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Robotic surgical devices, systems and related methods

Abstract

The various inventions relate to robotic surgical devices, consoles for operating such surgical devices, operating theaters in which the various devices can be used, insertion systems for inserting and using the surgical devices, and related methods.

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References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
2858947	12/1957	Chapman, Jr.	N/A	N/A
3817403	12/1973	Glachet et al.	N/A	N/A
3870264	12/1974	Robinson	N/A	N/A
3922930	12/1974	Fletcher et al.	N/A	N/A
3971266	12/1975	Inakura et al.	N/A	N/A
3989952	12/1975	Hohmann	N/A	N/A
4246661	12/1980	Pinson	N/A	N/A
4258716	12/1980	Sutherland	N/A	N/A
4278077	12/1980	Mizumoto	N/A	N/A
4353677	12/1981	Susnjara et al.	N/A	N/A
4538594	12/1984	Boebel et al.	N/A	N/A
4568311	12/1985	Miyake	N/A	N/A
4576545	12/1985	Maeda	N/A	N/A
4623183	12/1985	Aomori	N/A	N/A
4636138	12/1986	Gorman	N/A	N/A
4645409	12/1986	Gorman	N/A	N/A
4684313	12/1986	Minematsu et al.	N/A	N/A
4736645	12/1987	Zimmer	N/A	N/A

4762455	12/1987	Coughlan et al.	N/A	N/A
4771652	12/1987	Zimmer	N/A	N/A
4852391	12/1988	Ruch et al.	N/A	N/A
4854808	12/1988	Bisiach	N/A	N/A
4896015	12/1989	Taboada et al.	N/A	N/A
4897014	12/1989	Tietze	N/A	N/A
4922755	12/1989	Oshiro et al.	N/A	N/A
4922782	12/1989	Kawai	N/A	N/A
4984959	12/1990	Kato	N/A	N/A
4990050	12/1990	Tsuge et al.	N/A	N/A
5019968	12/1990	Wang et al.	N/A	N/A
5036724	12/1990	Rosheim	N/A	N/A
5108140	12/1991	Bartholet	N/A	N/A
5172639	12/1991	Wiesman et al.	N/A	N/A
5176649	12/1992	Wakabayashi	N/A	N/A
5178032	12/1992	Zona et al.	N/A	N/A
5187032	12/1992	Sasaki et al.	N/A	N/A
5187796	12/1992	Wang et al.	N/A	N/A
5195388	12/1992	Zona et al.	N/A	N/A
5201325	12/1992	Mcewen et al.	N/A	N/A
5217003	12/1992	Wilk	N/A	N/A
5263382	12/1992	Brooks et al.	N/A	N/A
5271384	12/1992	Mcewen et al.	N/A	N/A
5284096	12/1993	Pelrine et al.	N/A	N/A
5297443	12/1993	Wentz	N/A	N/A
5297536	12/1993	Wilk	N/A	N/A
5304899	12/1993	Sasaki et al.	N/A	N/A
5305653	12/1993	Ohtani et al.	N/A	N/A
5307447	12/1993	Asano et al.	N/A	N/A
5353807	12/1993	Demarco	N/A	N/A
5363935	12/1993	Schempf et al.	N/A	N/A
5372147	12/1993	Lathrop, Jr. et al.	N/A	N/A
5382885	12/1994	Salcudean et al.	N/A	N/A
5388528	12/1994	Pelrine et al.	N/A	N/A
5397323	12/1994	Taylor et al.	N/A	N/A
5436542	12/1994	Petelin et al.	N/A	N/A
5441494	12/1994	Ortiz	N/A	N/A
5456673	12/1994	Ziegler et al.	N/A	N/A
5458131	12/1994	Wilk	N/A	N/A
5458583	12/1994	Mcneely et al.	N/A	N/A
5458598	12/1994	Feinberg et al.	N/A	N/A
5471515	12/1994	Fossum et al.	N/A	N/A
5515478	12/1995	Wang	N/A	N/A
5524180	12/1995	Wang et al.	N/A	N/A
5553198	12/1995	Wang et al.	N/A	N/A
5562448	12/1995	Mushabac	N/A	N/A
5588442	12/1995	Scovil et al.	N/A	N/A
5620417	12/1996	Jang et al.	N/A	N/A
5623582	12/1996	Rosenberg	N/A	N/A
5624380	12/1996	Kaneko et al.	N/A	N/A

5624398	12/1996	Smith et al.	N/A	N/A
5632761	12/1996	Smith et al.	N/A	N/A
5645520	12/1996	Nakamura et al.	N/A	N/A
5657429	12/1996	Wang et al.	N/A	N/A
5657584	12/1996	Hamlin	N/A	N/A
5667354	12/1996	Nakazawa	N/A	N/A
5672168	12/1996	De La Torre et al.	N/A	N/A
5674030	12/1996	Sigel	N/A	N/A
5728599	12/1997	Rostoker et al.	N/A	N/A
5736821	12/1997	Suyama	N/A	N/A
5754741	12/1997	Wang et al.	N/A	N/A
5762458	12/1997	Wang et al.	N/A	N/A
5769640	12/1997	Jacobus et al.	N/A	N/A
5791231	12/1997	Cohn et al.	N/A	N/A
5792135	12/1997	Madhani et al.	N/A	N/A
5797538	12/1997	Heaton et al.	N/A	N/A
5797900	12/1997	Madhani et al.	N/A	N/A
5807377	12/1997	Madhani et al.	N/A	N/A
5808665	12/1997	Green	N/A	N/A
5815640	12/1997	Wang et al.	N/A	N/A
5825982	12/1997	Wright et al.	N/A	N/A
5833656	12/1997	Smith et al.	N/A	N/A
5841950	12/1997	Wang et al.	N/A	N/A
5842993	12/1997	Eichelberger et al.	N/A	N/A
5845646	12/1997	Lemelson	N/A	N/A
5855583	12/1998	Wang et al.	N/A	N/A
5876325	12/1998	Mizuno et al.	N/A	N/A
5878193	12/1998	Wang et al.	N/A	N/A
5878783	12/1998	Smart	N/A	N/A
5895377	12/1998	Smith et al.	N/A	N/A
5895417	12/1998	Pomeranz et al.	N/A	N/A
5906591	12/1998	Dario et al.	N/A	N/A
5907664	12/1998	Wang et al.	N/A	N/A
5910129	12/1998	Koblish et al.	N/A	N/A
5911036	12/1998	Wright et al.	N/A	N/A
5935126	12/1998	Riza	N/A	N/A
5954692	12/1998	Smith et al.	N/A	N/A
5971976	12/1998	Wang et al.	N/A	N/A
5993467	12/1998	Yoon	N/A	N/A
6001108	12/1998	Wang et al.	N/A	N/A
6007550	12/1998	Wang et al.	N/A	N/A
6030365	12/1999	Laufer	N/A	N/A
6031371	12/1999	Smart	N/A	N/A
6058323	12/1999	Lemelson	N/A	N/A
6063095	12/1999	Wang et al.	N/A	N/A
6066090	12/1999	Yoon	N/A	N/A
6086529	12/1999	Arndt	N/A	N/A
6102850	12/1999	Wang et al.	N/A	N/A
6106521	12/1999	Blewett et al.	N/A	N/A
6107795	12/1999	Smart	N/A	N/A

6132368	12/1999	Cooper	N/A	N/A
6132441	12/1999	Grace	N/A	N/A
6139563	12/1999	Cosgrove et al.	N/A	N/A
6156006	12/1999	Brosens et al.	N/A	N/A
6159146	12/1999	El Gazayerli	N/A	N/A
6162171	12/1999	Ng et al.	N/A	N/A
D438617	12/2000	Cooper et al.	N/A	N/A
6206903	12/2000	Ramans	N/A	N/A
D441076	12/2000	Cooper et al.	N/A	N/A
6223100	12/2000	Green	N/A	N/A
D441862	12/2000	Cooper et al.	N/A	N/A
6238415	12/2000	Sepetka et al.	N/A	N/A
6240312	12/2000	Alfano et al.	N/A	N/A
6241730	12/2000	Alby	N/A	N/A
6244809	12/2000	Wang et al.	N/A	N/A
6246200	12/2000	Blumenkranz et al.	N/A	N/A
D444555	12/2000	Cooper et al.	N/A	N/A
6286514	12/2000	Lemelson	N/A	N/A
6292678	12/2000	Hall et al.	N/A	N/A
6293282	12/2000	Lemelson	N/A	N/A
6296635	12/2000	Smith et al.	N/A	N/A
6309397	12/2000	Julian et al.	N/A	N/A
6309403	12/2000	Minor et al.	N/A	N/A
6312435	12/2000	Wallace et al.	N/A	N/A
6321106	12/2000	Lemelson	N/A	N/A
6327492	12/2000	Lemelson	N/A	N/A
6331181	12/2000	Tierney et al.	N/A	N/A
6346072	12/2001	Cooper	N/A	N/A
6352503	12/2001	Matsui et al.	N/A	N/A
6364888	12/2001	Niemeyer et al.	N/A	N/A
6371952	12/2001	Madhani et al.	N/A	N/A
6394998	12/2001	Wallace et al.	N/A	N/A
6398726	12/2001	Ramans et al.	N/A	N/A
6400980	12/2001	Lemelson	N/A	N/A
6408224	12/2001	Okamoto et al.	N/A	N/A
6424885	12/2001	Niemeyer et al.	N/A	N/A
6432112	12/2001	Brock et al.	N/A	N/A
6436107	12/2001	Wang et al.	N/A	N/A
6441577	12/2001	Blumenkranz et al.	N/A	N/A
6450104	12/2001	Grant et al.	N/A	N/A
6450992	12/2001	Cassidy	N/A	N/A
6451027	12/2001	Cooper et al.	N/A	N/A
6454758	12/2001	Thompson et al.	N/A	N/A
6459926	12/2001	Nowlin et al.	N/A	N/A
6463361	12/2001	Wang et al.	N/A	N/A
6468203	12/2001	Belson	N/A	N/A
6468265	12/2001	Evans et al.	N/A	N/A
6470236	12/2001	Ohtsuki	N/A	N/A
6491691	12/2001	Morley et al.	N/A	N/A
6491701	12/2001	Tierney et al.	N/A	N/A

6493608	12/2001	Niemeyer	N/A	N/A
6496099	12/2001	Wang et al.	N/A	N/A
6497651	12/2001	Kan et al.	N/A	N/A
6508413	12/2002	Bauer et al.	N/A	N/A
6512345	12/2002	Borenstein et al.	N/A	N/A
6522906	12/2002	Salisbury et al.	N/A	N/A
6544276	12/2002	Azizi	N/A	N/A
6548982	12/2002	Papanikolopoulos et al.	N/A	N/A
6554790	12/2002	Moll	N/A	N/A
6565554	12/2002	Niemeyer	N/A	N/A
6574355	12/2002	Green	N/A	N/A
6587750	12/2002	Gerbi et al.	N/A	N/A
6591239	12/2002	Mccall et al.	N/A	N/A
6594552	12/2002	Nowlin et al.	N/A	N/A
6610007	12/2002	Belson et al.	N/A	N/A
6620173	12/2002	Gerbi et al.	N/A	N/A
6642836	12/2002	Wang et al.	N/A	N/A
6645196	12/2002	Nixon et al.	N/A	N/A
6646541	12/2002	Wang et al.	N/A	N/A
6648814	12/2002	Kim et al.	N/A	N/A
6659939	12/2002	Moll et al.	N/A	N/A
6661571	12/2002	Shioda et al.	N/A	N/A
6671581	12/2002	Niemeyer et al.	N/A	N/A
6676684	12/2003	Morley et al.	N/A	N/A
6684129	12/2003	Salisbury et al.	N/A	N/A
6685648	12/2003	Flaherty et al.	N/A	N/A
6685698	12/2003	Morley et al.	N/A	N/A
6687571	12/2003	Byrne et al.	N/A	N/A
6692485	12/2003	Brock et al.	N/A	N/A
6699177	12/2003	Wang et al.	N/A	N/A
6699235	12/2003	Wallace et al.	N/A	N/A
6702734	12/2003	Kim et al.	N/A	N/A
6702805	12/2003	Stuart	N/A	N/A
6714839	12/2003	Salisbury et al.	N/A	N/A
6714841	12/2003	Wright et al.	N/A	N/A
6719684	12/2003	Kim et al.	N/A	N/A
6720988	12/2003	Gere et al.	N/A	N/A
6726699	12/2003	Wright et al.	N/A	N/A
6728599	12/2003	Wang et al.	N/A	N/A
6730021	12/2003	Vassiliades et al.	N/A	N/A
6731988	12/2003	Green	N/A	N/A
6746443	12/2003	Morley et al.	N/A	N/A
6764441	12/2003	Chiel et al.	N/A	N/A
6764445	12/2003	Ramans et al.	N/A	N/A
6766204	12/2003	Niemeyer et al.	N/A	N/A
6770081	12/2003	Cooper et al.	N/A	N/A
6774597	12/2003	Borenstein	N/A	N/A
6776165	12/2003	Jin	N/A	N/A
6780184	12/2003	Tanrisever	N/A	N/A

6783524	12/2003	Anderson et al.	N/A	N/A
6785593	12/2003	Wang et al.	N/A	N/A
6788018	12/2003	Blumenkranz	N/A	N/A
6792663	12/2003	Krzyzanowski	N/A	N/A
6793653	12/2003	Sanchez et al.	N/A	N/A
6799065	12/2003	Niemeyer	N/A	N/A
6799088	12/2003	Wang et al.	N/A	N/A
6801325	12/2003	Farr et al.	N/A	N/A
6804581	12/2003	Wang et al.	N/A	N/A
6810281	12/2003	Brock et al.	N/A	N/A
6817972	12/2003	Snow	N/A	N/A
6817974	12/2003	Cooper et al.	N/A	N/A
6817975	12/2003	Farr et al.	N/A	N/A
6820653	12/2003	Schempf et al.	N/A	N/A
6824508	12/2003	Kim et al.	N/A	N/A
6824510	12/2003	Kim et al.	N/A	N/A
6826977	12/2003	Grover et al.	N/A	N/A
6832988	12/2003	Sproul	N/A	N/A
6832996	12/2003	Woloszko et al.	N/A	N/A
6836703	12/2003	Wang et al.	N/A	N/A
6837846	12/2004	Jaffe et al.	N/A	N/A
6837883	12/2004	Moll et al.	N/A	N/A
6839612	12/2004	Sanchez et al.	N/A	N/A
6840938	12/2004	Morley et al.	N/A	N/A
6843793	12/2004	Brock et al.	N/A	N/A
6852107	12/2004	Wang et al.	N/A	N/A
6853879	12/2004	Sunaoshi	N/A	N/A
6858003	12/2004	Evans et al.	N/A	N/A
6860346	12/2004	Burt et al.	N/A	N/A
6860877	12/2004	Sanchez et al.	N/A	N/A
6866671	12/2004	Tierney et al.	N/A	N/A
6870343	12/2004	Borenstein et al.	N/A	N/A
6871117	12/2004	Wang et al.	N/A	N/A
6871563	12/2004	Choset et al.	N/A	N/A
6879880	12/2004	Nowlin et al.	N/A	N/A
6892112	12/2004	Wang et al.	N/A	N/A
6899705	12/2004	Niemeyer	N/A	N/A
6902560	12/2004	Morley et al.	N/A	N/A
6905460	12/2004	Wang et al.	N/A	N/A
6905491	12/2004	Wang et al.	N/A	N/A
6911916	12/2004	Wang et al.	N/A	N/A
6917176	12/2004	Schempf et al.	N/A	N/A
6933695	12/2004	Blumenkranz	N/A	N/A
6936001	12/2004	Snow	N/A	N/A
6936003	12/2004	Iddan	N/A	N/A
6936042	12/2004	Wallace et al.	N/A	N/A
6943663	12/2004	Wang et al.	N/A	N/A
6949096	12/2004	Davison et al.	N/A	N/A
6951535	12/2004	Ghodoussi et al.	N/A	N/A
6963792	12/2004	Green	N/A	N/A

