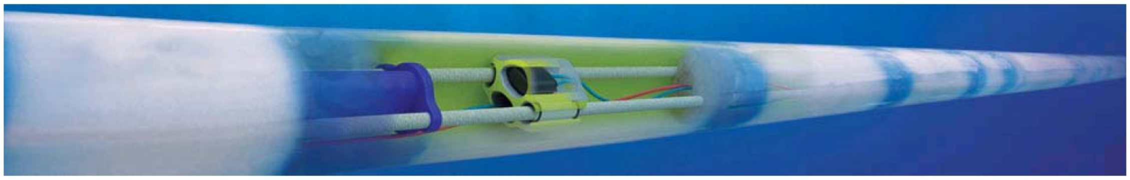
Conventional streamer
Click to enlarge



GeoStreamer®
Click to enlarge

The enhanced resolution from GeoStreamer data allows a more detailed characterization of the internal structure and the flat spot (arrowed)

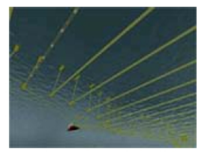
Petroleum Geo-Services



Improved Operational Efficiency

GeoStreamer operations exist in a longer weather window, sometimes in scenarios where conventional operations would be shut down. Efficient acquisition follows from only having to tow all streamers at one depth, exploiting the full streamer width capacity of the vessel, and easily controlling all streamer behaviour. Operations for streamer deployment, towing and recovery are conventional, thereby reducing risk and improving reliability.





Towing deep in a quiet environment with collocated pressure and velocity sensors improves operational performance and efficiency.

FEE RECORD SHEET

Serial Number: 77334252

RAM Sale Number: 9358

Total Fees: $100

RAM Accounting Date: 20100603

Transaction	Fee Code	Transaction Date	Fee per Class	Number of Classes	Total Fee
Statement of Use (SOU)	7003	20100603	$100	1	$100

Transaction Date: 20100603

Exhibit J

13-10472-KJC Geokinetics Inc.
Case type: bk **Chapter:** 11 **Asset:** Yes **Vol:** v **Judge:** Kevin J. Carey
Date filed: 03/10/2013 **Date of last filing:** 01/27/2014 **Plan confirmed:** 04/25/2013

Attorneys

Elihu Ezekiel Allinson, III Sullivan Hazeltine Allinson LLC 901 North Market Street Suite 1300 Wilmington, DE 19801 302-428-8191 302-428-8195 (fax) ZAllinson@SHA-LLC.com *Assigned: 04/08/2013*	representing	**Terry J. Allen** *(Creditor)*
Andreas P. Andromalos One Financial Center Boston, MA 02111 617.856.8229 (617) 856-8201 (fax) aandromalos@brownrudnick.com *Assigned: 03/11/2013*	representing	**Whitebox Advisors LLC, in its capacity as Administrative Agent and Collateral Agent** *(Interested Party)*
Robert T. Aulgur, Jr. Whittington & Aulgur 651 N. Broad Street, Suite 206 P.O. Box 1040 Middletown, DE 19709-1040 302-378-1661 302-285-0236 (fax) bk.service@aulgur.com *Assigned: 04/19/2013* *LEAD ATTORNEY*	representing	**Toyota Motor Credit Corporation** Whittington & Aulgur 651 North Broad Street, Suite 206 PO Box 1040 Middletown, DE 19709 302-378-1661 302-285-0236 (fax) bk.service@aulgur.com *(Creditor)*
Allison R Axenrod Claims Recevery Group LLC 92 Union Avenue Cresskill, NJ 07626 201-266-6988 201-266-6985 (fax) allison@claimsrecoveryllc.com *Assigned: 03/29/2013*	representing	**Claims Recovery Group LLC** 92 Union Avenue Cresskill, NJ 07626 201.266.6988 allison@claimsrecoveryllc.com *(Creditor)*
John T Banks Perdue Brandon Fielder Collins & Mott LL Suite 505	representing	**Colorado County, Colorado County Groundwater Conservation District, Rice CISD and Rice Hospital District** Perdue, Brandon, Fielder, Collins & Mot

schristianson@buchalter.com *Assigned: 03/14/2013*		415-227-0770 (fax) schristianson@buchalter.com *(Creditor)*
M. Blake Cleary Young, Conaway, Stargatt & Taylor 1000 North King Street Wilmington, DE 19801 302-571-6600 302-571-1253 (fax) bankfilings@ycst.com *Assigned: 04/12/2013*	representing	**Petroleum Geo-Services ASA** 15150 Memorial Drive Houston, TX 77079 *(Interested Party)*
Joseph Corrigan Iron Mountain Information Management, In 745 Atlantic Avenue 10th Floor Boston, MA 02111 617-535-4744 617-451-0409 (fax) Bankruptcy2@ironmountain.com *Assigned: 04/09/2013*	representing	**Iron Mountain Information Management, LLC** 745 Atlantic Avenue Attn: Joseph Corrigan Boston, MA 02111-2735 617-535-4744 Bankruptcy2@ironmountain.com *(Creditor)*
Sarah J. Crow Akin Gump Strauss Hauer & Feld LLP 1700 Pacific Avenue Suite 4100 Dallas, TX 75201 214-969-2800 214-969-4343 (fax) sjcrow@akingump.com *Assigned: 03/12/2013*	representing	**Geokinetics Inc.** P. O. Box 421129 Houston, TX 77242 *(Debtor)*
John P. Dillman Linebarger Goggan Blair & Sampson, LLP P.O. Box 3064 Houston, TX 77253-3064 713-844-3478 713-844-3503 (fax) houston_bankruptcy@publicans.com *Assigned: 03/22/2013*	representing	**City of Brookshire** John P. Dillman Linebarger Goggan Blair & Sampson LLP P.O. Box 3064 Houston, TX 77253-3064 713-844-3478 houston_bankruptcy@lgbs.com *(Creditor)*
		Cypress-Fairbanks Independent School District John P. Dillman Linebarger Goggan Blair & Sampson LLP P.O. Box 3064 Houston, TX 77253-3064 713-844-3478 houston_bankruptcy@lgbs.com *(Creditor)*

Steven K. Kortanek Womble Carlyle Sandridge & Rice, LLP 222 Delaware Avenue, Suite 1501 Wilmington, DE 19801 302-252-4363 302-661-7728 (fax) skortanek@wcsr.com *Assigned: 03/11/2013*	representing	**Whitebox Advisors LLC, in its capacity as Administrative Agent and Collateral Agent** *(Interested Party)*
George A. Kurisky, Jr. Johnson DeLuca Kurisky & Gould, P.C. 4 Houston Center 1221 Lamar Street Suite 1000 Houston, TX 77010 713-652-2525 713-652-5130 (fax) gkurisky@jdkklaw.com *Assigned: 04/03/2013*	representing	**Enterprise Fleet Management** Johnson DeLuca Kurisky & Gould, P.C. 1221 Lamar Street Houston, TX 77010 713-652-2525 713-652-5130 (fax) gkurisky@jdkglaw.com *(Creditor)*
Lacey Lawrence Akin Gump Strauss Hauer & Feld LLP 1700 Pacific Ave Ste. 4100 Dallas, TX 75201 214 969 2800 llawrence@akingump.com *Assigned: 04/10/2013*	representing	**Geokinetics Inc.** P. O. Box 421129 Houston, TX 77242 *(Debtor)*
Steven B. Levine Brown Rudnick LLP One Financial Center Boston, MA 02111 usa 617-856-8200 617-856-8201 (fax) slevine@brownrudnick.com *Assigned: 03/11/2013*	representing	**Whitebox Advisors LLC, in its capacity as Administrative Agent and Collateral Agent** *(Interested Party)*
Robert W. Mallard Dorsey & Whitney (Delaware) LLP 300 Delaware Avenue Suite 1010 Wilmington, DE 19801 302-425-7171 302-425-7177 (fax) mallard.robert@dorsey.com *Assigned: 03/11/2013*	representing	**U.S. Bank National Association, in its capacities as Indenture Trustee and Collateral Trustee** *(Creditor)*
C. Luckey McDowell Baker Botts L.L.P. 2001 Ross Avenue Dallas, TX 75201-2980	representing	**Petroleum Geo-Services ASA** 15150 Memorial Drive Houston, TX 77079 *(Interested Party)*

214-953-6466 214-661-6503 (fax) luckey.mcdowell@bakerbotts.com *Assigned: 04/12/2013*		
James E. O'Neill Pachulski Stang Ziehl & Jones LLP 919 North Market Street, 17th Floor P.O. Box 8705 Wilmington, DE 19899-8705 302-652-4100 302-652-4400 (fax) jo'neill@pszjlaw.com *Assigned: 03/11/2013*	representing	**American Securities Opportunities Advisors, LLC and Gates Capital Management, Inc.** *(Interested Party)*
Joshua L Reid Konsure Law Firm 36 East Choctaw P.O. Box 1031 McAlester, OK 74501 918-426-0700 *Assigned: 04/09/2013*	representing	**Terry J. Allen** *(Creditor)*
Ian E. Roberts Baker Botts LLP 2001 Ross Avenue Dallas, TX 75201 214-953-6500 214-953-6503 (fax) *Assigned: 04/12/2013*	representing	**Petroleum Geo-Services ASA** 15150 Memorial Drive Houston, TX 77079 *(Interested Party)*
Jennifer L. Rodburg Fried Frank Harris Shriver Jacobson LLP One New York Plaza New York, NY 10004 212-859-8000 212-859-4000 (fax) jennifer.rodburg@friedfrank.com *Assigned: 03/11/2013*	representing	**American Securities Opportunities Advisors, LLC and Gates Capital Management, Inc.** *(Interested Party)*
Richard L. Schepacarter Office of the United States Trustee U. S. Department of Justice 844 King Street, Suite 2207 Lockbox #35 Wilmington, DE 19801 usa 302-573-6491 302-573-6497 (fax) richard.schepacarter@usdoj.gov *Assigned: 04/11/2013*	representing	**United States Trustee** 844 King Street, Room 2207 Lockbox #35 Wilmington, DE 19899-0035 302-573-6491 302-573-6497 (fax) USTPREGION03.WL.ECF@USDOJ.GOV *(U.S. Trustee)*

Exhibit K

IN THE UNITED STATES DISTRICT COURT
FOR THE SOUTHERN DISTRICT OF TEXAS
HOUSTON DIVISION

WESTERNGECO L.L.C., *Plaintiff*	§	
v.	§	**CIVIL ACTION NO. 09-CV-01827**
ION GEOPHYSICAL CORPORATION, *Defendant.*	§	**Jury Trial Demanded**

AFFIDAVIT OF JAMES BRASHER

STATE OF TEXAS §
§
COUNTY OF HARRIS §

PERSONALLY APPEARING BEFORE ME AND HAVING BEEN DULY SWORN, the undersigned, deposes and says:

1. I am over the age of majority, of sound mind, and otherwise fully competent to make a statement under oath.

2. I am the Vice President and Senior Legal Counsel of Petroleum Geo-Services, Inc., and have held that position since August 2004. In such position, I am responsible for overseeing the legal affairs of Petroleum Geo-Services, Inc. As such, I have personal knowledge of the matters recited in this Affidavit.