6965812	12/2004	Wang et al.	N/A	N/A
6974411	12/2004	Belson	N/A	N/A
6974449	12/2004	Niemeyer	N/A	N/A
6979423	12/2004	Moll	N/A	N/A
6984203	12/2005	Tartaglia et al.	N/A	N/A
6984205	12/2005	Gazdzinski	N/A	N/A
6991627	12/2005	Madhani et al.	N/A	N/A
6993413	12/2005	Sunaoshi	N/A	N/A
6994703	12/2005	Wang et al.	N/A	N/A
6994708	12/2005	Manzo	N/A	N/A
6997908	12/2005	Carrillo, Jr. et al.	N/A	N/A
6999852	12/2005	Green	N/A	N/A
7025064	12/2005	Wang et al.	N/A	N/A
7027892	12/2005	Wang et al.	N/A	N/A
7033344	12/2005	Imran	N/A	N/A
7039453	12/2005	Mullick et al.	N/A	N/A
7042184	12/2005	Oleynikov et al.	N/A	N/A
7048745	12/2005	Tierney et al.	N/A	N/A
7053752	12/2005	Wang et al.	N/A	N/A
7063682	12/2005	Whayne et al.	N/A	N/A
7066879	12/2005	Fowler et al.	N/A	N/A
7066926	12/2005	Wallace et al.	N/A	N/A
7074179	12/2005	Wang et al.	N/A	N/A
7077446	12/2005	Kameda et al.	N/A	N/A
7083571	12/2005	Wang et al.	N/A	N/A
7083615	12/2005	Peterson et al.	N/A	N/A
7087049	12/2005	Nowlin et al.	N/A	N/A
7090683	12/2005	Brock et al.	N/A	N/A
7097640	12/2005	Wang et al.	N/A	N/A
7105000	12/2005	Mcbrayer	N/A	N/A
7107090	12/2005	Salisbury, Jr. et al.	N/A	N/A
7109678	12/2005	Kraus et al.	N/A	N/A
7118582	12/2005	Wang et al.	N/A	N/A
7121781	12/2005	Sanchez	N/A	N/A
7125403	12/2005	Julian et al.	N/A	N/A
7126303	12/2005	Farritor et al.	N/A	N/A
7147650	12/2005	Lee	N/A	N/A
7155315	12/2005	Niemeyer et al.	N/A	N/A
7155316	12/2005	Sutherland et al.	N/A	N/A
7163525	12/2006	Franer	N/A	N/A
7169141	12/2006	Brock et al.	N/A	N/A
7182025	12/2006	Ghorbel et al.	N/A	N/A
7182089	12/2006	Ries	N/A	N/A
7199545	12/2006	Oleynikov et al.	N/A	N/A
7206626	12/2006	Quaid	N/A	N/A
7206627	12/2006	Abovitz et al.	N/A	N/A
7210364	12/2006	Ghorbel et al.	N/A	N/A
7214230	12/2006	Brock et al.	N/A	N/A
7217240	12/2006	Snow	N/A	N/A
7239940	12/2006	Wang et al.	N/A	N/A

7250028	12/2006	Julian et al.	N/A	N/A
7259652	12/2006	Wang et al.	N/A	N/A
7273488	12/2006	Nakamura et al.	N/A	N/A
7311107	12/2006	Harel et al.	N/A	N/A
7339341	12/2007	Oleynikov et al.	N/A	N/A
7372229	12/2007	Farritor et al.	N/A	N/A
7403836	12/2007	Aoyama	N/A	N/A
7438702	12/2007	Hart et al.	N/A	N/A
7447537	12/2007	Funda et al.	N/A	N/A
7492116	12/2008	Oleynikov et al.	N/A	N/A
7566300	12/2008	Devierre et al.	N/A	N/A
7574250	12/2008	Niemeyer	N/A	N/A
7637905	12/2008	Saadat et al.	N/A	N/A
7645230	12/2009	Mikkaichi et al.	N/A	N/A
7655004	12/2009	Long	N/A	N/A
7670329	12/2009	Flaherty et al.	N/A	N/A
7678043	12/2009	Gilad	N/A	N/A
7731727	12/2009	Sauer	N/A	N/A
7734375	12/2009	Buehler et al.	N/A	N/A
7762825	12/2009	Burbank et al.	N/A	N/A
7772796	12/2009	Farritor et al.	N/A	N/A
7785251	12/2009	Wilk	N/A	N/A
7785294	12/2009	Hueil et al.	N/A	N/A
7785333	12/2009	Miyamoto et al.	N/A	N/A
7789825	12/2009	Nobis et al.	N/A	N/A
7789861	12/2009	Franer	N/A	N/A
7794494	12/2009	Sahatjian et al.	N/A	N/A
7865266	12/2010	Moll et al.	N/A	N/A
7960935	12/2010	Farritor et al.	N/A	N/A
7979157	12/2010	Anvari	N/A	N/A
8021358	12/2010	Doyle et al.	N/A	N/A
8179073	12/2011	Farritor et al.	N/A	N/A
8231610	12/2011	Jo et al.	N/A	N/A
8343171	12/2012	Farritor et al.	N/A	N/A
8353897	12/2012	Doyle et al.	N/A	N/A
8377045	12/2012	Schena	N/A	N/A
8430851	12/2012	Mcginley et al.	N/A	N/A
8604742	12/2012	Farritor et al.	N/A	N/A
8636686	12/2013	Minnelli et al.	N/A	N/A
8679096	12/2013	Farritor et al.	N/A	N/A
8827337	12/2013	Murata et al.	N/A	N/A
8828024	12/2013	Farritor et al.	N/A	N/A
8834488	12/2013	Farritor et al.	N/A	N/A
8864652	12/2013	Diolaiti et al.	N/A	N/A
8888687	12/2013	Ostrovsky et al.	N/A	N/A
8968332	12/2014	Farritor et al.	N/A	N/A
8974440	12/2014	Farritor et al.	N/A	N/A
8986196	12/2014	Larkin et al.	N/A	N/A
9010214	12/2014	Markvicka et al.	N/A	N/A
9060781	12/2014	Farritor et al.	N/A	N/A

9089256	12/2014	Tognaccini et al.	N/A	N/A
9089353	12/2014	Farritor et al.	N/A	N/A
9138129	12/2014	Diolaiti	N/A	N/A
9198728	12/2014	Wang et al.	N/A	N/A
9516996	12/2015	Diolaiti et al.	N/A	N/A
9579088	12/2016	Farritor et al.	N/A	N/A
9649020	12/2016	Finlay	N/A	N/A
9717563	12/2016	Tognaccini et al.	N/A	N/A
9743987	12/2016	Farritor et al.	N/A	N/A
9757187	12/2016	Farritor et al.	N/A	N/A
9770305	12/2016	Farritor et al.	N/A	N/A
9789608	12/2016	Itkowitz et al.	N/A	N/A
9814640	12/2016	Khaligh	N/A	N/A
9816641	12/2016	Bock-Aronson et al.	N/A	N/A
9849586	12/2016	Rosheim	N/A	N/A
9857786	12/2017	Cristiano	N/A	N/A
9888966	12/2017	Farritor et al.	N/A	N/A
9956043	12/2017	Farritor et al.	N/A	N/A
10008017	12/2017	Itkowitz et al.	N/A	N/A
10111711	12/2017	Farritor et al.	N/A	N/A
10137575	12/2017	Itkowitz et al.	N/A	N/A
10159533	12/2017	Moll et al.	N/A	N/A
10220522	12/2018	Rockrohr	N/A	N/A
10258425	12/2018	Mustufa et al.	N/A	N/A
10307199	12/2018	Farritor et al.	N/A	N/A
10342561	12/2018	Farritor et al.	N/A	N/A
10368952	12/2018	Tognaccini et al.	N/A	N/A
10398516	12/2018	Jackson et al.	N/A	N/A
10470828	12/2018	Markvicka et al.	N/A	N/A
10507066	12/2018	Dimaio et al.	N/A	N/A
10555775	12/2019	Hoffman et al.	N/A	N/A
10582973	12/2019	Wilson et al.	N/A	N/A
10695137	12/2019	Farritor et al.	N/A	N/A
10729503	12/2019	Cameron	N/A	N/A
10737394	12/2019	Itkowitz et al.	N/A	N/A
10751136	12/2019	Farritor	N/A	A61B 18/1206
10751883	12/2019	Nahum	N/A	N/A
10806538	12/2019	Farritor et al.	N/A	N/A
10966700	12/2020	Farritor et al.	N/A	N/A
11032125	12/2020	Farritor et al.	N/A	N/A
11298195	12/2021	Ye et al.	N/A	N/A
11382702	12/2021	Tognaccini et al.	N/A	N/A
11529201	12/2021	Mondry et al.	N/A	N/A
11595242	12/2022	Farritor et al.	N/A	N/A
11826014	12/2022	Farritor	N/A	A61B 18/1482
2001/0018591	12/2000	Brock et al.	N/A	N/A
2001/0049497	12/2000	Kalloo et al.	N/A	N/A
2002/0003173	12/2001	Bauer et al.	N/A	N/A

2002/0013601	12/2001	Nobles et al.	N/A	N/A
2002/0026186	12/2001	Woloszko et al.	N/A	N/A
2002/0038077	12/2001	De La Torre et al.	N/A	N/A
2002/0065507	12/2001	Zadno-Azizi	N/A	N/A
2002/0091374	12/2001	Cooper	N/A	N/A
2002/0103417	12/2001	Gazdzinski	N/A	N/A
2002/0111535	12/2001	Kim et al.	N/A	N/A
2002/0120254	12/2001	Julian et al.	N/A	N/A
2002/0128552	12/2001	Nowlin et al.	N/A	N/A
2002/0140392	12/2001	Borenstein et al.	N/A	N/A
2002/0147487	12/2001	Sundquist et al.	N/A	N/A
2002/0151906	12/2001	Demarais et al.	N/A	N/A
2002/0156347	12/2001	Kim et al.	N/A	N/A
2002/0171385	12/2001	Kim et al.	N/A	N/A
2002/0173700	12/2001	Kim et al.	N/A	N/A
2002/0190682	12/2001	Schempf et al.	N/A	N/A
2003/0020810	12/2002	Takizawa et al.	N/A	N/A
2003/0045888	12/2002	Brock et al.	N/A	N/A
2003/0065250	12/2002	Chiel et al.	N/A	N/A
2003/0089267	12/2002	Ghorbel et al.	N/A	N/A
2003/0092964	12/2002	Kim et al.	N/A	N/A
2003/0097129	12/2002	Davison et al.	N/A	N/A
2003/0100817	12/2002	Wang et al.	N/A	N/A
2003/0109780	12/2002	Coste-Maniere et al.	N/A	N/A
2003/0114731	12/2002	Cadeddu et al.	N/A	N/A
2003/0135203	12/2002	Wang et al.	N/A	N/A
2003/0139742	12/2002	Wampler et al.	N/A	N/A
2003/0144656	12/2002	Ocel et al.	N/A	N/A
2003/0159535	12/2002	Grover et al.	N/A	N/A
2003/0167000	12/2002	Mullick et al.	N/A	N/A
2003/0172871	12/2002	Scherer	N/A	N/A
2003/0179308	12/2002	Zamorano et al.	N/A	N/A
2003/0181788	12/2002	Yokoi et al.	N/A	N/A
2003/0225479	12/2002	Waled	N/A	N/A
2003/0229268	12/2002	Uchiyama et al.	N/A	N/A
2003/0229338	12/2002	Irion et al.	N/A	N/A
2003/0230372	12/2002	Schmidt	N/A	N/A
2004/0024311	12/2003	Quaid, III	N/A	N/A
2004/0034282	12/2003	Quaid, III	N/A	N/A
2004/0034283	12/2003	Quaid, III	N/A	N/A
2004/0034302	12/2003	Abovitz et al.	N/A	N/A
2004/0050394	12/2003	Jin	N/A	N/A
2004/0070822	12/2003	Takayama et al.	N/A	N/A
2004/0099175	12/2003	Perrot et al.	N/A	N/A
2004/0102772	12/2003	Baxter et al.	N/A	N/A
2004/0106916	12/2003	Quaid et al.	N/A	N/A
2004/0111113	12/2003	Nakamura et al.	N/A	N/A
2004/0117032	12/2003	Roth	N/A	N/A
2004/0138525	12/2003	Saadat et al.	N/A	N/A
2004/0138552	12/2003	Harel et al.	N/A	N/A

2004/0140786	12/2003	Borenstein	N/A	N/A
2004/0153057	12/2003	Davison	N/A	N/A
2004/0173116	12/2003	Ghorbel et al.	N/A	N/A
2004/0176664	12/2003	Iddan	N/A	N/A
2004/0215331	12/2003	Chew et al.	N/A	N/A
2004/0225229	12/2003	Viola	N/A	N/A
2004/0236316	12/2003	Danitz et al.	N/A	N/A
2004/0254680	12/2003	Sunaoshi	N/A	N/A
2004/0267326	12/2003	Ocel et al.	N/A	N/A
2005/0014994	12/2004	Fowler et al.	N/A	N/A
2005/0021069	12/2004	Feuer et al.	N/A	N/A
2005/0029978	12/2004	Oleynikov et al.	N/A	N/A
2005/0043583	12/2004	Killmann et al.	N/A	N/A
2005/0049462	12/2004	Kanazawa	N/A	N/A
2005/0054901	12/2004	Yoshino	N/A	N/A
2005/0054902	12/2004	Konno	N/A	N/A
2005/0064378	12/2004	Toly	N/A	N/A
2005/0065400	12/2004	Banik et al.	N/A	N/A
2005/0070850	12/2004	Albrecht	N/A	N/A
2005/0083460	12/2004	Hattori et al.	N/A	N/A
2005/0095650	12/2004	Julius et al.	N/A	N/A
2005/0096502	12/2004	Khalili	N/A	N/A
2005/0143644	12/2004	Gilad et al.	N/A	N/A
2005/0154376	12/2004	Riviere et al.	N/A	N/A
2005/0165449	12/2004	Cadeddu et al.	N/A	N/A
2005/0177026	12/2004	Hoeg et al.	N/A	N/A
2005/0234294	12/2004	Saadat et al.	N/A	N/A
2005/0234435	12/2004	Layer	N/A	N/A
2005/0272977	12/2004	Saadat et al.	N/A	N/A
2005/0283137	12/2004	Doyle et al.	N/A	N/A
2005/0288555	12/2004	Binmoeller	N/A	N/A
2005/0288665	12/2004	Woloszko	N/A	N/A
2006/0020272	12/2005	Gildenberg	N/A	N/A
2006/0046226	12/2005	Bergler et al.	N/A	N/A
2006/0079889	12/2005	Scott	N/A	N/A
2006/0100501	12/2005	Berkelman et al.	N/A	N/A
2006/0119304	12/2005	Farritor et al.	N/A	N/A
2006/0149135	12/2005	Paz	N/A	N/A
2006/0152591	12/2005	Lin	N/A	N/A
2006/0155263	12/2005	Lipow	N/A	N/A
2006/0189845	12/2005	Maahs et al.	N/A	N/A
2006/0195015	12/2005	Mullick et al.	N/A	N/A
2006/0196301	12/2005	Oleynikov et al.	N/A	N/A
2006/0198619	12/2005	Oleynikov et al.	N/A	N/A
2006/0241570	12/2005	Wilk	N/A	N/A
2006/0241732	12/2005	Denker et al.	N/A	N/A
2006/0253109	12/2005	Chu	N/A	N/A
2006/0258938	12/2005	Hoffman et al.	N/A	N/A
2006/0258954	12/2005	Timberlake et al.	N/A	N/A
2006/0261770	12/2005	Kishi et al.	N/A	N/A

2007/0032701	12/2006	Fowler et al.	N/A	N/A
2007/0043397	12/2006	Ocel et al.	N/A	N/A
2007/0055342	12/2006	Wu et al.	N/A	N/A
2007/0080658	12/2006	Farritor et al.	N/A	N/A
2007/0088277	12/2006	Mcginley et al.	N/A	N/A
2007/0088340	12/2006	Brock et al.	N/A	N/A
2007/0106113	12/2006	Ravo	N/A	N/A
2007/0106317	12/2006	Shelton et al.	N/A	N/A
2007/0123748	12/2006	Meglan	N/A	N/A
2007/0135803	12/2006	Belson	N/A	N/A
2007/0142725	12/2006	Hardin et al.	N/A	N/A
2007/0156019	12/2006	Larkin et al.	N/A	N/A
2007/0156211	12/2006	Wood et al.	N/A	N/A
2007/0167955	12/2006	Arnault De La Menardiere et al.	N/A	N/A
2007/0225633	12/2006	Wood et al.	N/A	N/A
2007/0225634	12/2006	Wood et al.	N/A	N/A
2007/0232858	12/2006	Macnamara et al.	N/A	N/A
2007/0241714	12/2006	Okeynikov et al.	N/A	N/A
2007/0244520	12/2006	Ferren et al.	N/A	N/A
2007/0250064	12/2006	Darois et al.	N/A	N/A
2007/0255273	12/2006	Fernandez et al.	N/A	N/A
2007/0287884	12/2006	Schena	N/A	N/A
2008/0004634	12/2007	Farritor et al.	N/A	N/A
2008/0015565	12/2007	Davison	N/A	N/A
2008/0015566	12/2007	Livneh	N/A	N/A
2008/0021440	12/2007	Solomon	N/A	N/A
2008/0033569	12/2007	Ferren et al.	N/A	N/A
2008/0045803	12/2007	Williams et al.	N/A	N/A
2008/0058835	12/2007	Farritor et al.	N/A	N/A
2008/0058989	12/2007	Oleynikov et al.	N/A	N/A
2008/0071289	12/2007	Cooper et al.	N/A	N/A
2008/0071290	12/2007	Larkin et al.	N/A	N/A
2008/0103440	12/2007	Ferren et al.	N/A	N/A
2008/0109014	12/2007	De La Pena	N/A	N/A
2008/0111513	12/2007	Farritor et al.	N/A	N/A
2008/0119870	12/2007	Williams	N/A	N/A
2008/0132890	12/2007	Woloszko et al.	N/A	N/A
2008/0161804	12/2007	Rioux et al.	N/A	N/A
2008/0164079	12/2007	Jacobsen	N/A	N/A
2008/0168639	12/2007	Otake et al.	N/A	N/A
2008/0183033	12/2007	Bern et al.	N/A	N/A
2008/0221591	12/2007	Farritor et al.	N/A	N/A
2008/0269557	12/2007	Marescaux et al.	N/A	N/A
2008/0269562	12/2007	Marescaux et al.	N/A	N/A
2009/0002414	12/2008	Shibata et al.	N/A	N/A
2009/0012532	12/2008	Blackwell et al.	N/A	N/A
2009/0020724	12/2008	Paffrath	N/A	N/A
2009/0024142	12/2008	Ruiz Morales	N/A	N/A
2009/0048612	12/2008	Farritor et al.	N/A	N/A

2009/0054909	12/2008	Farritor et al.	N/A	N/A
2009/0069821	12/2008	Farritor et al.	N/A	N/A
2009/0076536	12/2008	Rentschler et al.	N/A	N/A
2009/0137952	12/2008	Ramamurthy et al.	N/A	N/A
2009/0143787	12/2008	De La Pena	N/A	N/A
2009/0163929	12/2008	Yeung et al.	N/A	N/A
2009/0171373	12/2008	Farritor et al.	N/A	N/A
2009/0192524	12/2008	Itkowitz et al.	N/A	N/A
2009/0234369	12/2008	Bax et al.	N/A	N/A
2009/0236400	12/2008	Cole et al.	N/A	N/A
2009/0240246	12/2008	Deville et al.	N/A	N/A
2009/0247821	12/2008	Rogers	N/A	N/A
2009/0248038	12/2008	Blumenkranz et al.	N/A	N/A
2009/0281377	12/2008	Acosta et al.	N/A	N/A
2009/0299143	12/2008	Conlon et al.	N/A	N/A
2009/0305210	12/2008	Guru et al.	N/A	N/A
2009/0326322	12/2008	Diolaiti	N/A	N/A
2010/0010294	12/2009	Conlon et al.	N/A	N/A
2010/0016659	12/2009	Weitzner	N/A	N/A
2010/0016853	12/2009	Burbank	N/A	N/A
2010/0026347	12/2009	Iizuka	N/A	N/A
2010/0042097	12/2009	Newton et al.	N/A	N/A
2010/0056863	12/2009	Dejima et al.	N/A	N/A
2010/0069710	12/2009	Yamatani et al.	N/A	N/A
2010/0069940	12/2009	Miller et al.	N/A	N/A
2010/0081875	12/2009	Fowler et al.	N/A	N/A
2010/0101346	12/2009	Johnson et al.	N/A	N/A
2010/0130986	12/2009	Mailloux et al.	N/A	N/A
2010/0139436	12/2009	Kawashima et al.	N/A	N/A
2010/0185212	12/2009	Sholev	N/A	N/A
2010/0198231	12/2009	Scott	N/A	N/A
2010/0204713	12/2009	Ruiz Morales	N/A	N/A
2010/0245549	12/2009	Allen et al.	N/A	N/A
2010/0250000	12/2009	Blumenkranz et al.	N/A	N/A
2010/0262162	12/2009	Omori	N/A	N/A
2010/0263470	12/2009	Bannasch et al.	N/A	N/A
2010/0274079	12/2009	Kim et al.	N/A	N/A
2010/0292691	12/2009	Brogna	N/A	N/A
2010/0301095	12/2009	Shelton, IV et al.	N/A	N/A
2010/0318059	12/2009	Farritor et al.	N/A	N/A
2010/0331856	12/2009	Carlson et al.	N/A	N/A
2011/0015569	12/2010	Kirschenman et al.	N/A	N/A
2011/0020779	12/2010	Hannaford et al.	N/A	N/A
2011/0071347	12/2010	Rogers et al.	N/A	N/A
2011/0071544	12/2010	Steger et al.	N/A	N/A
2011/0075693	12/2010	Kuramochi et al.	N/A	N/A
2011/0077478	12/2010	Freeman et al.	N/A	N/A
2011/0082365	12/2010	Mcgrogan et al.	N/A	N/A
2011/0098529	12/2010	Ostrovsky et al.	N/A	N/A
2011/0107866	12/2010	Oka et al.	N/A	N/A

2011/0152615	12/2010	Schostek et al.	N/A	N/A
2011/0224605	12/2010	Farritor et al.	N/A	N/A
2011/0230894	12/2010	Simaan et al.	N/A	N/A
2011/0237890	12/2010	Farritor et al.	N/A	N/A
2011/0238079	12/2010	Hannaford et al.	N/A	N/A
2011/0238080	12/2010	Ranjit et al.	N/A	N/A
2011/0264078	12/2010	Lipow et al.	N/A	N/A
2011/0270443	12/2010	Kamiya et al.	N/A	N/A
2011/0276046	12/2010	Heimbecher et al.	N/A	N/A
2012/0016175	12/2011	Roberts et al.	N/A	N/A
2012/0029727	12/2011	Malik	N/A	N/A
2012/0035582	12/2011	Nelson et al.	N/A	N/A
2012/0059392	12/2011	Diolaiti	N/A	N/A
2012/0078053	12/2011	Phee et al.	N/A	N/A
2012/0109150	12/2011	Blackwell et al.	N/A	N/A
2012/0116362	12/2011	Kieturakis	N/A	N/A
2012/0179168	12/2011	Farritor et al.	N/A	N/A
2012/0221147	12/2011	Goldberg et al.	N/A	N/A
2012/0253515	12/2011	Coste-Maniere et al.	N/A	N/A
2013/0001970	12/2012	Suyama et al.	N/A	N/A
2013/0041360	12/2012	Farritor et al.	N/A	N/A
2013/0055560	12/2012	Nakasugi et al.	N/A	N/A
2013/0125696	12/2012	Long	N/A	N/A
2013/0131695	12/2012	Scarfogliero et al.	N/A	N/A
2013/0178867	12/2012	Farritor et al.	N/A	N/A
2013/0282023	12/2012	Burbank et al.	N/A	N/A
2013/0304084	12/2012	Beira et al.	N/A	N/A
2013/0325030	12/2012	Hourtash et al.	N/A	N/A
2013/0325181	12/2012	Moore	N/A	N/A
2013/0345717	12/2012	Markvicka et al.	N/A	N/A
2013/0345718	12/2012	Crawford et al.	N/A	N/A
2014/0039515	12/2013	Mondry et al.	N/A	N/A
2014/0046340	12/2013	Wilson et al.	N/A	N/A
2014/0055489	12/2013	Itkowitz et al.	N/A	N/A
2014/0058205	12/2013	Frederick et al.	N/A	N/A
2014/0100587	12/2013	Farritor et al.	N/A	N/A
2014/0137687	12/2013	Nogami et al.	N/A	N/A
2014/0195052	12/2013	Tsusaka et al.	N/A	N/A
2014/0221749	12/2013	Grant et al.	N/A	N/A
2014/0232824	12/2013	Dimaio et al.	N/A	N/A
2014/0276944	12/2013	Farritor et al.	N/A	N/A
2014/0303434	12/2013	Farritor et al.	N/A	N/A
2014/0371762	12/2013	Farritor et al.	N/A	N/A
2015/0051446	12/2014	Farritor et al.	N/A	N/A
2015/0057537	12/2014	Dillon et al.	N/A	N/A
2015/0157191	12/2014	Phee et al.	N/A	N/A
2015/0201918	12/2014	Kumar et al.	N/A	N/A
2015/0223896	12/2014	Farritor et al.	N/A	N/A
2015/0297299	12/2014	Yeung et al.	N/A	N/A
2016/0066999	12/2015	Forgione et al.	N/A	N/A

2016/0135898	12/2015	Frederick et al.	N/A	N/A
2016/0291571	12/2015	Cristiano	N/A	N/A
2016/0303745	12/2015	Rockrohr	N/A	N/A
2017/0007336	12/2016	Tsuboi et al.	N/A	N/A
2017/0014197	12/2016	Mccrea et al.	N/A	N/A
2017/0035526	12/2016	Farritor et al.	N/A	N/A
2017/0078583	12/2016	Haggerty et al.	N/A	N/A
2017/0252096	12/2016	Felder et al.	N/A	N/A
2017/0354470	12/2016	Farritor et al.	N/A	N/A
2018/0132956	12/2017	Cameron	N/A	N/A
2018/0153578	12/2017	Cooper et al.	N/A	N/A
2018/0153634	12/2017	Zemlok et al.	N/A	N/A
2018/0338777	12/2017	Bonadio et al.	N/A	N/A
2019/0059983	12/2018	Germain et al.	N/A	N/A
2019/0090965	12/2018	Farritor et al.	N/A	N/A
2019/0209262	12/2018	Mustufa et al.	N/A	N/A
2019/0327394	12/2018	Ramirez Luna et al.	N/A	N/A
2020/0107898	12/2019	Kim et al.	N/A	N/A
2020/0138534	12/2019	Garcia Kilroy et al.	N/A	N/A
2020/0214775	12/2019	Farritor et al.	N/A	N/A
2020/0330175	12/2019	Cameron	N/A	N/A
2020/0368915	12/2019	Itkowitz et al.	N/A	N/A
2022/0000510	12/2021	Xu et al.	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	**Application Date**	**Country**	**CPC**
2918531	12/2014	CA	N/A
101120888	12/2007	CN	N/A
102499759	12/2011	CN	N/A
102821918	12/2011	CN	N/A
104523309	12/2014	CN	N/A
104582600	12/2014	CN	N/A
104622528	12/2014	CN	N/A
204337044	12/2014	CN	N/A
104786233	12/2014	CN	N/A
105025826	12/2014	CN	N/A
102010040405	12/2011	DE	N/A
105656	12/1983	EP	N/A
279591	12/1987	EP	N/A
1354670	12/2002	EP	N/A
2286756	12/2010	EP	N/A
2329787	12/2010	EP	N/A
2563261	12/2012	EP	N/A
2684528	12/2013	EP	N/A
2123225	12/2013	EP	N/A
2815705	12/2013	EP	N/A
2881046	12/2014	EP	N/A
2937047	12/2014	EP	N/A
S59059371	12/1983	JP	N/A

60001456	12/1984	JP	N/A
S61165061	12/1985	JP	N/A
S62068293	12/1986	JP	N/A
01109094	12/1988	JP	N/A
H04144533	12/1991	JP	N/A
H05115425	12/1992	JP	N/A
H06507809	12/1993	JP	N/A
H06508049	12/1993	JP	N/A
H07016235	12/1994	JP	N/A
H07136173	12/1994	JP	N/A
H07306155	12/1994	JP	N/A
H08224248	12/1995	JP	N/A
2001505810	12/2000	JP	N/A
2002000524	12/2001	JP	N/A
2003220065	12/2002	JP	N/A
2004180781	12/2003	JP	N/A
2004283940	12/2003	JP	N/A
2004322310	12/2003	JP	N/A
2004329292	12/2003	JP	N/A
2009106606	12/2008	JP	N/A
2009297809	12/2008	JP	N/A
2010533045	12/2009	JP	N/A
2010536436	12/2009	JP	N/A
2011504794	12/2010	JP	N/A
2011045500	12/2010	JP	N/A
2011115591	12/2010	JP	N/A
2012504017	12/2011	JP	N/A
2012176489	12/2011	JP	N/A
5418704	12/2013	JP	N/A
2015526171	12/2014	JP	N/A
2016213937	12/2015	JP	N/A
2017113837	12/2016	JP	N/A
9221291	12/1991	WO	N/A
0189405	12/2000	WO	N/A
02082979	12/2001	WO	N/A
02100256	12/2001	WO	N/A
2005009211	12/2004	WO	N/A
2005044095	12/2004	WO	N/A
2006005075	12/2005	WO	N/A
2006052927	12/2005	WO	N/A
2006079108	12/2005	WO	N/A
2007011654	12/2006	WO	N/A
2007111571	12/2006	WO	N/A
2007149559	12/2006	WO	N/A
2009014917	12/2008	WO	N/A
2009023851	12/2008	WO	N/A
2009144729	12/2008	WO	N/A
2009158164	12/2008	WO	N/A
2010039394	12/2009	WO	N/A
2010042611	12/2009	WO	N/A

2010046823	12/2009	WO	N/A
2010050771	12/2009	WO	N/A
2010083480	12/2009	WO	N/A
2011075693	12/2010	WO	N/A
2011118646	12/2010	WO	N/A
2011135503	12/2010	WO	N/A
2011163520	12/2010	WO	N/A
2013009887	12/2012	WO	N/A
2013052137	12/2012	WO	N/A
2013106569	12/2012	WO	N/A
2014011238	12/2013	WO	N/A
2014025399	12/2013	WO	N/A
2014144220	12/2013	WO	N/A
2014146090	12/2013	WO	N/A
2015009949	12/2014	WO	N/A
2015031777	12/2014	WO	N/A
2015088655	12/2014	WO	N/A
2016077478	12/2015	WO	N/A
2017024081	12/2016	WO	N/A
2017064303	12/2016	WO	N/A
2017201310	12/2016	WO	N/A
2018045036	12/2017	WO	N/A