3. Petroleum Geo-Services, Inc. ("PGS, Inc.") is a Delaware corporation with its principal place of business in Houston, Texas. Petroleum Geo-Services ASA is a Kingdom of Norway public limited liability company and is the parent company of PGS, Inc. Petroleum Geo-Services ASA maintains its headquarters in Oslo, Norway.

4. PGS, Inc. is affiliated with several US-based subsidiaries, including PGS Americas, Inc. and PGS Data Processing, Inc. PGS, Inc., together with its US subsidiaries,. currently have 441 employees in their Houston, Texas offices, located at 15150 Memorial Dr., Houston, TX 77079.

5. PGS, Inc. and Petroleum Geo-Services ASA are distinct corporate entities that maintain separate daily operations. Each company has its own board of directors, and none of the members of Petroleum Geo-Services ASA's board serve on the board of PGS, Inc. PGS, Inc. has its own bank accounts, balance sheets, and profit and loss statements. PGS, Inc. pays taxes in the United States based solely on its income.

6. PGS, Inc. has no legal right, contractual or otherwise, to access the documents of Petroleum Geo-Services ASA, or the documents of foreign PGS entities.

7. PGS, Inc. is incapable of commanding or directing the cooperation of its parent company in making documents or witnesses available, and thus compliance with any order directing PGS, Inc. to produce documents owned by entities such as Petroleum Geo-Services ASA will likely be very difficult, if not impossible.

8. PGS, Inc. approached Petroleum Geo-Services ASA regarding obtaining access to its parent's records in order to respond to WesternGeco's subpoena. Petroleum Geo-Services ASA refused to consent to give PGS, Inc. access to its corporate files. PGS, Inc. does not control documents that relate to business transactions with ION regarding ION's marine seismic positioning equipment that I understand are the subject of the dispute between WesternGeco and ION. PGS, Inc. is unsure which foreign PGS entities, if any, may have documents related to WesternGeco's dispute or whether any such documents exist in any PGS entity.

9. Petroleum Geo-Services ASA or some other foreign PGS entity is responsible for outfitting marine seismic vessels and maintaining records regarding what equipment is used on these vessels. These are not activities performed by PGS, Inc. PGS, Inc. has not been involved in any bidding, purchasing, assembly, use or operation of ION's marine seismic positioning equipment that I understand to be the subject of WesternGeco's infringement assertions. Outside of what PGS, Inc. has already produced and subject to its objections, PGS, Inc. neither has nor needs access to any records Petroleum Geo-Services ASA or those of any other PGS entity reflecting events that may relate to WesternGeco's dispute with ION.

10. PGS, Inc. has searched its records and found nothing indicating it has purchased or tested any ION Accused Device.

11. PGS, Inc. and Petroleum Geo-Services ASA store e-mails and documents on different servers. PGS, Inc. does not have control of emails and documents that are in the custody of a foreign PGS entity, such as Petroleum Geo-Services ASA.

12. It is my understanding that Norwegian privacy laws could inhibit access to the files and documents of Petroleum Geo-Services ASA's employees and may increase the already substantial cost of searching for and retrieving Petroleum Geo-Services ASA's records.

13. PGS, Inc. owns and maintains documents that relate to its own business. PGS, Inc. does not have a policy or practice of storing documents abroad to shield them from discovery.

14. PGS, Inc. has not acted as an agent of any other PGS entity in any transaction with ION.

15. PGS, Inc. markets seismic services to customers in the United States. In addition, PGS Data Processing, Inc. processes seismic data when requested by customers in the Americas.

Such customer data is considered highly proprietary and held under very strict confidentiality terms. In most instances, the customers own the data, and PGS, Inc. does not control or own the data. PGS, Inc. also performs some research and development functions on certain discrete projects.

16. Subject to PGS, Inc.'s objections to WesternGeco's subpoena *duces tecum*, PGS, Inc. has produced relevant, responsive documents in its possession, custody, or control that it has been able to locate.

FURTHER AFFIANT SAYETH NOT.

James Brasher

SUBSCRIBED AND SWORN to me on this the 23rd day of April, 2010 to certify which witness my hand and official seal.

Barbara A. Selby
Notary Public in and for
The State of Texas

BARBARA A. SELBY
MY COMMISSION EXPIRES
FEBRUARY 24, 2013

10464-v1/1031.0050

Exhibit L

PGS Petroleum Geo-Services

Recruitment Events

Our recruitment events are excellent opportunities to meet and talk to the people who work at PGS and learn more about our organization and our opportunities. Please click here to read about our activities at some of the schools we visit regurlarly.

Below you will find an updated overview of our scheduled events. Please click on each link to register and receive more information about the specific event.

Event	**Date**
SPE Full Day Student Seminar - Oslo	11 Oct. 2013
Geologia 2013 - Vandœuvre-les-Nancy	18 Oct. 2013
Integrated Career Days - ITB, Indonesia	25-27 Oct. 2013
Company Presentation - NTNU, Norway	29 Oct. 2013
IAGC Annual Meeting Student Program, Houston, Texas, US	18 Feb 2014

Don't see your school or university? Send us an email telling us about your faculty and course and we just might visit there too.

Geoscience students & professors from local universities are invited to attend the 43rd IAGC Annual Membership Meeting free of charge.

Shuttles from each campus to meeting in Houston will be provided.

Breakfast/ Lunch will be provided.

Topics of discussion to include:

- Behavioral Response of Australian Humpbacks to Seismic Surveys
  -Dr Doug Cato , Principal Investigator University of Sydney
- Microseismic Imaging: Its Promise vs. Today's Reality
- Pore Pressure Prediction: The Role of Seismic Data

www.iagc.org

Reception to follow - opportunity to network with recruiters and executives from the geophysical industry - *ID required for alcoholic beverages

Save the Date -18 Feb 2014

register early: angela@iagc.org

Exhibit M

[hpc] heimpayne+chorushLLP

Intellectual Property Litigation
www.heimpaynechorush.com

MICHAEL F. HEIM
PARTNER

DIRECT DIAL: (713) 221-2001
EMAIL: MHEIM@HPCLLP.COM

March 26, 2010

Sarah K. Tsou
Kirkland & Ellis
601 Lexington Avenue
New York, NY 10022-4675

Ms. Tsou:

I am responding to your letter dated March 15, 2010. In that letter, you raise certain questions regarding the subpoena issued by WesternGeco to Petroleum Geo-Services, Inc. ("PGS, Inc.") and PGS, Inc.'s subsequent response. That subpoena and response followed a series of letters between Timothy Gilman and me. A copy of my letters dated December 22, 2009 and January 6, 2010 is attached. For the reasons discussed in those letters and as further explained below, PGS, Inc. has met its obligations under the subpoena with regard to the ION steerable stream equipment documentation that is the subject of the WesterGeco lawsuit.

All the relevant information sought from PGS, Inc. could be obtained directly from ION Geophysical Corp. ("ION"), the defendant in the litigation. For example, WesternGeco has requested production of "[a]ll communications between PGS and ION relating to DigiBIRD, DigiFIN, [and] ORCA."[1] PGS, Inc. has conducted a reasonable search of its records and produced documents responsive to this request. To the extent that WesternGeco seeks additional responsive documents, such documents are more appropriately sought directly from ION rather than from PGS, Inc. Notably, under WesternGeco's expansive definition of "PGS", PGS, Inc.—a Delaware corporation and a non-party to this proceeding—would be required to search for and retrieve documents controlled by distinct entities in numerous locations stretching across the world. As discussed below, PGS, Inc. does not have control of the documents held by the distinct foreign entities WesternGeco describes as "PGS." Yet even if, assuming *arguendo*, PGS, Inc. did control these documents, it is needlessly burdensome to require PGS, Inc. to engage in such a cumbersome process when ION is capable of producing all such documents, almost certainly with much greater ease. Thus, seeking further production from PGS, Inc. clearly poses an undue burden on PGS, Inc. and violates the Federal Rules of Civil Procedure.[2]

[1] Request No. 3 of WesternGeco's subpoena to PGS, Inc.

[2] *See* Fed. R. Civ. Pro. 45(c)(1) ("A party or attorney responsible for issuing and serving a subpoena must take reasonable steps to avoid imposing undue burden or expense on a person subject to the subpoena."); Hansen Beverage Co. v. Innovation Ventures, LLC, 2009 WL 2351769, at *1 (E.D. Mich. July 28, 2009) ("Courts also consider one's status as a nonparty to be a significant factor in the undue-burden analysis.") (citing N.C. Right to Life, Inc. v. Leake, 231 F.R.D. 49, 51 (D.D.C. 2005)).

It is my understanding that many, if not all, of the documents sought by WesternGeco relate to interactions between ION and Petroleum Geo-Services ASA, the Norwegian parent company of PGS, Inc. As discussed above, these documents may be properly obtained from ION. However, to the extent that WesternGeco seeks production of documents in the possession of a foreign entity such as Petroleum Geo-Services ASA, the Hague Convention provides the appropriate avenue for obtaining such documents. As I have done in both of my prior letters to your firm, I again encourage WesternGeco to seek discovery directly from the entities that may possess the documents you seek, rather than from PGS, Inc. which is not in possession or control of those documents.

As indicated in both of my prior letters to your firm, PGS, Inc. has not been involved in purchasing or testing ION's marine seismic equipment that is the subject of your ongoing lawsuit. If you desire information regarding the testing and acquisition of ION's equipment by Petroleum Geo-Services ASA beyond that which you can obtain directly from ION, then you should direct your inquiries to its General Counsel, Espen Sandvik, in the Oslo Headquarters of Petroleum Geo-Services ASA. Petroleum Geo-Services ASA is responsible for outfitting the marine vessels and for maintaining the records regarding what equipment is used on these vessels for its various customers. PGS, Inc. is not involved in those activities, nor does it maintain records regarding those activities.

The materials you reference in your letter as exhibits all relate to ION and Petroleum Geo-Services ASA. Exhibit 1 is a PowerPoint presentation that identifies Svein Rennemo on its title page. Mr. Rennemo was the former CEO of Petroleum Geo-Services ASA, located in Oslo. I also note that you state that Exhibit 1 evidences the purchase of ION equipment, although I have found nothing in the document that mentions ION equipment.