OTHER PUBLICATIONS

Hissink, “Olympus Medical develops capsule camera technology,” Dec. 2004, accessed Aug. 29, 2007, http://www.letsgodigital.org, 3 pp. cited by applicant
Horgan et al., “Technical Report: Robots in Laparoscopic Surgery,” Journal of Laparoendoscopic & Advanced Surgical Techniques, 2001; 11(6): 415-419. cited by applicant
Ishiyama et al., “Spiral-type Micro-machine for Medical Applications,” 2000 International Symposium on Micromechatronics and Human Science, 2000; 65-69. cited by applicant
Jagannath et al., “Peroral transgastric endoscopic ligation of fallopian tubes with long-term survival in a porcine model,” Gastrointestinal Endoscopy, 2005; 61 (3): 449-453. cited by applicant
Kalloo et al., “Flexible transgastric peritoneoscopy: a novel approach to diagnostic and therapeutic interventions in the peritoneal cavity,” Gastrointestinal Endoscopy, 2004; 60(1): 114-117. cited by applicant
Kang et al., “Robotic Assistants Aid Surgeons During Minimally Invasive Procedures,” IEEE Engineering in Medicine and Biology, Jan.-Feb. 2001: 94-104. cited by applicant
Kantsevoy et al., “Transgastric endoscopic splenectomy,” Surgical Endoscopy, 2006; 20: 522-525. cited by applicant
Kantsevoy et al., “Endoscopic gastrojejunostomy with survival in a porcine model,” Gastrointestinal Endoscopy, 2005; 62(2): 287-292. cited by applicant
Kazemier et al. (1998), “Vascular Injuries During Laparoscopy,” J. Am. Coli. Surg. 186(5): 604-5. cited by applicant
Keller et al., Design of the pediatric arm rehabilitation robot ChARMin, 2014, IEEE, p. 530-535 (Year: 2014). cited by applicant
Kim, “Early Experience with Telemanipulative Robot-Assisted Laparoscopic Cholecystectomy Using da Vinci,” Surgical Laparoscopy, Endoscopy & Percutaneous Techniques, 2002; 12(1): 33-40. cited by applicant
Ko et al., “Per-Oral transgastric abdominal surgery,” Chinese Journal of Digestive Diseases, 2006; 7: 67-70. cited by applicant

Lafullarde et al., “Laparoscopic Nissen Fundoplication: Five-year Results and Beyond,” Arch/Surg, Feb. 2001; 136: 180-184. cited by applicant
Leggett et al. (2002), “Aortic injury during laparoscopic Fundoplication,” Surg. Endoscopy 16(2): 362. cited by applicant
Li et al. (2000), “Microvascular Anastomoses Performed in Rats Using a Microsurgical Telemanipulator,” Comp. Aid. Surg., 5: 326-332. cited by applicant
Liem et al., “Comparison of Conventional Anterior Surgery and Laparoscopic Surgery for Inguinal-hernia Repair,” New England Journal of Medicine, 1997; 336 (22):1541-1547. cited by applicant
Lou Cubrich, “A Four-DOF Laparo-Endoscopic Single Site Platform for Rapidly-Developing Next Generation Surgical Robotics”, Journal of Medical Robotics Research, vol. 1, No. 4, 2016, 165006-1-165006-15. cited by applicant
Macfarlane et al., “Force-Feedback Grasper Helps Restore the Sense of Touch in Minimally Invasive Surgery,” Journal of Gastrointestinal Surgery, 1999; 3: 278-285. cited by applicant
Mack et al., “Present Role of Thoracoscopy in the Diagnosis and Treatment of Diseases of the Chest,” Ann Thorac Surgery, 1992; 54: 403-409. cited by applicant
Mack, “Minimally Invasive and Robotic Surgery,” JAMA, Feb. 2001; 285(5): 568-572. cited by applicant
Mei et al., “Wireless Drive and Control of a Swimming Microrobot,” Proceedings of the 2002 IEEE International Conference on Robotics & Automation, May 2002: 1131-1136. cited by applicant
Menciassi et al., “Robotic Solutions and Mechanisms for a Semi-Autonomous Endoscope,” Proceedings of the 2002 IEEE/RSJ Intl. Conference on Intelligent Robots and Systems, Oct. 2002; 1379-1384. cited by applicant
Melvin et al., “Computer-Enhanced vs. Standard Laparoscopic Antireflux Surgery,” J Gastrointest Surg 2002; 6: 11-16. cited by applicant
Menciassi et al., “Locomotion of a Leffed Capsule in the Gastrointestinal Tract: Theoretical Study and Preliminary Technological Results,” IEEE Int. Conf. on Engineering in Medicine and Biology, San Francisco, CA, pp. 2767-2770, Sep. 2004. cited by applicant
Menciassi et al., “Shape memory alloy clamping devices of a capsule for monitoring tasks in the gastrointestinal tract,” J. Micromech. Microeng, 2005; 15: 2045-2055. cited by applicant
Meron, “The development of the swallowable video capsule (M2A),” Gastrointestinal Endoscopy 2000; 52 6: 817-819. cited by applicant
Micron, http://www.micron.com, 2006, ¼-inch VGA NTSC/PAL CMOS Digital Image Sensor, 98 pp. cited by applicant
Midday Jeff et al., “Material Handling System for Robotic natural Orifice Surgery,”, Proceedings of the 2011 Design of medical Devices Conference, Apr. 12-14, 2011, Minneapolis, MN 4 pages. cited by applicant
Miller, Ph.D., et al., “In-Vivo Stereoscopic Imaging System with 5 Degrees-of-Freedom for Minimal Access Surgery,” Dept. of Computer Science and Dept. of Surgery, Columbia University, New York, NY, 7 pp., 2004. cited by applicant
Munro (2002), “Laparoscopic access: complications, technologies, and techniques,” Curro Opin. Obstet. Gynecol., 14 (4): 365-74. cited by applicant
Nio et al., “Efficiency of manual vs robotical (Zeus) assisted laparoscopic surgery in the performance of standardized tasks,” Surg Endosc, 2002; 16: 412-415. cited by applicant
Oleynikov et al., “In Vivo Camera Robots Provide Improved Vision for Laparoscopic Surgery,” Computer Assisted Radiology and Surgery (CARS), Chicago, IL, Jun. 23-26, 2004b. cited by applicant
Oleynikov et al., “Miniature Robots Can Assist in Laparoscopic Cholecystectomy,” Journal of Surgical Endoscopy, 19-4: 473-476, 2005. cited by applicant
Oleynikov et al., “In Vivo Robotic Laparoscopy,” Surgical Innovation, Jun. 2005, 12(2): 177-181.

cited by applicant
O'Neill, “Surgeon takes new route to gallbladder,” The Oregonian, Jun. 2007; 2 pp. cited by applicant
Orlando et al. (2003), “Needle and Trocar Injuries in Diagnostic Laparoscopy under Local Anesthesia: What Is the True Incidence of These Complications?” Journal of Laparoendoscopic & Advanced Surgical Techniques, 13(3): 181-184. cited by applicant
Palm. William. “Rapid Prototyping Primer” May 1998 (revised Jul. 30, 2002) (http://www.me.psu.edu/lamancusa/rapidpro/primer/chapter2.htm), 12 pages. cited by applicant
Park et al., “Experimental studies of transgastric gallbladder surgery: cholecystectomy and cholecystogastric anastomosis (videos),” Gastrointestinal Endoscopy, 2005; 61 (4): 601-606. cited by applicant
Park et al., “Trocar-less Instrumentation for Laparoscopy: Magnetic Positioning of Intra-abdominal Camera and Retractor,” Ann Surg, Mar. 2007; 245(3): 379-384. cited by applicant
Patronik et al., “Crawling on the Heart: A Mobile Robotic Device for Minimally Invasive Cardiac Interventions,” MICCAI, 2004, pp. 9-16. cited by applicant
Patronik et al., “Development of a Tethered Epicardial Crawler for Minimally Invasive Cardiac Therapies,” IEEE, pp. 239-240, 2004. cited by applicant
Patronik et al., “Preliminary evaluation of a mobile robotic device for navigation and intervention on the beating heart,” Computer Aided Surgery, 10(4): 225-232, Jul. 2005. cited by applicant
Peirs et al., “A miniature manipulator for integration in a self-propelling endoscope,” Sensors and Actuators A, 2001, 92: 343-349. cited by applicant
Peters, “Minimally Invasive Colectomy: Are the Potential Benefits Realized?” Dis Colon Rectum 1993; 36: 751-756. cited by applicant
Phee et al., “Development of Microrobotic Devices for Locomotion in the Human Gastrointestinal Tract,” International Conference on Computational Intelligence, Robotics and Autonomous Systems (CI RAS 2001), Nov. 28-30, 2001, Singapore, 6 pages. cited by applicant
Phee et al., “Analysis and Development of Locomotion Devices for the Gastrointestinal Tract,” IEEE Transactions on Biomedical Engineering, vol. 49, No. 6, Jun. 2002: 613-616. cited by applicant
Platt et al., “In Vivo Robotic Cameras can Enhance Imaging Capability During Laparoscopic Surgery,” from the Proceedings of the Society of American Gastrointestinal Endoscopic Surgeons (SAGES) Scientific Conference, Ft. Lauderdale, FL, Apr. 13-16, 2005; 1 pg. cited by applicant
Qian Huan et al., “Multi-joint Single-wound Minimally Invasive Abdominal Surgery Robot Design,” Mechanical Design and Manufacturing, May 8, 2014, pp. 134-137. cited by applicant
Rentschler et al., “In vivo Mobile Surgical Robotic Task Assistance,” 1 pg. cited by applicant
Rentschler et al., “Theoretical and Experimental Analysis of In Vivo Wheeled Mobility,” ASME Design Engineering Technical Conferences: 28th Biennial Mechanisms and Robotics Conference, Salt Lake City, Utah, Sep. 28-Oct. 2, 2004; pp. 1-9. cited by applicant
Rentschler et al., “In Vivo Robots for Laparoscopic Surgery,” Studies in Health Technology and Infonnatics—Medicine Meets Virtual Reality, ISO Press, Newport Beach, CA, 2004a, 98: 316-322. cited by applicant
Rentschler et al., “Toward In Vivo Mobility,” Studies in Health Technology and Infonnatics—Medicine Meets Virtual Reality, ISO Press, Long Beach, CA, 2005a, III: 397-403. cited by applicant
Rentschler et al., “Mobile In Vivo Robots Can Assist in Abdominal Exploration,” from the Proceedings of the Society of American Gastrointestinal Endoscopic Surgeons (SAGES) Scientific Conference, Ft. Lauderdale, FL, Apr. 13-16, 2005b. cited by applicant
Rentschler et al., “Modeling, Analysis, and Experimental Study of In Vivo Wheeled Robotic Mobility,” IEEE Transactions on Robotics, 22 (2): 308-321, 2005c. cited by applicant
Rentschler et al., “Miniature in vivo robots for remote and harsh environments,” IEEE Transaction

on Information Technology in Biomedicine, Jan. 2006; 12(1): pp. 66-75. cited by applicant
Rentschler et al., “Mechanical Design of Robotic In Vivo Wheeled Mobility,” ASME Journal of Mechanical Design, 2006a; pp. 1-11, Accepted. cited by applicant
Rentschler et al., “Mobile In Vivo Camera Robots Provide Sole Visual Feedback for Abdominal Exploration and Cholecystectomy,” Journal of Surgical Endoscopy, 20-1: 135-138, 2006b. cited by applicant
Rentschler et al., “Natural Orifice Surgery with an Endoluminal Mobile Robot,” The Society of American Gastrointestinal Endoscopic Surgeons, Dallas, TX, Apr. 2006d. cited by applicant
Rentschler et al., “Mobile In Vivo Biopsy and Camera Robot,” Studies in Health and Infonnatics Medicine Meets Virtual Reality, vol. 119: 449-454, IOS Press, Long Beach, CA, 2006e. cited by applicant
Rentschler et al., “Mobile In Vivo Biopsy Robot,” IEEE International Conference on Robotics and Automation, Orlando, Florida, May 2006; 4155-4160. cited by applicant
Rentschler et al., “In vivo Robotics during the NEEMO 9 Mission,” Medicine Meets Virtual Reality, Feb. 2007; 1 pg. cited by applicant
Rentschler et al., “An In Vivo Mobile Robot for Surgical Vision and Task Assistance,” Journal of Medical Devices, Mar. 2007; vol. 1: 23-29. cited by applicant
Riviere et al., “Toward Active Tremor Canceling in Handheld Microsurgical Instruments,” IEEE Transactions on Robotics and Automation, Oct. 2003, 19(5): 793-800. cited by applicant
Rosen et al., “Force Controlled and Teleoperated Endoscopic, Grasper for Minimally Invasive Surgery—Experimental Performance Evaluation,” IEEE Transactions of Biomedical Engineering, Oct. 1999; 46(10): 1212-1221. cited by applicant
Rosen et al., “Task Decomposition of Laparoscopic Surgery for Objective Evaluation of Surgical Residents' Learning Curve Using Hidden Markov Model,” Computer Aided Surgery, vol. 7, pp. 49-61, 2002. cited by applicant
Rosen et al., “The Blue DRAGON—A System of Measuring the Kinematics and the Dynamics of Minimally Invasive Surgical Tools In-Vivo,” Proc. of the 2002 IEEE International Conference on Robotics and Automation, Washington, DC, pp. 1876-1881, May 2002. cited by applicant
Rosen et al., Objective Evaluation of Laparoscopic Skills Based on Haptic Information and Tool/Tissue Interactions, Computer Aided Surgery, vol. 7, Issue 1, pp. 49-61, Jul. 2002. cited by applicant
Rosen et al., “Spherical Mechanism Analysis of a Surgical Robot for Minimally Invasive Surgery —Analytical and Experimental Approaches,” Studies in Health Technology and Infonnatics—Medicine Meets Virtual Reality, pp. 442-448, Jan. 2005. cited by applicant
Ruurda et al., “Feasibility of Robot-Assisted Laparoscopic Surgery,” Surgical Laparoscopy, Endoscopy & Percutaneous Techniques, 2002; 12(1):41-45. cited by applicant
Ruurda et al., “Robot-Assisted surgical systems: a new era in laparoscopic surgery,” Ann R. Coll Surg Engl. 2002; 84: 223-226. cited by applicant
Sackier et al., “Robotically assisted laparoscopic surgery,” Surgical Endoscopy, 1994; 8:63-6. cited by applicant
Salky, “What is the Penetration of Endoscopic Techniques into Surgical Practice?” Digestive Surgery 2000; 17:422-426. cited by applicant
Satava, “Surgical Robotics: The Early Chronicles,” Surgical Laparoscopy, Endoscopy & Percutaneous Techniques, 2002; 12(1):6-16. cited by applicant
Schippers et al. (1996), “Requirements and Possibilities of Computer-Assisted Endoscopic Surgery,” In: Computer Integrated Surgery: Technology and Clinical Applications, pp. 561-565. cited by applicant
Schurr et al., “Robotics and Telemanipulation Technologies for Endoscopic Surgery,” Surgical Endoscopy, 2000; 14:375-381. cited by applicant
Schwartz, “In the Lab: Robots that Slink and Squirm,” The New York Times, Mar. 27, 2007, 4 pp.