Exhibit 2 appears to be a press release of ION, the defendant in the lawsuit. The press release refers to the Atlantic Explorer and Pacific Explorer. PGS, Inc. does not own or control these vessels, and acquisition of equipment for those vessels is under the direction and control of Petroleum Geo-Services ASA, as indicated by the press release. Rune Eng, the PGS employee quoted in the press article, is the Group President of the Marine Acquisition Group of Petroleum Geo-Services ASA, located in Oslo. Also, it is my understanding that WesternGeco's infringement allegations require a particular use or configuration of ION materials, including, at a minimum, the implementation of each of the DigiBird, DigiFIN, and ORCA systems according to a particular methodology. I understand that the use of one or two of these systems in isolation are outside the scope of the WesternGeco patents, and thus the fact that Exhibit 2 mentions the testing of DigiFIN technology alone is of little or no relevance to your lawsuit.

Your Exhibit 3 is a PowerPoint presentation of Petroleum Geo-Services ASA, in Oslo, as the title of the document indicates. Thus, once again, the documents you reference make it clear that the proper entity from whom you should be seeking discovery is either ION or Petroleum Geo-Services ASA. In addition, this document only references DigiFIN technology, and not the particular combination that is the subject of your infringement allegations.

Exhibit 4 appears to be an article dated December 11, 2009 regarding the marine seismic business. This article was not authored by anyone from either PGS, Inc. or Petroleum Geo-Services ASA. Further, to the extent that the statements in this document are accurate, it only indicates that Petroleum Geo-Services ASA has used the DigiFIN system, and not the particular combination that is the subject of your infringement allegations.

Lastly, Exhibit 5 is a press release from ION indicating that new Petroleum Geo-Services ASA towed streamer vessels will be outfitted with the ORCA navigational control system. Once again, the document clearly shows that the information you seek originates from ION and Petroleum Geo-Services ASA, and not PGS, Inc. Moreover, the fact that vessels are outfitted with an ORCA navigational control system once again has little or no relevance to the infringement allegations in your lawsuit.

Despite the fact that the exhibits and documents show that it is ION and Petroleum Geo-Services ASA that have the information you seek, WesternGeco has persisted in taking the position that PGS, Inc. has custody or control of these documents, primarily because it is a subsidiary of Petroleum Geo-Services ASA. The mere fact that a company is a subsidiary of another does not mean it has possession or control of its parent's documents. WesternGeco is a business segment of Schlumberger. How would WesternGeco respond if it were served with a subpoena in the United States requesting the documents of Schlumberger located in France?

PGS, Inc. and Petroleum Geo-Services ASA have always maintained their status as distinct entities, both generally and in regard to the transactions at issue. As discussed above, PGS, Inc. was not involved in the transactions related to the current litigation. Furthermore, PGS, Inc. would neither have nor need access to documents in the possession of Petroleum Geo-Services ASA that relate to dealings with ION. Thus, PGS, Inc. clearly does not control any documents in the possession of Petroleum Geo-Services ASA. To the extent that PGS, Inc. employees have been copied on such correspondence, PGS, Inc. has supplied that correspondence to WesternGeco in response to its subpoena. But PGS, Inc. cannot be required to produce documents that are not in its possession or control.

Finally, I would like to reiterate PGS, Inc.'s position set forth in its Response to Plaintiff's Document Subpoena. In particular, WesternGeco's broad requests of irrelevant or minimally relevant information from PGS, Inc.—a non-party and competitor of WesternGeco—clearly exceed the bounds of proper discovery under the Federal Rules of Civil Procedure. PGS, Inc. should not be required to strip bear its highly confidential documents to its competitor under the guise of discovery with regard to its own internal research projects that are not the subject of the ongoing lawsuit between WesternGeco and ION.

I hope the explanation above makes clear that PGS, Inc. has met its obligations under the Federal Rules of Civil Procedure. If you have any remaining questions, please let me know.

Sincerely,

Michael J. Heim

Michael Heim

cc: James Brasher
Espen Sandvik

Exhibit N

Heim, Payne & Chorush, LLP

600 Travis St., Suite 6710
Houston, TX 77002

MICHAEL J. HEIM
PARTNER

DIRECT DIAL: (713) 221-2001
EMAIL: MHEIM@HPCLLP.COM

December 22, 2009

Timothy Gilman
Kirkland & Ellis
601 Lexington Avenue
New York, NY 10022-4675

Mr. Gilman,

I am responding to your email to James Brasher on December 8, as outside counsel for Petroleum Geo-Services, Inc. My client, Petroleum Geo-Services, Inc. is a Delaware corporation with its principal place of business in Houston, Texas. Petroleum Geo-Services, Inc. is a subsidiary of Petroleum Geo-Services ASA, which is a Norwegian company.

Your email requests, among other things, that Oyvind Hillesund be made available to assist WesternGeco in its pending lawsuit against ION Geophysical Corporation, and that Mr. Hillesund also possibly sit for a deposition in that case. Other portions of your letter suggest that Petroleum Geo-Services, Inc. was involved in some fashion in testing or using the ION products that WesternGeco accuses of infringement.

In response to your inquiry, please be advised that Mr. Hillesund is not an employee of Petroleum Geo-Services, Inc. It is my understanding that he is an employee of the parent corporation, Petroleum Geo-Services ASA. As you indicated in your email, he resides in Norway. Consequently, Petroleum Geo-Services, Inc. has no control over Mr. Hillesund, and your inquiry regarding Mr. Hillesund should be directed to Petroleum Geo-Services ASA.

Further, Petroleum Geo-Services, Inc has not been involved in testing or use of the ION products. Your letter suggests that some PGS entity may have tested or used the ION products outside of the United States. If you desire information regarding testing or use of ION products by a PGS entity that may have occurred outside the United States, I suggest you contact Petroleum Geo-Services ASA. Espen Sandvik is the general counsel of Petroleum Geo-Services ASA. Any communications you may wish to send to Petroleum Geo-Services ASA should be directed to him.

If you have any follow-up questions, please direct them to me.

Sincerely,

9975-v1/9997.0420

Michael Heim

cc: James Brasher
Espen Sandvik

9975-v1/9997.0420

Exhibit O

Petroleum Geo-Services

SITE MAP CONTACT SUBSCRIBE CLIENT AREA

About us | Geophysical Services | MultiClient | Investor Relations | Pressroom | Careers

Home › Pressroom › News › PGS Tests ION's DigiFIN Steerable Streamer System

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PGS Tests ION's DigiFIN Steerable Streamer System

26 Sep 2007


Atlantic Explorer

ION Geophysical Corporation, formerly known as I/O, has completed open water testing of its DigiFIN™ streamer control system on PGS's seismic vessels Atlantic Explorer and Pacific Explorer. DigiFIN is a steerable streamer system for marine seismic acquisition vessels that provides lateral streamer control, a feature which improves the efficiency of acquisition operations and allows more streamers to be towed closer together to enhance the quality of the acquired seismic data.

Dave Moffat, Senior Vice President of Marine Imaging Systems at ION, commented, "ION has developed DigiFIN to help contractors improve the productivity of their marine seismic operations and deliver higher resolution subsurface images to their oil & gas company customers. It is a 'drop-in' system designed to be compatible with most existing in-water streamers. We are delighted that PGS – widely recognized as a seismic acquisition leader in the industry – experienced first-hand the additional value that DigiFIN can bring to marine seismic operations."

DigiFIN maintains tighter, more uniform streamer separation along the entire length of the streamer cable, which allows for finer sampling of seismic data and improved subsurface images. DigiFIN also enables faster line changes and minimizes the requirements for in-fill, which together improve the productivity of towed streamer operations.

Contact

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Media Contact
Tore Langballe
Senior Vice President Group Communications
Direct: +47 67 52 64 00
Cell: +47 907 77 841
info@pgs.com

Rune Eng, Group President Marine, commented, "PGS is committed to being the technology leader in marine seismic acquisition. We are actively involved in maturing this technology through the ION-PGS Launch Partner Agreement, which enables first adoption of the technology by PGS. We are pleased with the results of the tests on the Atlantic Explorer and Pacific Explorer and expect DigiFIN to further improve our ability to deliver the tight streamer spacing that is often required on the most technically advanced marine programs, including 4D and HD3D surveys."

PGSI-T2725-WG-0009560

Exhibit P

PGS Petroleum Geo-Services

Share Purchase by Primary Insiders

28 Mar 2008

28 March, 2008, OSLO, NORWAY - PGS had a 2007 Bonus Incentive Plan, under which certain employees received a regular cash bonus and a cash bonus earmarked for share purchase. Of the cash bonus earmarked for share purchase, the net amount (after withholding taxes) must be used to purchase shares in the open market at the prevailing market prices. In total PGS has today on behalf of the employees covered by the 2007 Bonus Incentive Plan, purchased 139,941 shares at an average price of NOK 125.62 per share. The purchases by the primary insiders as disclosed below, were made as part of the respective primary insider`s obligation to purchase shares under the 2007 Bonus Incentive Plan.

Gottfred Langseth, Executive V.P. & CFO of Petroleum Geo-Services ASA, has on March 28, 2008 bought 2,774 shares in Petroleum Geo-Services ASA at an average price of NOK 125.62 per share. Following the transaction Gottfred Langseth holds 8,031shares and 90,000 options in Petroleum Geo-Services ASA.

Christin Steen-Nilsen, V.P. Chief Accounting Officer of Petroleum Geo-Services ASA, has on March 28, 2008 bought 1,016 shares in Petroleum Geo-Services ASA at an average price of NOK 125.62 per share. Following the transaction Christin Steen-Nilsen holds 3,165 shares and 8,001 options in Petroleum Geo-Services ASA.

Lars Inge Pettersen, V.P. & Technical Director GAAP of Petroleum Geo-Services ASA, has on March 28, 2008 bought 770 shares in Petroleum Geo-Services ASA at an average price of NOK 125.62 per share. Following the transaction Lars Inge Pettersen holds 1,573 shares and 12,000 options in Petroleum Geo-Services ASA.

Contact

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Media Contact
Tore Langballe
Senior Vice President Group Communications
Direct: +47 67 52 64 00
Cell: +47 907 77 841
info@pgs.com

Rune Eng, Group President Marine of Petroleum Geo-Services ASA, has on March 28, 2008 bought 2,736 shares in Petroleum Geo-Services ASA at an average price of NOK 125.62 per share. Following the transaction Rune Eng holds 20,874 shares and 60,000 options in Petroleum Geo-Services ASA.

Eric D. Wersich, Group President Onshore of Petroleum Geo-Services ASA, has on March 28, 2008 bought 2,022 shares in Petroleum Geo-Services ASA at an average price of NOK 125.62 per share. Following the transaction Eric D. Wersich holds 8,355 shares and 39,999 options in Petroleum Geo-Services ASA.