cited by applicant
Sharp LL-151-3D, http://www.sharp3d.com, 2006, 2 pp. cited by applicant
Slatkin et al., “The Development of a Robotic Endoscope,” Proceedings of the 1995 IEEE International Conference on Robotics and Automation, pp. 162-171, 1995. cited by applicant
Smart Pill “Fastastic Voyage: Smart Pill to Expand Testing,” http://www.smartpilldiagnostics.com, Apr. 13, 2005, 1 pg. cited by applicant
Sodeyama et al., A shoulder structure of muscle-driven humanoid with shoulder blades, 2005, IEEE, p. 1-6 (Year: 2005). cited by applicant
Southern Surgeons Club (1991), “A prospective analysis of 1518 laparoscopic cholecystectomies,” N. Eng. 1 Med. 324 (16): 1073-1078. cited by applicant
Stefanini et al., “Modeling and Experiments on a Legged Microrobot Locomoting in a Tubular Compliant and Slippery Environment,” Int. Journal of Robotics Research, vol. 25, No. 5-6, pp. 551-560, Mav-Jun. 2006. cited by applicant
Stiff et al., “Long-term Pain: Less Common After Laparoscopic than Open Cholecystectomy,” British Journal of Surgery, 1994; 81: 1368-1370. cited by applicant
Stoianovici et al., “Robotic Tools for Minimally Invasive Urologic Surgery”, Jan. 1, 2002, pp. 1-17. cited by applicant
Strong et al., “Efficacy of Novel Robotic Camera vs. a Standard Laproscopic Camera,” Surgical Innovation vol. 12, No. 4, Dec. 2005, Westminster Publications, Inc., pp. 315-318. cited by applicant
Suzumori et al., “Development of Flexible Microactuator and its Applications to Robotics Mechanisms,” Proceedings of the IEEE International Conference on Robotics and Automation, 1991: 1622-1627. cited by applicant
Taylor et al., “A Telerobotic Assistant for Laparoscopic Surgery,” IEEE Eng Med Biol, 1995; 279-87. cited by applicant
Tendick et al. (1993), “Sensing and Manipulation Problems in Endoscopic Surgery: Experiment, Analysis, and Observation,” Presence 2(1): 66-81. cited by applicant
Tendick et al., “Applications of Micromechatronics in Minimally Invasive Surgery,” IEEE/ASME Transactions on Mechatronics, 1998; 3(1): 34-42. cited by applicant
Thomann et al., “The Design of a new type of Micro Robot for the Intestinal Inspection,” Proceedings of the 2002 IEEE Intl. Conference on Intelligent Robots and Systems, Oct. 2002: 1385-1390. cited by applicant
U.S. Appl. No. 60/180,960, filed Feb. 2000. cited by applicant
U.S. Appl. No. 60/956,032, filed Aug. 15, 2007. cited by applicant
U.S. Appl. No. 60/983,445, filed Oct. 29, 2007. cited by applicant
U.S. Appl. No. 60/990,062, filed Nov. 26, 2007. cited by applicant
U.S. Appl. No. 60/990,076, filed Nov. 26, 2007. cited by applicant
U.S. Appl. No. 60/990,086, filed Nov. 26, 2007. cited by applicant
U.S. Appl. No. 60/990,106, filed Nov. 26, 2007. cited by applicant
U.S. Appl. No. 60/990,470, filed Nov. 27, 2007. cited by applicant
U.S. Appl. No. 61/025,346, filed Feb. 1, 2008. cited by applicant
U.S. Appl. No. 61/030,588, filed Feb. 22, 2008. cited by applicant
Asada et al. “Introduction” Direct-Drive Robots: Theory and Practice, MIT Press, 1987, pp. 1-17. cited by applicant
U.S. Appl. No. 61/030,617, filed Feb. 22, 2008. cited by applicant
Worn et al., “Espirit Project No. 33915: Miniaturised Robot for Micro Manipulation (MINIMAN),” Nov. 1998, http://www.ipr.ira.ujka.de/-microbot/miniman. cited by applicant
Way et al., editors, “Fundamentals of Laparoscopic Surgery,” Churchill Livingstone Inc., 1995; 14 pp. cited by applicant
Wolfe et al. (1991), Endoscopic Cholecystectomy: An analysis of Complications, Arch. Surg. 1991;

126: 1192-1196. cited by applicant
Xu et al., “System Design of an Insertable Robotic Effector Platform for Single Access (SPA) Surgery”, The 2009 IEEE/RSJ International Conference on Intelligent Robots and Systems, Oct. 11-15, 2009, St. Louis MO USA pp. 5546-5552. cited by applicant
Yu, BSN, RN, “M2ATM Capsule Endoscopy a Breakthrough Diagnostic Tool for Small Intestine Imagining,” vol. 25, No. 1, 2001, Gastroenterology Nursing, pp. 24-27. cited by applicant
Yu et al., “Microrobotic Cell Injection,” Proceedings of the 2001 IEEE International Conference on Robotics and Automation, May 2001: 620-625. cited by applicant
Abbou et al., “Laparoscopic Radical Prostatectomy with a Remote Controlled Robot,” The Journal of Urology, Jun. 2001; 165: 1964-1966. cited by applicant
Abbott et al., “Design of an Endoluminal NOTES Robotic System,” Proceedings of the 2007 IEEE/RSJ Int'l Conf. on Intelligent Robot Systems, San Diego, CA, Oct. 29-Nov. 2, 2007: 410-416. cited by applicant
Albers et al., Design and development process of a humanoid robot upper body through experimentation, 2004, IEEE, p. 77-92 (Year: 2004). cited by applicant
Allendorf et al., “Postoperative Immune Function Varies Inversely with the Degree of Surgical Trauma in a Murine Model,” Surgical Endoscopy, 1997; 11: 427-430. cited by applicant
Ang, “Active Tremor Compensation in Handheld Instrument for Microsurgery,” Doctoral dissertation, tech report CMU-RI-TR-04-28, Robotics Institute, Carnegie Mellon University, May 2004, 150 pp. cited by applicant
Atmel 80C5X2 Core, http://www.atmel.com, 2006, 186 pp. cited by applicant
Bailey et al., “Complications of Laparoscopic Surgery,” Quality Medical Publishers, Inc., 1995; 25 pp. cited by applicant
Ballantyne, “Robotic Surgery, Telerobotic Surgery, Telepresence, and Telementoring,” Surgical Endoscopy, 2002; 16: 1389-1402. cited by applicant
Bauer et al., “Case Report: Remote Percutaneous Renal Access Using a New Automated Telesurgical Robotic System,” Telemedicine Journal and e-Health 2001; (4): 341-347. cited by applicant
Begos et al., “Laparoscopic Cholecystectomy: From Gimmick to Gold Standard,” J Clin Gastroenterol, 1994; 19(4): 325-330. cited by applicant
Berg et al., “Surgery with Cooperative Robots,” Medicine Meets Virtual Reality, Feb. 2007; 1 pg. cited by applicant
Breda et al., “Future developments and perspectives in laparoscopy,” Eur. Urology 2001: 40(1): 84-91. cited by applicant
Breedveld et al., “Design of Steerable Endoscopes to Improve the Visual Perception of Depth During Laparoscopic Surgery,” ASME, Jan. 2004; 126: 1-5. cited by applicant
Breedveld et al., “Locomotion through the Intestine by means of Rolling Stents,” Proceedings of the ASME Design Engineering Technical Conferences, 2004. cited by applicant
Calafiore et al., “Multiple Arterial Conduits Without Cardiopulmonary Bypass: Early Angiographic Results,” Ann Thorac Surg, 1999; 67: 450-456. cited by applicant
Camarillo et al., “Robotic Technology in Surgery: Past, Present, and Future,” The American Journal of Surgery, 2004; 188: 2S-15. cited by applicant
Cavusoglu et al., “Telesurgery and Surgical Simulation: Haptic Interfaces to Real and Virtual Surgical Environments,” In Mclaughlin, M. L., Hespanha, J. P., and Sukhatme, G., editors. Touch in virtual environments, IMSC Series in Multimedia 2001; 28 pp. cited by applicant
Cavusoglu et al., “Robotics for Telesurgery: Second Generation BerkeleyIUCSF Laparoscopic Telesurgical Workstation and Looking Towards the Future Applications,” Industrial Robot: An International Journal, 2003; 30(1): 22-29. cited by applicant
Chanthasopeephan et al. (2003), “Measuring Forces in Liver Cutting: New Equipment and Experimental Results,” Annals of Biomedical Engineering 31: 1372-1382. cited by applicant

Choi et al., “Flexure-based Manipulator for Active Handheld Microsurgical Instrument,” Proceedings of the 27th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBS), Sep. 2005. cited by applicant
Cleary et al., “State of the Art in Surgical Robotics: Clinical Applications and Technology Challenges”, “Computer Aided Surgery”, Jan. 1, 2002, pp. 312-328, vol. 6. cited by applicant
Crystal Eyes, http://www.reald.com, 2007 (Stereo 3D visualization for CAVEs, theaters and immersive environments), 1 pg. cited by applicant
Cuschieri, “Technology for Minimal Access Surgery,” BMJ, 1999; 319: 1-6. cited by applicant
Dakin et al., “Comparison of laparoscopic skills performance between standard instruments and two surgical robotic systems,” Surg Endosc., 2003; 17: 574-579. cited by applicant
Definition of Individually. Dictionary.com, retrieved on Aug. 9, 2016; Retrieved from the Internet: <http://www.dictionary.com/browse/individually>, 1 page. cited by applicant
Dumpert et al., “Improving In Vivo Robot Vision Quality,” in the Proceedings of Medicine Meets Virtual Reality, Long Beach, CA, Jan. 26-29, 2005. cited by applicant
Dumpert et al., “Stereoscopic In Vivo Surgical Robots,” IEEE Sensors Special Issue on In Vivo Sensors for Medicine, Jan. 2007, 10 pp. cited by applicant
Falcone et al., “Robotic Surgery,” Clin. Obstet. Gynecol. 2003; 46(1): 37-43. cited by applicant
Faraz et al., “Engineering Approaches to Mechanical and Robotic Design for Minimally Invasive Surgery (MIS),” Kluwer Academic Publishers (Boston), 2000, 13 pp. cited by applicant
Fearing et al., “Wing Transmission for a Micromechanical Flying Insect,” Proceedings of the 2000 IEEE International Conference on Robotics & Automation, Apr. 2000: 1509-1516. cited by applicant
Fireman et al., “Diagnosing small bowel Crohn's disease with wireless capsule endoscopy,” Gut 2003; 52:390-392. cited by applicant
Flynn et al., “Tomorrow's Surgery; Micro-motors and Microrobots for Minimally Invasive Procedures,” Minimally Invasive Surgery & Allied Technologies, 1998, 7(4): pp. 343-352. cited by applicant
Franklin et al., “Prospective Comparison of Open vs. Laparoscopic Colon Surgery for Carcinoma: Five-Year Results,” Dis Colon Rectum, 1996; 39: S35-S46. cited by applicant
Franzino, “The Laprotek Surgical System and the Next Generation of Robotics,” Surg. Clin. North Am, 2003; 83(6): 1317-1320. cited by applicant
Fraulob et al., “Miniature assistance module for robot-assisted heart surgery,” Biomed. Tech. 2002; 47 Suppl. 1, Pt. 1: 12-5. cited by applicant
Fukuda et al., “Mechanism and Swimming Experiment of Micro Mobile Robot in Water,” Proceedings of the 1994 IEEE International Conference on Robotics and Automation, 1994; 814-819. cited by applicant
Fukuda et al., “Micro Active Catheter System with Multi Degrees of Freedom,” Proceedings of the IEEE International Conference on Robotics and Automation, May 1994: 2290-2295. cited by applicant
Fuller et al., “Laparoscopic Trocar Injuries: A Report from a U.S. Food and Drug Administration (FDA) Center for Devices and Radiological Health (CDRH) Systematic Technology Assessment of Medical Products (STAMP) Committee,” U.S. Food and Drug Administration, available at http://www.fda.gov, Finalized: Nov. 7, 2003; Updated: Jun. 24, 2005, 11 pp. cited by applicant
Glukhovsky et al., “The development and application of wireless capsule endoscopy,” Int. J. Med. Robot. Comput. Assist. Surgery, 2004; 1(1): 114-123. cited by applicant
Gong et al., “Wireless endoscopy,” Gastrointestinal Endoscopy 2000; 51 (6): 725-729. cited by applicant
Gopura et al., Mechanical designs of active upper-limb exoskeleton robots: State-of-the-art and design difficulties, 2009, IEEE, p. 178-187 (Year: 2009). cited by applicant
Gopura et al., A brief review on upper extremity robotic exoskeleton systems, 2011, IEEE, p. 346-

351 (Year: 2011). cited by applicant
Grady, “Doctors Try New Surgery for Gallbladder Removal,” The New York Times, Apr. 20, 2007; 3pp. cited by applicant
Green, “Telepresence Surgery”, Jan. 1, 1995, Publisher: IEEE Engineering in Medicine and Biology. cited by applicant
Guber et al., “Miniaturized Instrument Systems for Minimally Invasive Diagnosis and Therapy,” Biomedizinische Technic, 2002; Band 47, Erganmngsband 1: 198-201. cited by applicant
Guo et al., “Micro Active Guide Wire Catheter System—Characteristic Evaluation, Electrical Model* and Operability Evaluation of Micro Active Catheter,” Proceedings of the 1996 IEEE International Conference on Robotics and Automation, Apr. 1996; 2226-2231. cited by applicant
Guo et al., “Fish-like Underwater Microrobot with 3 DOF,” Proceedings of the 2002 IEEE International Conference on Robotics & Automation, May 2002; 738-743. cited by applicant
Hanly et al., “Robotic Abdominal Surgery,” The American Journal of Surgery, 2004; 188 (Suppl. to Oct. 1994); 19S-26S. cited by applicant
Hanly et al., “Value of the SAGES Learning Center in introducing new technology,” Surgical Endoscopy, 2004; 19(4): 477-483. cited by applicant
Heikkinen et al., “Comparison of laparoscopic and open Nissen fundoplication two years after operation: A prospective randomized trial,” Surgical Endoscopy, 2000; 14:1019-1023. cited by applicant
Lehman et al., Dexterous miniature in vivo robot for NOTES, 2009, IEEE, p. 244-249. cited by applicant
Mihelj et al., ARMin II—7 DoF rehabilitation robot: mechanics and kinematics, 2007, IEEE, p. 4120-4125. cited by applicant
Zhang et al., Cooperative robotic assistant for laparoscopic surgery: CoBRASurge, 2009, IEEE, p. 5540-5545. cited by applicant

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION(S) (1) This application claims priority as a continuation application to U.S. patent application Ser. No. 16/926,025, filed Jul. 10, 2020, and entitled “Robotic Surgical Devices, Systems, and Related Methods,” which claims priority as a continuation application to U.S. patent application Ser. No. 15/599,231, filed May 18, 2017, and entitled “Robotic Surgical Devices, Systems, and Related Methods,” which issued as U.S. Pat. No. 10,751,136 on Aug. 25, 2020, which claims the benefit under 35 U.S.C. § 119(e) to U.S. Provisional Application No. 62/338,375, filed on May 18, 2016 and entitled “Robotic Surgical Devices, Systems and Related Methods,” all of which are hereby incorporated herein by reference in their entireties.