David J. Dakin, Corporate Controller of Petroleum Geo-Services ASA has on March 28, 2008 bought 930 shares in Petroleum Geo-Services ASA at an average price of NOK 125.62 per share. Following the transaction David J. Dakin holds 3,046 shares and 20,000 options in Petroleum Geo-Services ASA.

Jarle Pøsche Ruud, Vice President Business Development of Petroleum Geo-Services ASA has on March 28, 2008 bought 827 shares in Petroleum Geo-Services ASA at an average price of NOK 125.62 per share. Following the transaction Jarle Pøsche Ruud holds 1,941 shares and 14,000 options in Petroleum Geo-Services ASA.

Sverre Lorentz Strandenes, Group President Data Processing & Technology of Petroleum Geo-Services ASA has on March 28, 2008 bought 2,432 shares in Petroleum Geo-Services ASA at an average price of NOK 125.62 per share. Following the transaction Sverre Lorentz Strandenes holds 6,994 shares and 50,001 options in Petroleum Geo-Services ASA.

****

Petroleum Geo-Services is a focused geophysical company providing a broad range of seismic and reservoir services, including acquisition, processing, interpretation, and field evaluation. The company also possesses the world's most extensive multi-client data library. PGS operates on a worldwide basis with headquarters at Lysaker, Norway.
For more information on Petroleum Geo-Services visit www.pgs.com.

****

The information included herein contains certain forward-looking statements within the meaning of Section 27A of the Securities Act of 1933 and Section 21E of the Securities Exchange Act of 1934. These statements are based on various assumptions made by the Company, which are beyond its control and are subject to certain additional risks and uncertainties as disclosed by the Company in its filings with the Securities and Exchange Commission including the Company's most recent Annual Report on Form 20-F for the year ended December 31, 2007. As a result of these factors, actual events may differ materially from those indicated in or implied by such forward-looking statements.

PGSI-T2725-WG-0001758

FOR DETAILS, CONTACT:

Bård Stenberg
Phone: +47 67 52 64 00
Cellular: +47 99 24 52 35

US Investor Services,
Katrina Parrott
Phone: +1 281 509 8000

Exhibit Q

STRONG FUNDAMENTALS
COMPETITIVELY POSITIONED

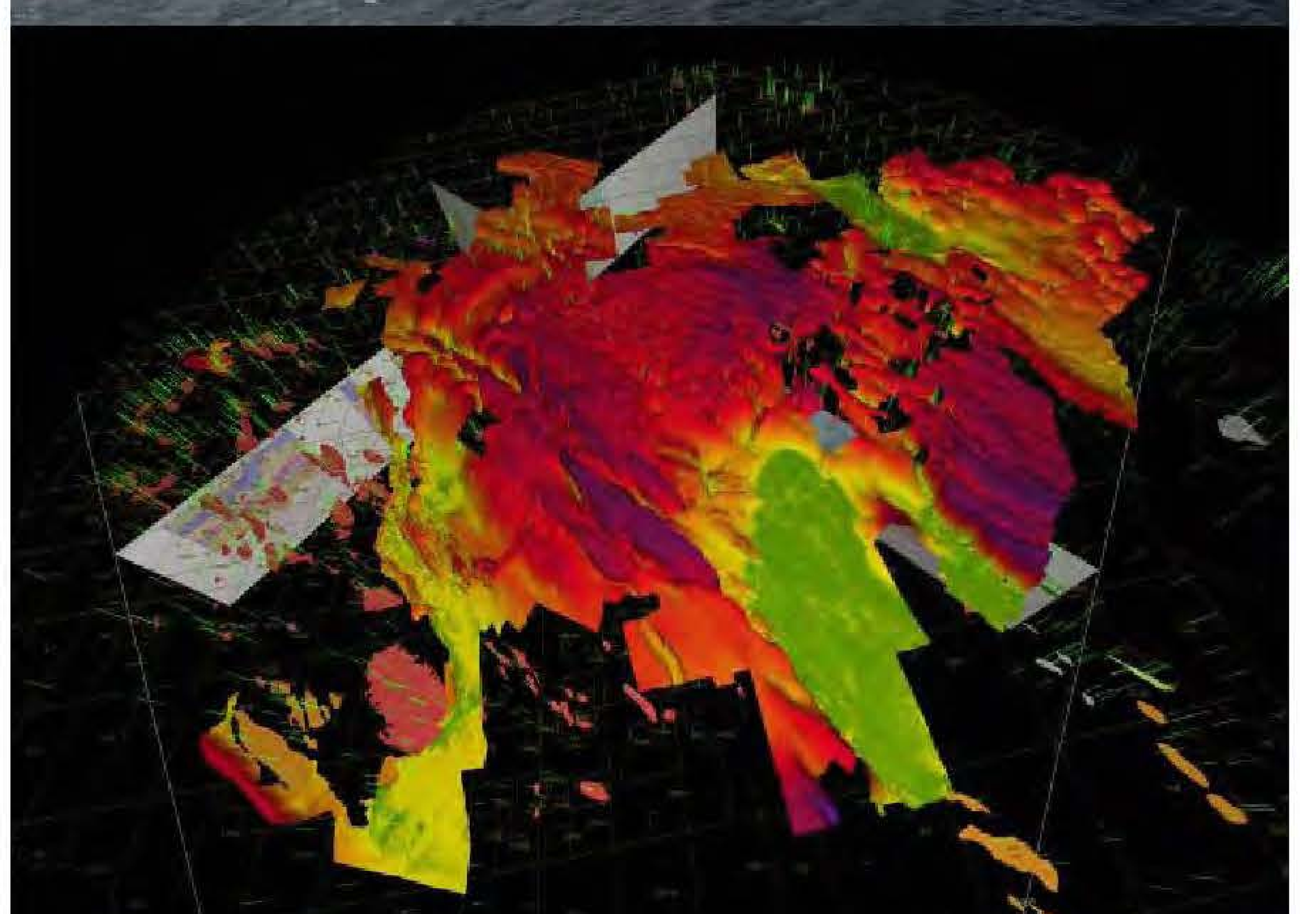
MARINE | **DATA PROCESSING & TECHNOLOGY** | **ONSHORE**

PETROLEUM GEO-SERVICES ASA

CAPITAL MARKETS DAY 2008

OSLO

PGS – Agenda Capital Markets Day 2008



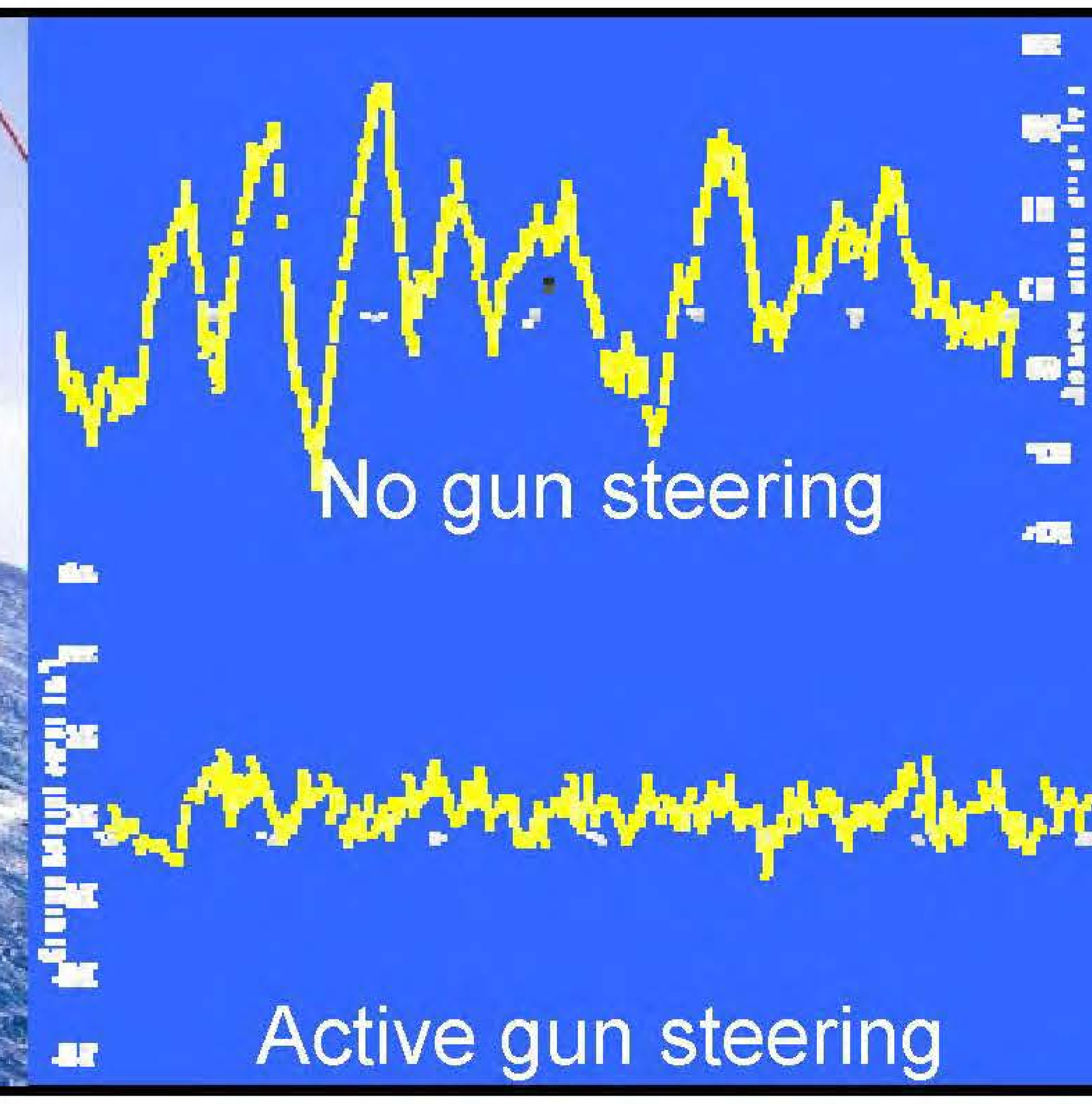
- 08:30 Introduction
  - Jon Erik Reinhardsen, President and CEO
- 09:00 Financials
  - Gottfred Langseth, EVP & CFO
- 09:30 Q&A
- 09:45 Break
- 10:00 Data Processing and Technology
  - Sverre Strandenes, Group President Data Processing and Technology
- 10:30 Marine
  - Rune Eng, Group President Marine
- 11:00 Onshore
  - Eric Wersich, Group President Onshore
- 11:30 Concluding remarks and Q&A
  - Jon Erik Reinhardsen, President and CEO
- 12:00 Lunch

Data Processing and Technology

Sverre Strandenes, Group President
DP and Technology

PGS Capital Markets Day
December 3, 2008

Steerable Sources and Streamers: Accuracy and Efficiency



Direct, automated steering of gun floats

- Increased operational efficiency
- Improves data quality of 4D surveys and Wide Azimuth surveys

New generation steerable devices developed for the GeoStreamer®

Digifin steerable streamers deployed on Ramform Sovereign

- Faster deployment and retrieval
- Reduced tangling risk and faster line turns

Exhibit R

PUBLIC

Attachment 1

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF OCEAN ENERGY MANAGEMENT

GOM OCS REGION BOEM AUG 23 2013 New Orleans LA OFFSHORE RESOURCE EVALUATION

NEW ORLEANS
(Insert Appropriate Regional Office)

APPLICATION FOR PERMIT TO CONDUCT GEOLOGICAL OR GEOPHYSICAL EXPLORATION FOR MINERAL RESOURCES OR SCIENTIFIC RESEARCH ON THE OUTER CONTINENTAL SHELF

(Section 11, Outer Continental Shelf Lands Act of August 7, 1953, as amended on September 18, 1978, by Public Law 95-372, 92 Statute 629, 43 U.S.C. 1340; and 30 CFR Parts 251 and 551)

MULTI KLIENT INVEST AS
Name of Applicant

LILLEAKERVEIEN 4C, PO BOX 251 LILLEAKER
Number and Street

0216 OSLO, NORWAY
City, State, and Zip Code

Application is made for the following activity: (check one)

GOM OCS REGION BOEM RELEASABLE SEP 05 2013 New Orleans, LA OFFSHORE RESOURCE EVALUATION

_______ Geological exploration for mineral resources

_______ Geological scientific research

___X___ Geophysical exploration for mineral resources

_______ Geophysical scientific research

Submit: Original plus three copies, totaling four copies, which include one digital copy, and one public information copy.

==

To be completed by BOEM

Permit Number: T13-004 **Date:** 27-Aug-2013

A General Information

1 The activity will be conducted by

PETROLEUM GEO SERVICES For MULTIKLIENT INVEST AS
Service Company Name Purchaser(s) of the Data

15150 MEMORIAL DRIVE LILLEAKERVEIEN 4C
Address Address

HOUSTON TX 77079 POBOX 251 LILLEAKER, OSLO, NORWAY 0216
City, State Zip City State Zip

281-509-8253 281-509-8451
Telephone/FAX Numbers Telephone/FAX Numbers

Jack van zeelst@pgs com gary morrow@pgs com
E-Mail Address E-Mail Address

2 The purpose of the activity is X Mineral exploration

____ Scientific research

3 Describe your proposed survey activities (i e vessel use benthic impacts acoustic sources etc) and describe the environmental effects of the proposed activity including potential adverse effects on marine life Describe what steps are planned to minimize these adverse effects (mitigation measures) For example 1) Potential Effect Excessive sound level Mitigation Soft Start, MMOs mammal exclusion zone or 2) Potential Effect Bottom disturbance Mitigation ROV deployment/retrieval of bottom nodes) (use continuation sheets as necessary or provide a separate attachment)

Seismic research vessel, no adverse effects, five single source arrays, mitigations in place to protect environment NTL regulations followed

4 The expected commencement date is OCTOBER 1, 2013

The expected completion date is JULY 15, 2014

5 The name of the individual(s) in charge of the field operation is
Gary Morrow

May be contacted at
PGS, 15150 MEMORIAL DRIVE, HOUSTON, TX 77079

Telephone (Local) 281 509 8451 (Marine) PLEASE SEE

Email Address gary morrow@pgs com Radio call sign ATTACHMENT

6 The vessel(s) to be used in the operation is (are) see attached

Name (s) Registry Number(s) Registered owners)
Two (single source, 10 Streamer) vessels } 5 total
Three (single source only) vessels
one spare (single source only) vessel, 1 supply, 2 chase

7 The port from which the vessel(s) will operate is Galveston, Texas

8 Briefly describe the navigation system (vessel navigation only)
Differential GPS

B Complete for Geological Exploration for Mineral Resources or Geological Scientific Research

1 The type of operation(s) to be employed is (check one)

(a) _________ Deep stratigraphic test or

(b) _________ Shallow stratigraphic test with proposed total depth of _________, or

(c) _________ Other _________

2 Attach a page size plat showing 1) The generalized proposed location for each test where appropriate a polygon enclosing the test sites may be used 2) BOEM protraction areas coastline point of reference 3) Distance and direction from a point of reference to area of activity

C Complete for Geophysical Exploration for Mineral Resources or Geophysical Scientific Research

1 The type(s) of operation(s) to be employed is (are)
a) Acquisition method (OBN OBC Streamer) Streamer
b) Type of acquisition (High Resolution Seismic 2D Seismic 3D Seismic gravity magnetic CSEM etc)
3D Seismic (GeoStreamer FAZ)

2 Attach a page size plat showing
a) The generalized proposed location of the activity with a representative polygon
b) BOEM protraction areas coastline point of reference
c) Distance and direction from a point of reference to area of activity

3 List all energy source types to be used in the operation(s) (Air gun air gun array(s) sub bottom profiler sparker towed dipole side scan sonar etc)

Air Gun

4. Explosive charges will ____ will not X be used. If applicable, indicate the type of explosive and maximum charge size (in pounds) to be used:

Type N/A Pounds N/A Equivalent Pounds of TNT N/A

D. Proprietary Information Attachments

Use the appropriate form on page 9 for a "geological" permit application or the form on page 11 for a "geophysical" permit application. You must submit a separate Form BOEM-0327 to apply for each geological or geophysical permit.

E. Certification

I hereby certify that foregoing and attached information are true and correct.

Print Name: Sverre Strandenes
Executive vice president

SIGNED [signature] DATE 19 AUG. 2013

TITLE ____

COMPANY NAME: ____

TO BE COMPLETED BY BOEM

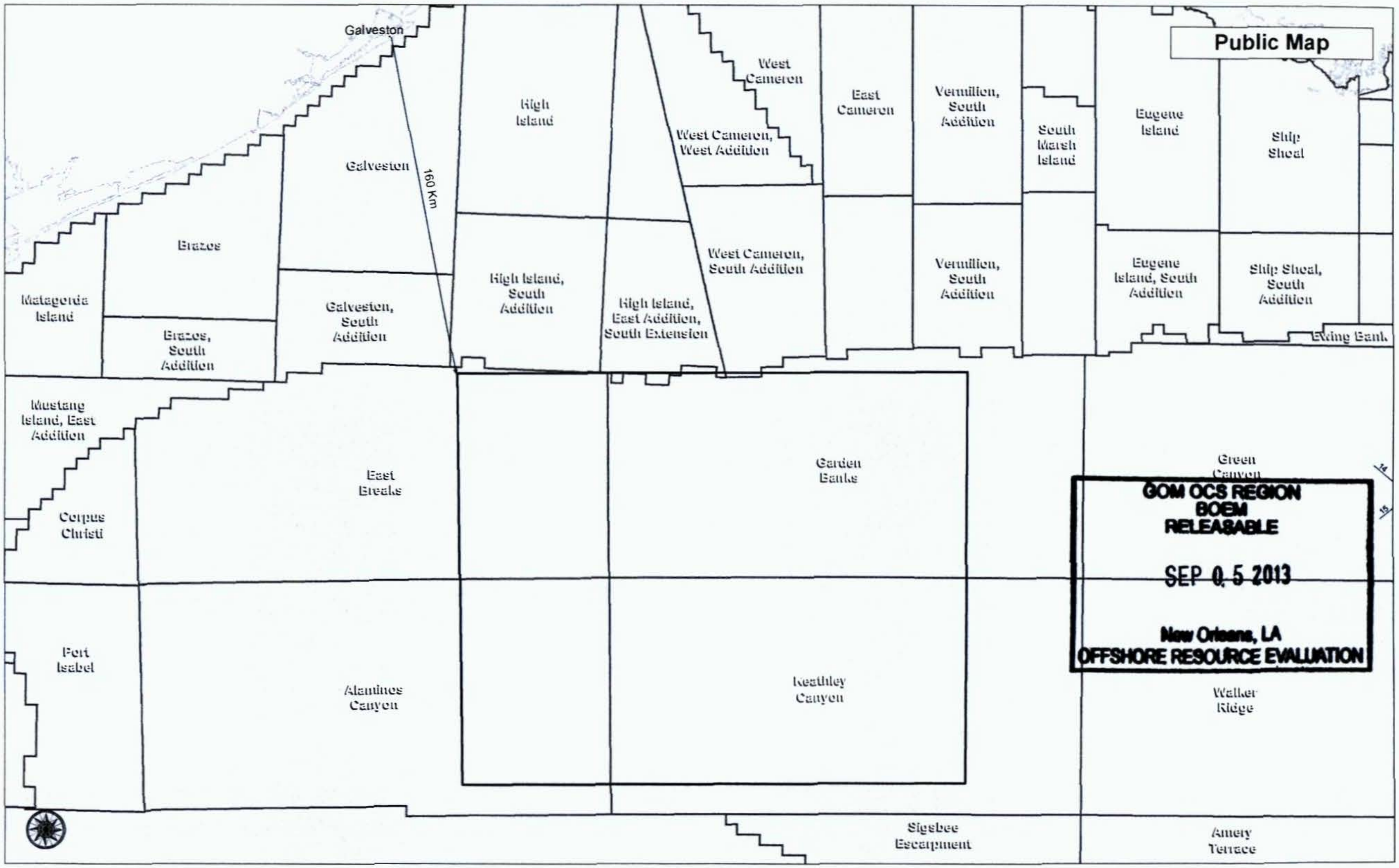
Permit No. T13-004 Assigned by Terree Campbell of BOEM Date [redacted] 9/4/13

This application is hereby:

a. / Accepted

b. ____ Returned for reasons in the attached

SIGNED [signature] TITLE Regional Supervisor DATE 9/5/13



Area: Gulf of Mexico

Date: Friday, August 02, 2013

Vessel	Radio Call Sign	Registry (IMO)	Owner
Ramform Valiant	C6TU7	9165023	PGS Falcon AS
PGS Apollo	C6ZH9	9378228	PGS Falcon AS
Pacific Explorer	YJZW5	8212829	PGS Falcon AS
Nordic Explorer	C6TU3	8517449	PGS Falcon AS
Ocean Pearl	C6ZW4	9125140	Norfield AS
Sanco Star	ZDIT8	9410313	Sanco Holding AS
Marlene Ostervold	LCIU3	6415051	Norfield AS
Supply vessels			
Thor Alpha	OZ2070	9458559	Thor Offshore
Nautika Resolute	WDA3186	7716842	Sea Support Ventures

2 spare vessels

Exhibit S

PUBLIC

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF OCEAN ENERGY MANAGEMENT

NEW ORLEANS
(Insert Appropriate Regional Office)

GOM OCS REGION
BOEM
AUG 23 2013
New Orleans LA
OFFSHORE RESOURCE EVALUATION

PERMIT FOR GEOPHYSICAL EXPLORATION FOR MINERAL RESOURCES OR SCIENTIFIC RESEARCH ON THE OUTER CONTINENTAL SHELF

In consideration of the terms and conditions contained herein and the authorization granted hereby, this permit is entered into by and between the United States of America (the Government), acting through the Bureau of Ocean Energy Management (BOEM) of the Department of the Interior, and

MULTI KLIENT INVEST AS
(Name of Permittee)

LILLEAKERVEIEN 4C, PO BOX 251 LILLEAKER
(Number and Street)

0216 OSLO, NORWAY
(City, State, and Zip Code)

PERMIT NUMBER: T13-004 DATE: 27-Aug-2013

This permit is issued pursuant to the authority of the Outer Continental Shelf Lands Act, as amended, (43 U.S.C. 1331 et seq.), hereinafter called the "Act," and Title 30 Code of Federal Regulations Parts 251 and 551 (Geological and Geophysical (G&G) Explorations of the Outer Continental Shelf).