TECHNICAL FIELD
(1) The embodiments disclosed herein relate to various medical devices and related components, including robotic and/or in vivo medical devices and related components. Certain embodiments include various robotic medical devices, including robotic devices that are disposed within a body cavity and positioned using a support component disposed through an orifice or opening in the body cavity. Further embodiments relate to methods and devices for operating the above devices.
BACKGROUND

(2) Invasive surgical procedures are essential for addressing various medical conditions. When possible, minimally invasive procedures such as laparoscopy are preferred.
(3) However, known minimally invasive technologies such as laparoscopy are limited in scope and complexity due in part to 1) mobility restrictions resulting from using rigid tools inserted through access ports, and 2) limited visual feedback. Known robotic systems such as the da Vinci® Surgical System (available from Intuitive Surgical, Inc., located in Sunnyvale, CA) are also restricted by the access ports, as well as having the additional disadvantages of being very large, very expensive, unavailable in most hospitals, and having limited sensory and mobility capabilities.
(4) There is a need in the art for improved surgical methods, systems, and devices.
BRIEF SUMMARY OF THE INVENTION
(5) Discussed herein are various robotic surgical systems, including certain systems having camera lumens configured to receive various camera systems. Further embodiments relate to surgical insertion devices configured to be used to insert various surgical devices into a cavity of a patient while maintaining insufflations of the cavity.
(6) In one Example, a robotic surgical system, including: a robotic surgical device including: a device body including front and back sides and a distal end and a proximal end; first and second shoulder joints operably coupled to the distal end of the device body; a first robotic arm operably coupled to the first shoulder joint; and a second robotic arm operably coupled to the second shoulder joint; and a camera component, including a flexible section and a distal imager, where the first and second robotic arms are constructed and arranged so as to be positioned on the front or back sides of the body.
(7) Implementations may include one or more of the following features. The robotic surgical system where the surgical device includes at least one actuator. The robotic surgical system where the first and second robotic arms include at least one motor disposed within each of the first and second robotic arms. The robotic surgical system further including a support device configured to remote center the robotic surgical device. The robotic surgical system further including an surgical console. The robotic surgical system where the camera is disposed through a lumen defined in the robotic surgical device. The robotic surgical system where the camera is configured to be an adjustable height camera. The robotic surgical system where the camera is constructed and arranged to be capable of pitch and yaw. The robotic surgical system where the distal camera tip is configured to orient to a define workspace. The robotic surgical system where the camera includes lights. The robotic surgical system where the robotic surgical device further includes first and second end effectors. The robotic surgical system where the first robotic arm further includes an upper arm and a forearm. The robotic surgical system where the first robotic arm further includes: a first arm upper arm; a first arm elbow joint; and a first arm lower arm, where the first arm upper arm is configured to be capable of roll, pitch and yaw relative to the first shoulder joint and the first arm lower arm is configured to be capable of yaw relative to the first arm upper arm by way of the first arm elbow joint. The surgical robotic system where the first robotic arm further includes at least one first arm actuator disposed within the first robotic arm. The robotic surgical system where the second robotic arm further includes: a second arm upper arm; \a second arm elbow joint; and a second arm lower arm, where the second arm upper arm is configured to be capable of roll, pitch and yaw relative to the second shoulder joint and the second arm lower arm is configured to be capable of yaw relative to the second arm upper arm by way of the second arm elbow joint. The surgical robotic system where the second robotic arm further includes at least one second arm actuator disposed within the second robotic arm. The surgical robotic system where the first and second arms include at least one motor disposed in each arm. The surgical robotic system further including at least one PCB disposed within at least one of the first or second robotic arms and in operational communication with at least one of the first robotic arm and second robotic arm, where the PCB is configured to perform yaw and pitch functions.
(8) One Example includes A robotic surgical system, including: a robotic surgical device including:

a device body including: a distal end; a proximal end; a front side; and a back side; first and second shoulder joints operably coupled to the distal end of the device body; a first robotic arm operably coupled to the first shoulder joint; and a second robotic arm operably coupled to the second shoulder joint; and a camera component, including: a shaft; an imager; and a flexible section operably coupling the imager to the shaft, where the first and second robotic arms are constructed and arranged so as to be positioned on the front or back sides of the body. Implementations may include one or more of the following features. The robotic surgical system where the first robotic arm further includes an upper arm and a forearm. The robotic surgical system where the first robotic arm further includes: a first arm upper arm; a first arm elbow joint; and a first arm lower arm, where the first arm upper arm is configured to be capable of roll, pitch and yaw relative to the first shoulder joint and the first arm lower arm is configured to be capable of yaw relative to the first arm upper arm by way of the first arm elbow joint. The surgical robotic system where the first robotic arm further includes at least one first arm actuator disposed within the first robotic arm. The robotic surgical system where the second robotic arm further includes: a second arm upper arm; a second arm elbow joint; and a second arm lower arm, where the second arm upper arm is configured to be capable of roll, pitch and yaw relative to the second shoulder joint and the second arm lower arm is configured to be capable of yaw relative to the second arm upper arm by way of the second arm elbow joint. The surgical robotic system where the second robotic arm further includes at least one second arm actuator disposed within the second robotic arm. The surgical robotic system where the first and second arms include at least one motor disposed in each arm. The surgical robotic system further including at least one PCB disposed within at least one of the first or second robotic arms and in operational communication with at least one of the first robotic arm and second robotic arm, where the PCB is configured to perform yaw and pitch functions. Implementations of the described techniques may include hardware, a method or process, or computer software on a computer-accessible medium.

(9) Another Example includes A robotic surgical system, including: a robotic surgical device including: a device body including: a distal end; a proximal end, and a camera lumen defined within the device body, the camera lumen including: a proximal lumen opening in the proximal end of the device body; a socket portion defined distally of the proximal lumen opening, the socket portion including a first diameter and a first coupling component; an extended portion defined distally of the socket portion, the extended portion having a second, smaller diameter; and a distal lumen opening in the distal end of the device body, the distal lumen opening defined at a distal end of the extended portion; first and second shoulder joints operably coupled to the distal end of the device body; a first robotic arm operably coupled to the first shoulder joint; and a second robotic arm operably coupled to the second shoulder joint; and a camera component, including an elongate tube operably coupled to the handle, where the elongate tube is configured and sized to be positionable through the extended portion, the elongate tube including: a shaft; an imager; and a flexible section operably coupling the optical section to the rigid section, where the elongate tube has a length such that at least the optical section is configured to extend distally from the distal lumen opening when the camera component is positioned through the camera lumen.

(10) Implementations may include one or more of the following features. The surgical robotic system where the first and second arms include at least one motor disposed in each arm. The surgical robotic system further including at least one PCB disposed within at least one of the first or second robotic arms and in operational communication with at least one of the first robotic arm and second robotic arm, where the PCB is configured to perform yaw and pitch functions.

(11) While multiple embodiments are disclosed, still other embodiments of the present invention will become apparent to those skilled in the art from the following detailed description, which shows and describes illustrative embodiments of the invention. As will be realized, the invention is capable of modifications in various obvious aspects, all without departing from the spirit and scope

of the present invention. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not restrictive.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1**A is a front view of a surgical device, according to one embodiment.
(2) FIG. **1**B is a front view of the device of FIG. **1**A inserted into the body cavity.
(3) FIG. **2** is a front view of a surgical device, according to one embodiment.
(4) FIG. **3** is a three-quarters perspective view of the robot of the implementation of FIG. **2** without the camera.
(5) FIG. **4** is a three-quarters perspective view of the camera of the implementation of FIG. **2** without the robot.
(6) FIG. **5**A is a close-up perspective view of a surgical device, according to one embodiment.
(7) FIG. **5**B is front view of the embodiment of FIG. **5**A, wherein the arms and camera are in the “insertion” position.
(8) FIG. **6**A is a perspective view of a surgical device showing various workspaces for the arms, according to one embodiment.
(9) FIG. **6**B is a further perspective view of the surgical device of FIG. **6**A, showing the workspace of one arm.
(10) FIG. **7**A is a side view of the robot according to one embodiment, showing the range of motion of the arms and the associated workspaces, according to one embodiment.
(11) FIG. **7**B is a top view of the implementation of FIG. **7**A, showing the range of motion of the arms and the associated workspaces.
(12) FIG. **7**C is a perspective view of the implementation of FIG. **7**A, showing the range of motion of the arms and the associated workspaces.
(13) FIG. **8**A is a rear perspective view of one implementation of a surgical device, showing the positioning of the arms to the ahead and behind the device, according to one embodiment.
(14) FIG. **8**B is a three-quarters rear view of the device of FIG. **8**A, showing several possible arm positions.
(15) FIG. **8**C is a lower perspective front view of the device showing the arm positions of FIG. **8**B.
(16) FIG. **9** is a perspective view of a surgical device according to one embodiment showing the camera and arms oriented in a central “down” work position.
(17) FIG. **10** is a front view of the device of FIG. **9** showing the arms in an central “up” position.
(18) FIG. **11** is a perspective view of a surgical device according to one embodiment showing the arms in a “down” position.
(19) FIG. **12**A is a top view of a surgical device, according to one implementation.
(20) FIG. **12**B is a top view of a surgical device, according to another implementation.
(21) FIG. **12**C is a front view of a surgical device, according to one implementation.
(22) FIG. **12**D is a front view of a surgical device, according to another implementation.
(23) FIG. **12**E is a side view of a surgical device, according to one implementation.
(24) FIG. **12**F is a side view of a surgical device, according to another implementation.
(25) FIG. **13**A is a perspective view of a surgical device according to one embodiment, showing the movement of the first joint.
(26) FIG. **13**B is a perspective view of a surgical device according to one embodiment, showing the movement of the second joint.
(27) FIG. **13**C is a perspective view of a surgical device according to one embodiment, showing the movement of the third joint.
(28) FIG. **13**D is a perspective view of a surgical device according to one embodiment, showing the

movement of the fourth joint.
(29) FIG. **14** is a perspective view of a surgical robotic device showing the internal components, according to one implementation.
(30) FIG. **15** is a front view showing the internal components of the body and shoulders, according to one embodiment.
(31) FIG. **16** is a perspective view showing the internal components of the body, according to one embodiment
(32) FIG. **17** is a perspective view showing the internal components of the shoulders, according to one embodiment.
(33) FIG. **18** is a side view showing the internal components of the shoulders, according to one embodiment.
(34) FIG. **19** is a reverse perspective view showing the internal components of the body and shoulders, according to one embodiment.
(35) FIG. **20** is a perspective view showing the internal components of the upper arm, according to one embodiment.
(36) FIG. **21** is a perspective view showing further internal components of the upper arm, according to one embodiment.
(37) FIG. **22** is a front view showing further internal components of the upper arm, according to one embodiment.
(38) FIG. **23** is a perspective view showing further internal components of the upper arm, according to one embodiment.
(39) FIG. **24** is a perspective view showing internal components of the lower arm, according to one embodiment.
(40) FIG. **25** is a perspective view showing further internal components of the upper arm, according to one embodiment.
(41) FIG. **26** is a perspective view showing further internal components of the upper arm, according to one embodiment.
(42) FIG. **27** is a perspective view showing yet further internal components of the upper arm, according to one embodiment.
(43) FIG. **28**A is a front perspective view of a surgical device having an articulating camera, according to one embodiment.
(44) FIG. **28**B is a close-up perspective view of the camera of FIG. **28**A showing a variety of possible movements.
(45) FIG. **28**C is a front view of a robotic device and camera having adjustable depth, according to one embodiment.
(46) FIG. **28**D is a close up view of the device lumen and camera shaft showing the adjustable depth mechanism, according to one implementation, showing the camera in an "up" position.
(47) FIG. **28**E is a front view of the robot and camera, according to the implementations of FIGS. **28**C and **28**D.
(48) FIG. **28**F is a front view of a robotic device and camera having adjustable depth, according to one embodiment.
(49) FIG. **28**G is a close up view of the device lumen and camera shaft showing the adjustable depth mechanism, according to one implementation, showing the camera in an "down" position.
(50) FIG. **28**H is a front view of the robot and camera, according to the implementations of FIGS. **28**F and **28**G.
(51) FIG. **28**I is a cross-sectional view of the body lumen, according to one embodiment.
(52) FIG. **29**A depicts a surgical device workspace and field of view, according to exemplary implementation.
(53) FIG. **29**B depicts a surgical device workspace and field of view, according to another exemplary implementation.

(54) FIG. **30**A depicts a surgical device and zero-degree camera in one of a range of possible positions, according to one implementation.
(55) FIG. **30**B depicts a surgical device and zero-degree camera in one of a range of possible positions, according to one implementation.
(56) FIG. **30**C depicts a surgical device and zero-degree camera in one of a range of possible positions, according to one implementation.
(57) FIG. **30**D depicts a surgical device and zero-degree camera in one of a range of possible positions, according to one implementation.
(58) FIG. **30**E depicts a surgical device and zero-degree camera in one of a range of possible positions, according to one implementation.
(59) FIG. **30**F depicts a surgical device and zero-degree camera in one of a range of possible positions, according to one implementation.
(60) FIG. **31**A depicts a surgical device and zero-degree camera in one of a range of possible positions, according to another implementation.
(61) FIG. **31**B depicts a surgical device and zero-degree camera in one of a range of possible positions, according to another implementation.
(62) FIG. **31**C depicts a surgical device and zero-degree camera in one of a range of possible positions, according to another implementation.
(63) FIG. **31**D depicts a surgical device and zero-degree camera in one of a range of possible positions, according to another implementation.
(64) FIG. **31**E depicts a surgical device and zero-degree camera in one of a range of possible positions, according to another implementation.
(65) FIG. **31**F depicts a surgical device and zero-degree camera in one of a range of possible positions, according to another implementation.
(66) FIG. **32**A depicts a surgical device and zero-degree camera in one of a range of possible positions, according to another implementation.
(67) FIG. **32**B depicts a surgical device and zero-degree camera in one of a range of possible positions, according to another implementation.
(68) FIG. **32**C depicts a surgical device and zero-degree camera in one of a range of possible positions, according to another implementation.
(69) FIG. **32**D depicts a surgical device and zero-degree camera in one of a range of possible positions, according to another implementation.
(70) FIG. **32**E depicts a surgical device and zero-degree camera in one of a range of possible positions, according to another implementation.
(71) FIG. **32**F depicts a surgical device and zero-degree camera in one of a range of possible positions, according to another implementation.
(72) FIG. **33**A depicts a surgical device and camera in a first viewing position with an “S-scope” configuration, according to one implementation.
(73) FIG. **33**B depicts a surgical device and camera in a second viewing position with an “S-scope” configuration, according to one implementation.
(74) FIG. **33**C depicts a surgical device and camera in a first viewing position with an “S-scope” configuration, according to one implementation.
(75) FIG. **34**A is one implementation of the articulating camera tip.
(76) FIG. **34**B is another implementation of the articulating camera tip.
(77) FIG. **34**C is yet another implementation of the articulating camera tip.
(78) FIG. **35**A is a side view of the surgical device and camera showing the camera between at a first depth, according to one embodiment.
(79) FIG. **35**B is a side view of the surgical device and camera showing the camera between at a second depth, according to one embodiment.
(80) FIG. **35**C is a side view of the surgical device and camera showing the camera between at a

third depth, according to one embodiment.
(81) FIG. **36**A is a side view of a surgical device end effector, according to one embodiment.
(82) FIG. **36**B is a side view of a surgical device end effector, according to another embodiment.
(83) FIG. **36**C is a side view of a surgical device end effector, according to another embodiment.
(84) FIG. **37** is a front view of the surgical device on a support structure, according to one implementation.
(85) FIG. **38** is a perspective view of the surgical device on a support structure, according to one implementation.
(86) FIG. **39** is a cross-sectional view of the surgical device at the insertion point, according to one implementation.
(87) FIG. **40**A is a perspective view of the surgical device on a support structure, according to one implementation.
(88) FIG. **40**B is a side view of the surgical device on a support structure, according to one implementation.
(89) FIG. **41**A is a perspective view of the surgical device on a support structure, according to one implementation.
(90) FIG. **41**B is a further perspective view of the surgical device on a support structure, according to the implementation of FIG. **41**A.
(91) FIG. **42**A is a perspective view of the surgical device on another support structure, according to one implementation.
(92) FIG. **42**B is a further perspective view of the surgical device on a support structure, according to the implementation of FIG. **42**A.
(93) FIG. **42**C is yet a further perspective view of the surgical device on a support structure, according to the implementation of FIG. **42**A.
(94) FIG. **43** is a side view of the surgical device on yet another support structure, according to one implementation.
(95) FIG. **44** is yet a further perspective view of the surgical device on a support structure, according to another implementation.
(96) FIG. **45** is a perspective view of the surgical device on a support robot, according to another implementation.
(97) FIG. **46** is a perspective view of the surgical device on a support robot, according to another implementation.
(98) FIG. **47** is a perspective view of the surgical device on a ball joint support structure, according to another implementation.
(99) FIG. **48**A is a perspective view of a support structure for positioning the surgical device, according to one implementation.
(100) FIG. **48**B-**1** is a side view of the support device according to the embodiment of FIG. **48** in a first position.
(101) FIG. **48**B-**2** is a top view of the implementation of the support device of FIG. **48**B-**1**.
(102) FIG. **48**C-**1** is a side view of the support device according to the embodiment of FIG. **48** in a second position.
(103) FIG. **48**C-**2** is a top view of the implementation of the support device of FIG. **480-1**.
(104) FIG. **48**D-**1** is a side view of the support device according to the embodiment of FIG. **48** in a third position.
(105) FIG. **48**D-**2** is a top view of the implementation of the support device of FIG. **48**D-**1**
(106) FIG. **49** is a perspective view of a support structure positioning the surgical device, according to one implementation.
(107) FIG. **50**A is a perspective view of another support structure positioning the surgical device, according to one implementation.
(108) FIG. **50**B is a side view of another support structure positioning the surgical device,

according to one implementation.
(109) FIG. **50**C is a side view of another support structure positioning the surgical device, according to one implementation.
(110) FIG. **50**D is a side view of another support structure positioning the surgical device, according to one implementation.
(111) FIG. **51** is a perspective view of another support structure positioning the surgical device, according to one implementation.
(112) FIG. **52**A is a side view of another support structure positioning the surgical device, according to one implementation.
(113) FIG. **52**B is a perspective view of another support structure positioning the surgical device, according to one implementation.
(114) FIG. **52**C is a perspective view of another support structure positioning the surgical device, according to one implementation.
(115) FIG. **52**D is a perspective view of another support structure positioning the surgical device, according to one implementation.
(116) FIG. **52**E is a perspective view of another support structure positioning the surgical device, according to one implementation.
(117) FIG. **52**F is a perspective view of another support structure positioning the surgical device, according to one implementation.
(118) FIG. **53** is a perspective view of the surgical console, according to one implementation.
(119) FIG. **54** is a schematic view of a surgical system, according to one implementation.
(120) FIG. **55** is another schematic view of a surgical system, according to one implementation.