GOM OCS REGION
BOEM
RELEASABLE
OCT 28 2013
New Orleans, LA
OFFSHORE RESOURCE EVALUATION

Paperwork Reduction Act of 1995 (PRA) Statement: This permit refers to information collection requirements contained in 30 CFR Parts 251 and 551 regulations. The Office of Management and Budget (OMB) has approved those reporting requirements under OMB Control Number 1010-0048.

Section I. Authorization

The Government authorizes the permittee to conduct:

X Geophysical exploration for mineral resources as defined in 30 CFR 551.1.

____ Geophysical scientific research as defined in 30 CFR 551.1. A permit is required for any geophysical investigation that involves the use of solid or liquid explosives or developing data and information for proprietary use or sale.

This permit authorizes the permittee to conduct the above geophysical activity during the period from 28-Oct-2013 to 28-Dec-2013, in the following area(s): See attached map. Extensions of the time period specified above must be requested in writing. A permit plus extensions for activities will be limited to a period of not more than 1 year from the original issuance date of the permit. Inspection and reporting of geophysical exploration activities, suspension and cancellation of authority to conduct exploration or scientific research activities under permit, and penalties and appeals will be carried out in accordance with 30 CFR 551.8, 551.9, and551.10.

The authority of the Regional Director may be delegated to the Regional Supervisor for Resource Evaluation for the purposes of this permit.

Section II. Type(s) of Operations and Technique(s)

A. The permittee will employ the following type(s) of operations: 3D Seismic (Geo Streamer Full Azimuth);

and will utilize the following instruments and/or technique(s) in such operations: Air Gun and Geo Streamer.

B. The permittee will conduct all activities in compliance with the terms and conditions of this permit, including the "Stipulations," "Special Provisions," and the approved "Application for Permit," which are attached to and incorporated into this permit.

C. The permittee will conduct all geophysical exploration or scientific research activities in compliance with the Act, the regulations in 30 CFR Parts 251 and 551, and other applicable statutes and regulations whether such statutes and regulations are enacted, promulgated, issued, or amended before or after this permit is issued. Some of the provisions of 30 CFR Parts 251 and 551 are restated in this permit for emphasis. However, all of the provisions of 30 CFR Parts 251 and 551 apply to this permit.

Section III. Reports on Operations

A. The permittee must submit status reports on a bi-weekly basis in a manner approved or prescribed by the Regional Supervisor, Resource Evaluation (hereinafter referred to as Supervisor). The report must include a daily log of operations and a map (preferably on a scale of 1: 250,000) showing traverse lines according to Bureau of Ocean Energy Management (BOEM) area and block numbers.

B. The permittee must submit to the Supervisor a final report within 30 days after the completion of operations. The final report must contain the following:

1. A description of the work performed and areal extent including number of line miles for 2-D or high resolution surveys or OCS blocks for 3-D geophysical data acquired;

2 Chart(s), map(s), or plat(s) depicting the areas and blocks in which any exploration or scientific research activities were conducted. These graphics must clearly indicate the location of the activities so that the data produced from the activities can be accurately located and identified

3. The dates on which the actual geophysical exploration or scientific research activities were performed;

4. A narrative summary of any: (a) hydrocarbon occurrences or environmental hazards observed and (b) adverse effects of the geophysical exploration or scientific research activities on the environment, aquatic life, archaeological resources, or other uses of the area in which the activities were conducted;

5. The estimated date on which the processed or interpreted data or information will be available for inspection by BOEM;

6. A final edited navigation file on suitable storage medium of all data or sample locations in latitude/longitude degrees including datum used. The navigation for 2D lines should include line name and locations for the first, last and every tenth SP. For 3D surveys, please supply a navigation file for the acquired track lines that includes the location of the first and last SP and/or the corner locations for the area acquired. Contact the G&G permitting office for the specific navigation required for this permitted activity. The digital file is to be formatted in standard SEG-P1, UKOOA P1-90 or other current, standard industry format, coded in ASCII. A printed data listing and a format statement are to be included;

7. Identification of geocentric ellipsoid (NAD 27 or NAD 83) used as a reference for the data or sample locations; and

8. Such other descriptions of the activities conducted as may be specified by the Supervisor.

C. The last status report and the final report can be combined into one report.

Section IV. <u>Submission, Inspection, and Selection of Geophysical Data and Information</u>

A. The permittee must notify the Supervisor, in writing, when the permittee has completed the initial processing and interpretation of any geophysical data and information collected under an exploration permit or a scientific research permit that involves developing data and information for proprietary use or sale. If the Supervisor asks if the permittee has further processed or interpreted any geophysical data and information collected under a permit, the permittee must respond within 30 days. *If further processing of the data and information is conducted, it is the responsibility of* the permittee to keep the most current resulting products available in the event the Supervisor requests the current status of data processing. At any time within 10 years after receiving notification of the completion of the acquisition activities conducted under the permit, the Supervisor may request that the permittee submit for inspection and possible retention all or part of the geophysical data, processed geophysical information, and interpreted geophysical information.

B. The Supervisor will have the right to inspect and select the geophysical data, processed geophysical information, or interpreted geophysical information. This inspection will be performed on the permittee's premises unless the Supervisor requests that the permittee submit the data or information to the Supervisor for inspection. Such submission must be within 30 days following the receipt of the Supervisor's request unless the Supervisor authorizes a later delivery date. If the inspection is done on the permittee's premises, the permittee must submit the geophysical data or information selected within 30 days following receipt of the Supervisor's request, unless the Supervisor authorizes a longer period of time for delivery. The data or information requested for inspection or selected by the Supervisor must be submitted regardless of whether the permittee and the Government have or have not concluded an agreement for reimbursement. If the Supervisor decides to retain all or a portion of the geophysical data or information, the Supervisor will notify the permittee, in writing, of this decision.

C. In the event that a third party obtains geophysical data, processed geophysical information, or interpreted geophysical information from a permittee, or from another third party, by sale, trade, license agreement, or other means:

1. The third party recipient of the data and information assumes the obligations under this section except for notification of initial processing and interpretation of the data and information and is subject to the penalty provisions of 30 CFR Part 550, Subpart N; and

2. A permittee or third party that sells, trades, licenses, or otherwise provides the data and information to a third party must advise the recipient, in writing, that accepting these obligations is a condition precedent of the sale, trade, license, or other agreement; and

3. Except for license agreements, a permittee or third party that sells, trades, or otherwise provides data and information to a third party must advise the Supervisor in writing within 30 days of the sale, trade, or other agreement, including the identity of the recipient of the data and information; or

4. With regard to license agreements, a permittee or third party that licenses data and information to a third party, within 30 days of a request by the Supervisor, must advise the Supervisor, in writing, of the license agreement, including the identity of the recipient of the data and information.

D. Each submission of geophysical data, processed geophysical information, and interpreted geophysical information must contain, unless otherwise specified by the Supervisor, the following:

1. An accurate and complete record of each geophysical survey conducted under the permit, including digital navigational data and final location maps of all surveys;

2. All seismic data developed under a permit presented in a format and of a quality suitable for processing;

3. Processed geophysical information derived from seismic data with extraneous signals and interference removed, presented in a format and of a quality suitable for interpretive evaluation, reflecting state-of-the-art processing techniques; and

4. Other geophysical data, processed geophysical information, and interpreted geophysical information obtained from, but not limited to, shallow and deep subbottom profiles, bathymetry, side-scan sonar, gravity, magnetic, and electrical surveys, and special studies such as refraction, shear wave, and velocity surveys.

Section V. Reimbursement to Permittees

A. After the delivery of geophysical data, processed geophysical information, and interpreted geophysical information requested by the Supervisor in accordance with subsection IV of this permit, and upon receipt of a request for reimbursement and a determination by BOEM that the requested reimbursement is proper, BOEM will reimburse the permittee or third party for the reasonable costs of reproducing the submitted data and information at the permittee's or third party's lowest rate or at the lowest commercial rate established in the area, whichever is less.

B. If the processing was in a form and manner other than that used in the normal conduct of the permittee's business at BOEM's request, BOEM will reimburse the permittee or third party for the reasonable costs of processing or reprocessing such data. Requests for reimbursement must identify processing costs separate from acquisition costs.

C. The permittee or third party will not be reimbursed for the costs of acquiring or interpreting geophysical information.

D. Data and information required under section IV.D.1. of this permit are not considered to be geophysical data or processed geophysical information and must be provided by the permittee at no cost to the Government.

Section VI. Disclosure of Data and Information to the Public

A. BOEM will make data and information submitted by a permittee available in accordance with the requirements and subject to the limitations of the Freedom of Information Act (5 U.S.C. 552) and the implementing regulations (43 CFR Part 2), the requirements of the Act, and the regulations contained in 30 CFR Parts 250 and 550 (Oil and Gas and Sulphur Operations in the Outer Continental Shelf), 30 CFR Parts 251 and 551, and 30 CFR Parts 252 and 552 (Outer Continental Shelf (OCS) Oil and Gas Information Program).

B. Except as specified in this section, or Section VIII, or in 30 CFR Parts 250, 252, 550, and 552, no data or information determined by BOEM or the Bureau of Safety and Environmental Enforcement to be exempt from public disclosure under subsection A of this section will be provided to any affected State or be made available to the executive of any affected local government or to the public, unless the permittee or third party and all persons to whom such permittee has sold, traded, or licensed the data or information under promise of confidentiality agree to such an action.

C. Geophysical data and processed or interpreted geophysical information submitted under a permit, and retained by BOEM, will be disclosed as follows:

1. Except for deep stratigraphic tests, BOEM will make available to the public geophysical data 50 years after the date of issuance of the permit under which the data were collected (see 30 CFR 551.12 (a) (b) (c) and (d)).

2. Except for deep stratigraphic tests, BOEM will make available to the public processed geophysical information and interpreted geophysical information 25 years after the date of issuance of the permit under which the original data were collected (see 30 CFR 551.12(a), (b), (c) and (d)).

3. BOEM will make available to the public all geophysical data and information and geophysical interpretations related to a deep stratigraphic test, at the earlier of the following times: (a) 25

years after the completion of the test, or (b) for a lease sale held after the test well is completed, 60 calendar days after the Department of the Interior executes the first lease for a block, any part of which is within 50 geographic miles (92.6 kilometers) of the site of the completed test.

D. All line-specific preplot or postplot plat(s), and navigation tapes, including but not limited to seismic survey traverses and shotpoint locations, submitted as a requirement of 30 CFR 251.7, 551.7 or 551.l2, will be considered as "PROPRIETARY INFORMATION." Such information will not be made available to the public without the consent of the permittee for a period of 25 years from the date of issuance of the permit, unless the Director, BOEM, determines that earlier release is necessary for the proper development of the area permitted.

E. All other information submitted as a requirement of 30 CFR 551.8 and determined by BOEM to be exempt from public disclosure will be considered as "PROPRIETARY." Such data and information will not be made available to the public without the consent of the permittee for a period of up to 25 years from the date of issuance of the permit as addressed in 30 CFR 551.14, unless the Director, BOEM, determines that earlier release is necessary for the proper development of the area permitted. The executed permit will be considered as "PROPRIETARY" except the public information copy which will be available to the public upon request.

F. The identities of third party recipients of data and information collected under a permit will be kept confidential. The identities will not be released unless the permittee and the third parties agree to the disclosure.

Section VII. Disclosure to Independent Contractors

BOEM reserves the right to disclose any data or information acquired from a permittee to an independent contractor or agent for the purpose of reproducing, processing, reprocessing, or interpreting such data or information. When practicable, BOEM will advise the permittee who provided the data or information of intent to disclose the data or information to an independent contractor or agent. BOEM's notice of intent will afford the permittee a period of not less than 5 working days within which to comment on the intended action. When BOEM so advises a permittee of the intent to disclose data or information to an independent contractor or agent, all other owners of such data or information will be deemed to have been notified of BOEM's intent. Prior to any such disclosure, the contractor or agent will be required to execute a written commitment not to sell, trade, license, or disclose any data or information to anyone without the express consent of BOEM.

Section VIII. Sharing of Information with Affected States

A. At the time of soliciting nominations for the leasing of lands within 3 geographic miles of the seaward boundary of any coastal State, BOEM, pursuant to the provisions of 30 CFR Parts 252.7 552.7 and subsections 8(g) and 26(e) (43 U.S.C. 1337(g) and 1352(e)) of the Act, will provide the Governor of the State (or the Governor's designated representative) the following information that has been acquired by BOEM on such lands proposed to be offered for leasing:

1. All information on the geographical, geological, and ecological characteristics of the areas and regions proposed to be offered for leasing;

2. An estimate of the oil and gas reserves in the area proposed for leasing; and

3. An identification of any field, geological structure, or trap located within 3 miles of the seaward boundary of the State.

B. After the time of receipt of nominations for any area of the OCS within 3 geographic miles of the seaward boundary of any coastal State and Area Identification in accordance with the provisions of Subparts D and E of 30 CFR Part 556, BOEM, in consultation with the Governor of the State (or the Governor's designated representative), will determine whether any tracts being given further consideration for leasing may contain one or more oil or gas reservoirs underlying both the OCS and lands subject to the jurisdiction of the State.

C. At any time prior to a sale, information acquired by BOEM that pertains to the identification of potential and/or proven common hydrocarbon-bearing areas within 3 geographic miles of the seaward boundary of any such State will be shared, upon request by the Governor and pursuant to the provisions of 30 CFR Parts 252.7 and 552.7 and subsections 8(g) and 26(e) of the Act, with the Governor of such State (or the Governor's designated representative).

D. Knowledge obtained by a State official who receives information under subsections A, B, and C of this section will be subject to the requirements and limitations of the Act and the regulations contained in 30 CFR Parts 250, 251, 252, 550, 551, and 552.

Section IX. Permit Modifications

The Department will have the right at any time to modify or amend any provisions of this permit, except that the Department will not have such right with respect to the provisions of Sections VI, VII, and VIII hereof, unless required by an Act of Congress.

IN WITNESS WHEREOF the parties have executed this permit and it will be effective as of the date of signature by the Supervisor.

PERMITTEE: **THE UNITED STATES OF AMERICA:**

Sverre Strandenes (signature)
(Signature of Permittee)

for Matthew G. Wilson (signature)
(Signature of Regional Supervisor)

(Type or Print Name of Permittee)
Sverre Strandenes
Executive vice president

Matthew G. Wilson
(Type or Print Name of Regional Supervisor)

(Title)

19 AUG. 2013

10-28-2013
(Date)

(Date)

STANDARD ENVIRONMENTAL PROTECTIVE MEASURES

1. Comply with the provisions of NTL No. 2012-JOINT-G02, Implementation of Seismic Survey Mitigation Measures and Protected Species Observer Program, effective January 1, 2012 (see the BOEM website at: http://www.boem.gov/Regulations/Notices-To-Lessees/2012/2012-JOINT-G02-pdf.aspx).

2. Comply with the provisions of NTL No. 2012-BSEE-G01, Marine Trash and Debris Awareness and Elimination, effective January 1, 2012 (see the BOEM website at: http://www.bsee.gov/Regulations-and-Guidance/Notices-to-Lessees/2012/2012-BSEE-G01-pdf.aspx).

3. Comply with the provisions of NTL No. 2012-JOINT-G01, Vessel Strike Avoidance and Injured/Dead Protected Species Reporting, effective January 1, 2012 (see the BOEM website at: http://www.boem.gov/Regulations/Notices-To-Lessees/2012/2012-JOINT-G01-pdf.aspx).

4. Man-made structure(s) such as pipeline(s) or other potential hazard(s) may be located in the permitted work area; therefore, prior to performing operations that involve bottom surface disturbance (e.g., coring), take precautions in accordance with Notice to Lessees and Operators No. 2008-G05, Section VI.B. (see the BOEM website at: http://www.boem.gov/Regulations/Notices-To-Lessees/2008/08-g05.aspx)

5. If you conduct activities that could disturb the seafloor in an Ordnance Dumping Area (see the BOEM website at: at http://www.boem.gov/Environmental-Stewardship/Environmental-Studies/Gulf-of-Mexico-Region/OrdnanceDumpingAreas.aspx for a map), exercise caution, since this area might contain old ordnance, including unexploded shells and depth charges, dumped before 1970. In addition, the U.S. Air Force has released an undeterminable amount of unexploded ordnance in Water Test Areas 1 through 5 (most of the Eastern Planning Area of the GOM).

6. If you discover any site, structure, or object of potential archaeological significance (i.e., cannot be definitively identified as modern debris or refuse) while conducting operations, the provisions of 30 CFR 250.194(c) and NTL 2005-G07 require you to immediately halt operations within 1,000 feet of the area of discovery and report this discovery to the Regional Supervisor of Leasing and Environment (RSLE) within 48 hours. Every reasonable effort must be taken to preserve the archaeological resource from damage until the RSLE has told you how to protect it.

10/29/2012

7. If you conduct activities within a military warning or water test area (see the BOEM website at: http://www.boem.gov/Environmental-Stewardship/Environmental-Studies/Gulf-of-Mexico-Region/MWA_boundaries-pdf.aspx for a map), or if the associated boat or aircraft traffic will traverse a military warning or water test area, contact the commander(s) of the appropriate command headquarters having jurisdiction over the respective area(s) before you commence such traffic. You can obtain the names and telephone numbers of the command headquarters for each military warning and water test area by consulting the BOEM website at: http://www.boem.gov/Environmental-Stewardship/Environmental-Studies/Gulf-of-Mexico-Region/Military-Contacts-pdf.aspx.

8. Comply with the provisions of NTL 2009-G39, Biologically Sensitive Areas of the Gulf of Mexico, effective January 27, 2010, (see the BOEM website at: http://www.boem.gov/Regulations/Notices-To-Lessees/2009/09-G39.aspx). If you conduct activities near an identified biologically sensitive topographic feature (see the BOEM website at: http://www.boem.gov/Environmental-Stewardship/Environmental-Studies/Gulf-of-Mexico-Region/topoblocks-pdf.aspx for a list and http://www.boem.gov/Environmental-Stewardship/Environmental-Studies/Gulf-of-Mexico-Region/topomap-pdf.aspx for a map), make sure that you do not anchor or otherwise disturb the seafloor within 152 meters (500 feet) of its designated "No Activity Zone." Within 90 calendar days after completing activities that disturbed the seafloor within 305 meters (1,000 feet) of the "No Activity Zone" of a biologically sensitive topographic feature, submit to the BOEM GOMR Data Acquisition and Special Project Unit (see page 5 of these "Protective Measures" for the address) a map at a scale of 1 inch = 1,000 feet with DGPS accuracy, showing the location of the seafloor disturbance relative to these features.

9. Comply with the provisions of NTL 2009-G39, Biologically Sensitive Areas of the Gulf of Mexico, effective January 27, 2010, (see the BOEM website at: http://www.boem.gov/Regulations/Notices-To-Lessees/2009/09-G39.aspx. If you conduct activities in the Live Bottom "Pinnacle Trend" area (see the BOEM website at: http://www.boem.gov/Environmental-Stewardship/Environmental-Studies/Gulf-of-Mexico-Region/topoblocks-pdf.aspx for a list and http://www.boem.gov/Environmental-Stewardship/Environmental-Studies/Gulf-of-Mexico-Region/topomap-pdf.aspx for a map), make sure that you do not anchor or otherwise disturb the seafloor within 30 meters (100 feet) of any identified pinnacles or other hard bottoms that have a vertical relief of eight feet or more. Within 90 calendar days after completing an ancillary activity that disturbed the seafloor within 61 meters (200 feet) of pinnacles in the "Pinnacle Trend" area, submit to the BOEM GOMR Data Acquisition and Special Project Unit (see page 5 of these "Protective Measures" for the address) a map at a scale of 1 inch = 1,000 feet with DGPS accuracy, showing the location of the seafloor disturbance relative to these features.