DETAILED DESCRIPTION

(121) The various systems and devices disclosed herein relate to devices for use in medical procedures and systems. More specifically, various embodiments relate to various medical devices, including robotic devices and related methods and systems.
(122) It is understood that the various embodiments of robotic devices and related methods and systems disclosed herein can be incorporated into or used with any other known medical devices, systems, and methods.
(123) It is understood that the various embodiments of robotic devices and related methods and systems disclosed herein can be incorporated into or used with any other known medical devices, systems, and methods. For example, the various embodiments disclosed herein may be incorporated into or used with any of the medical devices and systems disclosed in copending U.S. application Ser. No. 11/766,683 (filed on Jun. 21, 2007 and entitled “Magnetically Coupleable Robotic Devices and Related Methods”), Ser. No. 11/766,720 (filed on Jun. 21, 2007 and entitled “Magnetically Coupleable Surgical Robotic Devices and Related Methods”), Ser. No. 11/966,741 (filed on Dec. 28, 2007 and entitled “Methods, Systems, and Devices for Surgical Visualization and Device Manipulation”), 61/030,588 (filed on Feb. 22, 2008), Ser. No. 12/171,413 (filed on Jul. 11, 2008 and entitled “Methods and Systems of Actuation in Robotic Devices”), Ser. No. 12/192,663 (filed Aug. 15, 2008 and entitled Medical Inflation, Attachment, and Delivery Devices and Related Methods”), Ser. No. 12/192,779 (filed on Aug. 15, 2008 and entitled “Modular and Cooperative Medical Devices and Related Systems and Methods”), Ser. No. 12/324,364 (filed Nov. 26, 2008 and entitled “Multifunctional Operational Component for Robotic Devices”), 61/640,879 (filed on May 1, 2012), Ser. No. 13/493,725 (filed Jun. 11, 2012 and entitled “Methods, Systems, and Devices Relating to Surgical End Effectors”), Ser. No. 13/546,831 (filed Jul. 11, 2012 and entitled “Robotic Surgical Devices, Systems, and Related Methods”), 61/680,809 (filed Aug. 8, 2012), Ser. No. 13/573,849 (filed Oct. 9, 2012 and entitled “Robotic Surgical Devices, Systems, and Related Methods”), Ser. No. 13/738,706 (filed Jan. 10, 2013 and entitled “Methods, Systems, and Devices for Surgical Access and Insertion”), Ser. No. 13/833,605 (filed Mar. 15, 2013 and entitled “Robotic Surgical Devices, Systems, and Related Methods”), Ser. No. 13/839,422 (filed Mar. 15, 2013 and

entitled “Single Site Robotic Devices and Related Systems and Methods”), Ser. No. 13/834,792 (filed Mar. 15, 2013 and entitled “Local Control Robotic Surgical Devices and Related Methods”), Ser. No. 14/208,515 (filed Mar. 13, 2014 and entitled “Methods, Systems, and Devices Relating to Robotic Surgical Devices, End Effectors, and Controllers”), Ser. No. 14/210,934 (filed Mar. 14, 2014 and entitled “Methods, Systems, and Devices Relating to Force Control Surgical Systems), Ser. No. 14/212,686 (filed Mar. 14, 2014 and entitled “Robotic Surgical Devices, Systems, and Related Methods”), and Ser. No. 14/334,383 (filed Jul. 17, 2014 and entitled “Robotic Surgical Devices, Systems, and Related Methods”), and U.S. Pat. No. 7,492,116 (filed on Oct. 31, 2007 and entitled “Robot for Surgical Applications”), U.S. Pat. No. 7,772,796 (filed on Apr. 3, 2007 and entitled “Robot for Surgical Applications”), and U.S. Pat. No. 8,179,073 (issued May 15, 2011, and entitled “Robotic Devices with Agent Delivery Components and Related Methods”), U.S. Published Application No. 2016/0074120 (filed Sep. 14, 2015, and entitled “Quick-Release End Effectors and Related Systems and Methods”), U.S. Published Application No. 2016/0135898 (filed Nov. 11, 2015 entitled “Robotic Device with Compact Joint Design and Related Systems and Methods”), U.S. patent application Ser. No. 15/227,813 (filed Aug. 3, 2016 and entitled “Robotic Surgical Devices, Systems, and Related Methods”), U.S. Provisional Application No. 62/379,344 (filed Aug. 25, 2016 and entitled “Quick-Release End Effector Tool Interface and Related Systems and Methods”), U.S. Provisional Application No. 62/425,149 (filed Nov. 22, 2016 and entitled “Improved Gross Positioning Device and Related Systems and Methods”), U.S. Provisional Application No. 62/427,357 (filed Nov. 29, 2016 and entitled “Controller with User Presence Detection and Related Systems and Methods”), U.S. Provisional Application No. 62/433,837 (filed Dec. 14, 2016 and entitled “Releasable Attachment Device for Coupling to Medical Devices and Related Systems and Methods”), and U.S. Provisional Application No. 62/381,299 (filed Aug. 30, 2016 and entitled “Robotic Device with Compact Joint Design and an Additional Degree of Freedom and Related Systems and Methods”) a all of which are hereby incorporated herein by reference in their entireties.

(124) Certain device and system implementations disclosed in the applications listed above can be positioned within a body cavity of a patient in combination with a support component similar to those disclosed herein. An “in vivo device” as used herein means any device that can be positioned, operated, or controlled at least in part by a user while being positioned within a body cavity of a patient, including any device that is coupled to a support component such as a rod or other such component that is disposed through an opening or orifice of the body cavity, also including any device positioned substantially against or adjacent to a wall of a body cavity of a patient, further including any such device that is internally actuated (having no external source of motive force), and additionally including any device that may be used laparoscopically or endoscopically during a surgical procedure. As used herein, the terms “robot,” and “robotic device” shall refer to any device that can perform a task either automatically or in response to a command.

(125) Certain embodiments provide for insertion of the present invention into the cavity while maintaining sufficient insufflation of the cavity. Further embodiments minimize the physical contact of the surgeon or surgical users with the present invention during the insertion process. Other implementations enhance the safety of the insertion process for the patient and the present invention. For example, some embodiments provide visualization of the present invention as it is being inserted into the patient's cavity to ensure that no damaging contact occurs between the system/device and the patient. In addition, certain embodiments allow for minimization of the incision size/length. Further implementations reduce the complexity of the access/insertion procedure and/or the steps required for the procedure. Other embodiments relate to devices that have minimal profiles, minimal size, or are generally minimal in function and appearance to enhance ease of handling and use.

(126) Certain implementations disclosed herein relate to “combination” or “modular” medical devices that can be assembled in a variety of configurations. For purposes of this application, both

“combination device” and “modular device” shall mean any medical device having modular or interchangeable components that can be arranged in a variety of different configurations. The modular components and combination devices disclosed herein also include segmented triangular or quadrangular-shaped combination devices. These devices, which are made up of modular components (also referred to herein as “segments”) that are connected to create the triangular or quadrangular configuration, can provide leverage and/or stability during use while also providing for substantial payload space within the device that can be used for larger components or more operational components. As with the various combination devices disclosed and discussed above, according to one embodiment these triangular or quadrangular devices can be positioned inside the body cavity of a patient in the same fashion as those devices discussed and disclosed above.

(127) Certain embodiments disclosed or contemplated herein can be used for colon resection, a surgical procedure performed to treat patients with lower gastrointestinal diseases such as diverticulitis, Crohn's disease, inflammatory bowel disease and colon cancer. Approximately two-thirds of known colon resection procedures are performed via a completely open surgical procedure involving an 8- to 12-inch incision and up to six weeks of recovery time. Because of the complicated nature of the procedure, existing robot-assisted surgical devices are rarely used for colon resection surgeries, and manual laparoscopic approaches are only used in one-third of cases. In contrast, the various implementations disclosed herein can be used in a minimally invasive approach to a variety of procedures that are typically performed ‘open’ by known technologies, with the potential to improve clinical outcomes and health care costs. Further, the various implementations disclosed herein can be used in place of the known mainframe-like laparoscopic surgical robots that reach into the body from outside the patient. That is the less-invasive robotic systems, methods, and devices disclosed herein feature small, self-contained surgical devices that are inserted in their entireties through a single incision in the patient's abdomen. Designed to utilize existing tools and techniques familiar to surgeons, the devices disclosed herein will not require a dedicated operating room or specialized infrastructure, and, because of their much smaller size, are expected to be significantly less expensive than existing robotic alternatives for laparoscopic surgery. Due to these technological advances, the various embodiments herein could enable a minimally invasive approach to procedures performed in open surgery today.

(128) The various embodiments are disclosed in additional detail in the attached figures, which include some written description therein.

(129) The various system embodiments described herein are used to perform robotic surgery. The systems are used for general surgery applications in the abdominal cavity, including colon resection. In certain implementations, the various systems described herein are based on and/or utilize techniques used in manual laparoscopic surgery including insufflation of the abdominal cavity and the use of ports to insert tools into the abdominal cavity.

(130) Major components of the various system embodiments include a robot and a surgeon control console. The robot implementations are configured to be inserted into the insufflated abdominal cavity. Certain robot embodiments have an integrated camera system that captures a view of the surgical target. The surgeon can then use that view on a display to help control the robot's movements. In certain implementations, the camera is designed so that it can be removed so it can be cleaned and used in other applications.

(131) The surgeon console, according to some embodiments, has a display to view the feedback from the camera. This display can also have overlays to provide some additional information to the surgeon including the robot's state and other information. The console can also have a touch screen used to control various system functions. In addition, the various console embodiments can also have user input devices (e.g. haptic joysticks) that the surgeon can use to control the movement of the robot's arms and other movement. Further, the console can also has one or more pedals used to control various robot control and functions.

(132) In other embodiments as will be discussed in further detail herein, the system can include

disposable or permanent sleeves, an electro-surgery cautery generator, an insertion port, a support arm/structure, a camera, remote surgical displays, end-effectors (tools), an interface pod, a light source, and other support components.

(133) FIGS. **1**A and **1**B depict one embodiment of the system **1** with a robot or robotic device **10** with a camera **12**. As shown in FIG. **1**A, the robotic device **10** has two robotic arms **14**, **16** operably coupled thereto and a camera component or "camera" **12** disposed between the two arms **14**, **16** and positionable therein. That is, device **10** has a first (or "right") arm **14** and a second (or "left) arm **16**, both of which are operably coupled to the device **10** as discussed in additional detail below. The device **10** as shown has a casing (also referred to as a "cover" or "enclosure") **11**. The device **10** is also referred to as a "device body" **10**A and has two rotatable cylindrical components (also referred to as "shoulders" or "turrets"): a first (or "right") shoulder **14**A and a second (or "left") shoulder **16**A. Each arm **14**, **16** also has an upper arm (also referred to herein as an "inner arm," "inner arm assembly," "inner link," "inner link assembly," "upper arm assembly," "first link," or "first link assembly") **14**B, **16**B, and a forearm (also referred to herein as an "outer arm," "outer arm assembly," "outer link," "outer link assembly," "forearm assembly," "second link," or "second link assembly") **14**C, **16**C. The right upper arm **14**B is operably coupled to the right shoulder **14**A of the body **10**A at the right shoulder joint **14**D and the left upper arm **16**B is operably coupled to the left shoulder **16**A of the body **10** at the left shoulder joint **16**D. Further, for each arm **14**, **16**, the forearm **14**C, **16**C is rotatably coupled to the upper arm **14**B, **16**B at the elbow joint **14**E, **16**E.

(134) As shown in FIG. **1**B, the robotic device **10** has been inserted into a model of the abdominal cavity **6** through a gel port **7** in a fashion similar to the way it would be inserted into a patient's abdominal cavity **6**. The gel port **7** allows for an irregularly shaped robotic device **10** to be inserted while maintaining insufflation pressure. In this implementation, a standard manual laparoscopic port **7** is used in addition to the robot **10**. Alternatively, two or more such ports can be utilized (not shown). In a further alternative, no standard manual laparoscopic ports are used.

(135) In FIG. **1**B, the device body **10**A is shown having been inserted in a ventral-dorsal orientation into the abdominal cavity such that the longitudinal body axis (as is shown by reference arrow A) is generally perpendicular relative to the rostrocaudal/anteroposterior and mediolateral axes (reference arrows B and C, respectively). It is understood that following insertion, the device body **10**A can be variously positioned, so as to be rotated, tilted or angled relative to the cavity **6** to alter the device workspace and access various regions of the cavity, as is described in detail below in relation to FIGS. **6**A-**8**C.

(136) FIG. **2** shows the robot with the integrated camera system, according to one embodiment. The robot of FIG. **2** has two arms **14**, **16** and a body **10**A (or torso) having a distal end **10**B and proximal end **10**C. The arms **14**, **16** each have active degrees of freedom and an additional active joint **14**F, **16**F to actuate the end effectors, or tools **18**, **20**. It is understood that more or less degrees of freedom could be included. The device in this embodiment has a connection line **8** (also referred to as a "pigtail cable") (partially shown) that includes electrical power, electrocautery, and information/communication signals. In certain implementations, the device has distributed control electronics and software to help control the device **10**. Some buttons can be included to support insertion and extraction of the device into and out of the abdominal cavity. In this embodiment, the integrated camera **12** is also shown inserted in the device body **10**A. When inserted into the body **10**A, the camera **12** has a handle or body **12**A that extends proximally from the proximal body end **10**C and a flexible camera imager **12**B extending from the distal body end **10**B.