10/29/2012

10. Comply with the provisions of NTL 2009-G39, Biologically Sensitive Areas of the Gulf of Mexico, effective January 27, 2010, (see the BOEM website at: http://www.boem.gov/Regulations/Notices-To-Lessees/2009/09-G39.aspx. If you conduct activities in the Live Bottom "Low Relief" area (see the BOEMRE website at http://www.boem.gov/Environmental-Stewardship/Environmental-Studies/Gulf-of-Mexico-Region/topomap-pdf.aspx for a map), make sure that you do not anchor or otherwise disturb the seafloor near any identified live bottom low relief features. Within 90 calendar days after completing an ancillary activity that disturbed the seafloor within 30 meters (100 feet) of live bottom low relief features, submit to the BOEM GOMR Data Acquisition and Special Project Unit (see page 5 of these "Protective Measures" for the address) a map at a scale of 1 inch = 1,000 feet with DGPS accuracy, showing the location of the seafloor disturbance relative to these features.

11. If you conduct activities in water depths 400 meters (1,312 feet) or greater, make sure that you do not anchor, use anchor chains wire ropes or cables, or otherwise disturb the seafloor within 76 meters (250 feet) of any features or areas that could support high-density chemosynthetic communities. The known chemosynthetic community sites are listed in Appendix A of NTL No. 2009-G40, Deepwater Chemosynthetic Communities, effective January 27, 2010 (see the BOEM website at: http://www.boem.gov/Regulations/Notices-To-Lessees/2009/09-G40.aspx). Within 90 calendar days after completing an ancillary activity that disturbed the seafloor within 152 meters (500 feet) of features or areas that could support high-density chemosynthetic communities, submit to the BOEMRE GOMR Data Acquisition and Special Project Unit (see page 5 of these "Protective Measures" for the address) a map at a scale of 1 inch = 1,000 feet with DGPS accuracy, showing the location of the seafloor disturbance relative to these features.

12. Comply with the provisions of NTL 2009-G39, Biologically-Sensitive Underwater Features and Areas of the Gulf of Mexico, effective January 27, 2010, (see the BOEM website at: http://www.boem.gov/Regulations/Notices-To-Lessees/2009/09-G39.aspx). If you discover any high-relief topographic feature with a relief greater than eight (8) feet while conducting activities, report the discovery to the BOEM GOMR Regional Director. Make sure you do not anchor on or otherwise disturb such a feature. Within 90 calendar days after completing an ancillary activity that disturbed the seafloor within 30 meters (100 feet) of such a feature, submit to the BOEM GOMR Data Acquisition and Special Project Unit (see page 5 of these "Protective Measures" for the address) a map at a scale of 1 inch = 1,000 feet with DGPS accuracy, showing the location of the seafloor disturbance relative to the feature.

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13. Before you conduct activities that could disturb the seafloor within 254 meters (1,000 feet) of a Texas artificial reef site or artificial reef permit area, within152 meters (500 feet) of a Louisiana artificial reef site or artificial reef permit area, or could disturb the seafloor within a General Permit Area established by the States of Texas, Alabama or Florida for the placement of artificial reef material, contact the appropriate State reef management agency. See the BOEM websites at: http://www.boem.gov/Environmental-Stewardship/Environmental-Studies/Gulf-of-Mexico-Region/artreefmap.aspx for a map and http://www.boem.gov/Environmental-Stewardship/Environmental-Studies/Gulf-of-Mexico-Region/artreefcontacts-pdf.aspx for State contacts.

14. If you conduct activities within the boundaries of the Flower Gardens National Marine Sanctuary (Flower Gardens Banks and Stetson Bank), exercise caution to ensure that such activities do not endanger any other users of the Sanctuary. See the BOEM website at: http://www.boem.gov/Environmental-Stewardship/Environmental-Studies/Gulf-of-Mexico-Region/FGNMSmap-pdf.aspx for map. Additionally, if the activities involve moving the marker buoys at the Sanctuary, contact Mr. G. P. Schmahl, the current Sanctuary Manager, for instructions. See the BOEM website at: http://www.boem.gov/Environmental-Stewardship/Environmental-Studies/Gulf-of-Mexico-Region/FGNMScontacts-pdf.aspx for Mr. Schmahl's contact information. See the BOEM website at: http://www.boem.gov/Environmental-Stewardship/Environmental-Studies/Gulf-of-Mexico-Region/FGNMSbuoys-pdf.aspx for the locations of the Flower Gardens' marker buoys.

15. If your proposed activities will involve using boats from a port located south of the Suwannee River mouth in Florida, make sure that you adhere to the following manatee protection plan:

a. Advise your personnel of the possibility of the presence of manatees in the inland and coastal waters of Florida in the Eastern GOM.

b. Advise your personnel that there are civil and criminal penalties for harming, harassing, or killing manatees, which are protected under the Endangered Species Act, the Marine Mammal Protection Act, and the Florida Manatee Sanctuary Act of 1978.

c. Advise your vessel operators to (1) use the deeper ship channels to the maximum extent possible; (2) avoid collisions with manatees and to stay within the existing channels; and (3) obey all speed restrictions and travel at "no wake/idle" speeds at all times while operating in shallow water or in channels where the draft of the vessel provides less than four (4) feet of clearance. (Areas of manatee concentrations have been identified and speed limit signs have been erected in accordance with Federal, State, and local regulations.)

d. While vessels are berthed in port, advise your vessel operators to use fenders between the dock and the vessel and/or between adjacent vessels berthed side-by-side. Make sure that the fenders have a minimum clearance of three feet when compressed between the dock and the vessel.

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e. Ensure that your vessel operators keep logs detailing any sighting of, collision with, damage to, or death of manatees that occur while you conduct an ancillary activity. If a mishap involving a manatee should occur, make sure that the vessel operator immediately calls the "Manatee Hotline" ((888) 404-3922), and the U.S. Fish and Wildlife Service, Jacksonville Field Office ((904) 232-2580) for north Florida or the U.S. Fish and Wildlife Service, Vero Beach Ecosystem Office ((772) 562-3909) for south Florida.

f. Within 60 calendar days after completing the ancillary activity, submit a report summarizing all manatee incidents and sightings to the Florida Marine Research Institute, Florida Fish and Wildlife Conservation Commission, 100 Eighth Avenue SE, St. Petersburg, FL 33701-5095; and to the U.S. Fish and Wildlife Service, 6620 Southpoint Drive South, Suite 310, Jacksonville, FL 32216-0958, for north Florida, or to the U.S. Fish and Wildlife Service, 1339 20th Street, Vero Beach, Florida 32960-3559, for south Florida.

16. The Magnuson-Stevens Fisheries Conservation and Management Act (see 50 CFR 600.725) prohibits the use of explosives to take reef fish in the Exclusive Economic Zone. Therefore, if your activities involve the use of explosives, and the explosions result in stunned or killed fish, do not take such fish on board your vessels. If you do, you could be charged by the National Oceanic and Atmospheric Administration Fisheries Service (NOAA Fisheries Service) with a violation of the aforementioned Act. If you have any questions, contact NOAA Fisheries Service, Office for Law Enforcement, Southeast Division, at (727) 824-5344.

17. When operations extend south of approximately 26 degrees north latitude in the Western Gulf of Mexico or 24 degrees to 25 degrees north latitude in the Eastern Gulf (the 200-nautical mile provisional maritime also called the Exclusive Economic Zone Conservation Zone Limit), notify the Department of State: Ms. Liz Tirpak Room 5801, OES/OA, Department of State, Director, Office of Ocean Affairs, Washington, D.C., 20520, at (202) 647-1106.

18. BOEM GOMR Data Acquisition and Special Project Unit Address:

Regional Supervisor, Resource Evaluation
Resource Studies Section
Data Acquisition and Special Project Unit (MS 5123)
Bureau of Ocean Energy Management
Gulf of Mexico OCS Region
1201 Elmwood Park Boulevard
New Orleans, Louisiana 70123-2394

(Rev. 01/2012)

Standard Stipulations

In performance of any operations under the Permit and Agreement for Outer Continental Shelf Geophysical or Geological Exploration for Mineral Resources or Scientific Research, the Permittee shall comply with the following Stipulations:

1. As part of the requirements of 30 CFR 551.6(a), if any operation under this Permit and Agreement is to be conducted in a leased area, the Permittee shall take all necessary precautions to avoid interference with operations on the lease and damage of existing structures and facilities. The lessee (or operator) of the leased area will be notified, in writing, before the Permittee enters the leased area, or commences operations, and a copy of the notification will be sent to the Regional Supervisor executing this Permit and Agreement.

2. (a) Solid or liquid explosives shall not be used, except pursuant to written authorization from the Regional Supervisor. Requests of the use of such explosives must be in writing, giving the size of charges to be used, the depth at which they are to be detonated, and the specific precautionary methods proposed for the protection of fish, oysters, shrimp, and other natural resources. The use of explosives represents a may affect situation under Section 7 of the Endangered Species Act of 1973, as amended.

   (b) The following provisions are made applicable when geophysical exploration on the Outer Continental Shelf using explosives is approved:

      (i) Each explosive charge will be permanently identified by markings so that unexploded charges may be positively traced to the Permittee and to the specific field party of the Permittee responsible for the explosive charge.

(ii) The placing of explosive charges on the seafloor is prohibited. No explosive charges shall be detonated nearer to the seafloor than five (5) feet (1.52 meters).

(iii) No explosive shall be discharged within 1,000 feet (304.8 meters) of any boat not involved in the survey.

3. Any serious accident, personal injury, or loss of property shall be immediately reported to the Regional Supervisor.

4. All pipes, buoys, and other markers used in connection with seismic work shall be properly flagged and lighted according to the navigation rules of the U.S. Corps of Engineers and the U.S. Coast Guard.

5. In compliance with Section III- B(6) of this permit, digital navigation data shall be recorded on tape or other suitable storage media for seismic reflection surveys. The navigation data shall be in a format according to SEG P1 (Morgan, J.G., et al, 1983, SEG Standard Exchange Formats for Positional Data, Society of Exploration Geophysicists, Special Report). For 2-dimensional seismic events, a geographic location shall be reported for every shot point, irrespective of SEG P1 specifications. For 3-dimensional surveys, the first and last binned and centered locations for each line only shall be reported in SEG P1 format. Suitable media include, but are not limited to, CD-ROM coded in ASCII. All formatting are to be in accordance with Exchange Format for Postplot Location Data presented in Notice to Permittees dated August 14,1990.

6. In addition to the Stipulations above, the Environmental Protective Measures attached hereto shall apply.