(137) FIGS. **3** and **4** depict the robotic device **10** with the camera assembly **12** removed, according to one embodiment. In these embodiments, and as shown in FIG. **2** and FIGS. **3-4**, the camera imager **12**B is designed to be positioned between the two arms **14**, **16** and capture that view between the two arms **14**, **16**. In these implementations, the camera **12** extends through the robot body **10**A such that the camera imager **12**B exits near the joints between the body and the robotic arms (the "shoulder" joints **14**A, **16**A). The camera **12** has a flexible, steerable tip **12**C to allow the

user to adjust the viewing direction. The end effectors **18**, **20** on the distal end of the arms **14**, **16** can include various tools **18**, **20** (scissors, graspers, needle drivers, etc.). In certain embodiments, the tools **18**, **20** are designed to be removable by a small twist of the tool knob that couples the end effector to the arm **14**, **16**.
(138) As is shown in FIGS. **3-4**, the camera assembly **12** has a handle **12**A and a long shaft **12**D with the camera imager **12**B at the distal tip **12**C. In various implementations, the flexible tip **12**C and therefore camera imager **12**B can be steered or otherwise moved in two independent directions in relation to the shaft **12**D at a flexible section **12**E (black section on shaft) to change the direction of view. In certain implementations, the camera **12** has some control buttons **12**G as shown. In some embodiments, the camera assembly **12** can be used independently of the robotic device **10** as shown in FIG. **4**.
(139) Alternatively, the assembly can be inserted into the robot **10** though a lumen **10**D defined through the body **10**A of the robotic device **10** as shown. In certain embodiments, the lumen **10**D includes a seal/port **10**E to ensure that the patient's cavity remains insufflated (as shown in relation to FIG. **1**B). According to one embodiment, the robotic device **10** can have a sensor to determine if the camera is positioned in the camera lumen **10**D of the device **10**.
(140) FIG. **5** depicts a robotic device **10** according to one embodiment in a configuration in which the positionable arms **14**, **16** are positioned such that the tools **18**, **20** are positioned in line with the camera tip **12**C. That is, in this embodiment the arms **14**, **16** are disposed in the workspace so as to be within the field of view of the camera imager **12**B (designated by reference lines “V.sub.1” and “V.sub.2”). In the implementation of FIG. **5**, the device **10** is positioned within the cavity of the patient at an angle—that is, such that the longitudinal axis of the device body **10**A (designated by reference line A) is not perpendicular to the body of the patient (as shown, for example, in FIG. **1**B).
(141) In the implementation of FIG. **5**A, the device body **10**A is therefore oriented so as to have a “top,” “upper,” or “front” side **22** and a “bottom,” “lower,” or “back” side **24**. It is understood that further configurations are possible, and as described in detail herein, the camera **12** and arms **14**, **16** are capable of extending into either side **22**, **24** so as to provide large workspaces without the need to rotate the device body **10**A.
(142) In the implementation shown in FIG. **5**B, the arms **14**, **16** of the robotic device **10** are positioned in an “insertion” configuration. As shown, in the insertion configuration, the arms **14**, **16** and camera **12** are all primarily aligned with the robotic device body **10**A such that the longitudinal axes of each of the components are substantially parallel to one another (as shown by reference arrow I) for insertion through the port (as is shown, for example, in FIG. **1**B at **7**). It is understood that the insertion configuration minimizes the overall “footprint” of the device **10**, so as to allow the smallest possible incision. In certain implementations, during insertion the device **10** can be passed through a variety of positions while being inserted, as has been previously described in U.S. patent application Ser. No. 15/227,813 filed Aug. 3, 2016 and entitled “Robotic Surgical Devices, Systems, and Related Methods,” which is incorporated by reference herein in its entirety.
(143) A principle advantage of the system **1** in certain implementations is a wide workspace range for the arms, including embodiments wherein the arms are positioned “behind” the device. In use, increasing the workspace range of each of the arms can reduce the need to reposition to the device, and therefore lead to greater efficiency and faster total surgery times and recovery. Several implementations showing the increased arm range are described herein.
(144) FIGS. **6**A, **6**B, **7**A, **7**B, and **7**C schematically depict the entire workspace **30** as well as the individual reachable workspaces **30**A, **30**B of each of the arms **14**, **16** of a robotic device **10**, according to certain embodiments. In these embodiments, “workspace” **30** means the space **30** around the robotic device **10** in which either arm and/or end effector **18**, **20** can move, access, and perform its function within that space.
(145) More specifically, FIG. **6**A depicts a perspective view of the device body **10**A and further

schematically shows the entire workspace **30** as well as the individual workspaces **30**A, **30**B of the first arm **14** and second arm **16**, respectively. Note that the each arm **14**, **16** has a range of motion and corresponding workspace **30**A, **30**B that extends from the front **22** of the device to the back **24** of the device **10**. Thus, the first arm **14** equally to the front **22** and the back **24**, through about 180° of space relative to the axis of the device body **10**A for each arm **14**, **16**. This workspace **30** allows the robotic device to work to the front **22** and back **24** equally well without having to reposition the body **10**A.
(146) As best shown in FIG. **6**B, the overlap of the ranges of motion for the individual arms in these implementations also enables an intersecting workspace **30**C (as is also shown in FIG. **6**A). It is understood that the intersecting workspace **30**C in these implementations encompasses the workspace **30**C reachable by both arms **14**, **16** and end effectors **18**, **20** in any individual device **10** position. Again, in these implementations, the intersecting workspace **30**C includes a range of about 180° of space relative to the axis of the device body **10**A.
(147) FIG. **7**A depicts a side view of the device body **10**A and further schematically shows the workspace **30**A of the first arm **14**. Note that the first arm **14** has a range of motion that extends from the front **22** of the device to the back **24** of the device **10**. Thus, the first arm **14** equally to the front **22** and the back **24**. This allows the robotic device to work to the front **22** and back **24** equally well without having to reposition the body **10**A. With respect to the actual position of the arms **14**, **16**, FIG. **7**A depicts the first arm **14** extending out from the front **22** of the device while the second arm **16** is extending out from the back **24**.
(148) Similarly, FIGS. **7**B and **7**C depict different views of the device body **10**A and arms **14**, **16** of FIG. **7**A. For example, FIG. **7**B depicts a top view of the body **10**A and arms **14**, **16**. In this embodiment, both the workspace **30**A of the first arm **14** and the workspace **30**B of the second arm **16** are shown from a top view. Further, FIG. **7**C depicts the body **10**A and arms **14**, **16** from a perspective view that shows another angle of the workspaces **30**A, **30**B.
(149) In each of FIGS. **7**A-**7**C, the same configuration of the body **10**A and arms **14**, **16** is shown, with the first arm **14** extending out from the front **22** of the device while the second arm **16** is extending out from the back **24** (as best shown in FIG. **7**A). This wide range of motion demonstrated by the workspaces **30**A, **30**B for both of its arms **14**, **16** gives the robotic device **10** a relatively large workspace when compared to the length of its arms **14**, **16**.
(150) FIGS. **8**A, **8**B, and **8**C further depict the wide range of motion that can be achieved by the arms of this specific device **10**, according to one embodiment. FIG. **8**A depicts a perspective view of the back of the device **10** in which the arms **14**, **16** are both depicted in a single position that is substantially similar to that depicted in FIGS. **7**A-**7**C: a first arm **14** extends away from the front **22** of the device body **10**A, while the second arm **16** extends away from the back **24** of the device body **10**A.
(151) FIG. **8**B depicts a side view of the device **10** in which the first arm **14** is depicted in multiple different positions, including a first position **14-1**, a second position **14-2**, a third position **14-3**, and a fourth position **14-4**, thereby providing some examples of the range of motion of which the arms (in this case, the first arm **14**) are capable.
(152) The implementation of FIG. **8**C depicts a perspective front view of the device **10** in which the first arm **14** is again depicted in the same positions as shown in FIG. **8**B, including the first **14-1**, second **14-2**, third **14-3**, and fourth **14-4** positions within the workspace **30**A. One of skill in the art would appreciate that many additional positions between those shown are also possible, and that these positions of the first arm **14** are also possible for the second arm **16**.
(153) FIG. **9** is a perspective front view of an implementation of the device **10** with an articulating, or flexible camera **12** extending from the distal end **10**B of the device body **10**A. In these implementations, the camera **12** has a distal lens **12**B on the tip portion **12**C, as well as a flexible sheath **15** enclosing the flexible section **12**E. In FIG. **9**A, the camera **12** and arms are generally oriented in a slightly "down" working position, wherein the tip portion **12**C is oriented away from

the front **22** of the body **10**A. Again, it is understood that in these implementations, the camera **12** can therefore be positioned to best view the end effectors, or tools **18**, **20**. It is further understood that in these implementations the robot **10** exits the body on the forward surface **22**.
(154) FIG. **910** depicts a further implementation of the device **10** with the arms in an "up" or "normal" position, where the camera is angled slightly toward the front **22** of the body **10**A. Further, the device of FIG. **10** has proximal sleeve attachments **32**, **34** between the shoulders **14**A, **16**A and device body **10**A. The sleeve attachments **32**, **34** can be "grooves," where two flanges **32**A, **32**B, **34**A, **34**B are disposed around each shoulder shaft **36**, **38**. It is understood that flanges **32**A, **32**B, **34**A, **34**B are configured or otherwise constructed and arranged so that a permanent and/or disposable sleeve (not shown, but as is discussed in the incorporated references) can be attached and held in place between the respective flanges **32**A, **32**B, **34**A, **34**B. Corresponding distal mating areas **40**, **42** for each sleeve (not shown) are disposed on the distal ends of the forearms **14**C, **16**C and at the base of each tool **18**, **20**.
(155) FIG. **11** depicts a further implementation of a robot **10** having arms **14**, **16** positioned substantially "down," compared to the positions of FIGS. **9** and **10**. That is, in FIG. **11**, the camera tip **12**C is oriented perpendicularly from the longitudinal axis (reference arrow A) of the robot body **10**A on the back side **24** (as opposed to the front side **22**) within a region of the workspace **30**, and that the camera **12** disposed such that the arms **14**, **16**, and more specifically the tools, or end effectors **18**, **20** are within the field of view (shown generally with reference arrow V). In this implementation, various operations cables **45** are also shown as being connected to the device body **10**A and camera **12**.
(156) FIGS. **12**A-F depict alternate implementations of the robot **10-1**, **10-2**. In the first implementation, and as shown in FIGS. **12**A, **12**C and **12**E, the robot **10-1** has a sloped distal body **10**B-**1** portion **48** the camera **12** extends from within. In the second implementation, as shown in FIGS. **12**B, **12**D and **12**F, the robot **10-2** camera **12** extends from the distal body end **10**B-**2**. In these implementations, the arms **14**, **16** have generally cylindrical upper links, or shoulders **14**A, **16**A disposed in parallel—laterally and separately—on the distal body end **10**B such that there is a "gap" or opening **46** between the shoulders **14**A, **16**A. In these implementations, the camera **12** extends from the distal end of the device body **10**B within the opening **46**, so as to be directly between the generally cylindrical shoulders **14**A, **16**A and equidistant between the front side **22** and back side **24**. In these implementations, the camera **12** can therefore be curved to view forward and rearward equally, as is shown, for example, in relation to FIG. **6**A-**8**C.
(157) FIGS. **13-30** depict the internal components of the body **10**A, which is shown in these figures without its casing or housing **11**. It is understood that in use, these implementations are covered, as is shown in relation to FIG. **1**A. FIGS. **13-30** include the internal structural or support components of the body **10**A. These components maintain the structure of the body **12** and provide structural support for the components disposed therein.
(158) In use, there are many ways to actuate the robot **10** and its associated components, such as DC motors, AC motors, Permanent magnet DC motors, brushless motors, pneumatics, cables to remote motors, hydraulics, and the like. A more detailed description of one possible system is described in relation to FIGS. **13-30**. Other technologies described in the previously-filed and incorporated applications and patents can also be implemented to actuate the various components, as would be understood.
(159) FIG. **13** shows an implementation of the robot **10** and each joint of one arm—here, the left arm **16**. it is understood that the right arm **14** of this implementation is a mirror image of the left **16**. It is understood that the internal components in the left arm **16** that operate/control/actuate the left arm **16** are substantially the same as those depicted and described herein and that the descriptions provided below apply equally to those components as well.
(160) In the implementation of FIG. **14**, a shoulder yaw joint **100** actuates a yaw joint **100** in the robot shoulder **14**A, **16**A. In this implementation, the robot **10** also has a shoulder pitch joint **102**,

that is, a pitch joint **102** on the robot shoulder **14**A, **16**A. In these implementations, an upper arm roll joint **104**, an elbow joint **106**, and a tool roll joint **108** are also provided which enable the range of motion described in relation to Table 1, below. In various implementations, a tool actuation joint (not shown) interfaces with the tool (not shown) to actuate open and close of the tool, as has been previously described.
(161) In various implementations, these joints **100**, **102**, **104**, **106** have practical defined ranges of motions that, together with the robot geometry, lead to the final workspace of the robot **10**. For the examples given herein, the joint limits allow for a significant robot workspace, as is described above. This workspace allows the various implementations of the robot to use both arms and hands effectively in several locations within the body cavity of the patient. The joint ranges of motion defined in the implementations of FIGS. **13**A-**27** are given in Table 1. It is understood that further ranges are possible, and so this set of ranges is not limiting, but rather representative of a particular embodiment. Further, alternate embodiments are possible.
(162) The direction of rotation and zero positions are shown in FIGS. **13**A-D. In FIGS. **13**A-D, the robot **10** is shown with each of the first four angles in the zero location. In these implementations, each joint (the shoulder yaw joint **100**, shoulder roll joint **102**, upper arm roll joint **104** and elbow joint **106**) is shown with an axis of rotation (dotted) and a zero location. An arrow is then used to indicate the direction of positive joint angle about the axis of rotation. Since the tool roll joint **108** and tool actuation joints **109** are allow continuous rotation the zero location is arbitrary and not shown.
(163) TABLE-US-00001 TABLE 1 Joint Ranges of Motion Joint No. Range of Motion 1 −90 to +90 2 −90 to +30 3 −90 to +90 4 0 to 150 5 Continuous 6 Continuous
(164) In the implementation of FIG. **14**, the body **10**A and each link (meaning the upper arm **16**B, and forearm **16**C) contain Printed Circuit Boards (“PCBs”) **110**, **112**, **114** that have embedded sensor, amplification, and control electronics. One PCB is in each forearm and upper arm and two PCBs are in the body. Each PCB also has a full 6 axis accelerometer-based Inertial Measurement Unit and temperature sensors that can be used to monitor the temperature of the motors. Each joint can also have either an absolute position sensor or an incremental position sensor or both. In certain implementations, the some joints contain both absolute position sensors (magnetic encoders) and incremental sensors (hall effect). In other implementations, certain joints only have incremental sensors. These sensors are used for motor control. The joints could also contain many other types of sensors. A more detailed description of one possible method is included here.
(165) In this implementation, a larger PCB **110** is mounted to the posterior side of the body **10**A. This body PCB **110** controls the motors **116** in the base link, or body **10**A (the shoulder yaw joint **100** and shoulder pitch joint **102** for left and right arms, respectively). Each upper arm has a PCB **112** to control the upper arm roll joint **104** and elbow joint **106**. Each forearm has a PCB **114** to control the tool roll joint **108** and tool actuation joint (not shown). In the implementation of FIG. **14**, each PCB **110**, **112**, **114** also has a full six axis accelerometer-based inertial measurement unit and several temperature sensors that can be used to monitor the temperature of the various motors described herein.
(166) In these embodiments, each joint **100**, **102**, **104**, **106**, **108** can also have either an absolute position sensor or an incremental position sensor or both, as described and otherwise disclosed in U.S. Provisional Application 61,680,809, filed on Aug. 8, 2012, which is hereby incorporated herein by reference in its entirety. In one implementation, and as shown in FIG. **15** and elsewhere the various actuators or motors **116**, **130**, **154**, **178** described herein have at least one temperature sensor **101** disposed on the surface of the motor, for example by temperature-sensitive epoxy, such that the temperature sensors (as shown in FIG. **22** at **101**) can collect temperature information from each actuator for transmission to the control unit, as discussed below. In one embodiment, any of the motors discussed and depicted herein can be brush or brushless motors. Further, the motors can be, for example, 6 mm, 8 mm, or 10 mm diameter motors. Alternatively, any known size that can

be integrated into a medical device can be used. In a further alternative, the actuators can be any known actuators used in medical devices to actuate movement or action of a component. Examples of motors that could be used for the motors described herein include the EC 10 BLDC+GP10A Planetary Gearhead, EC 8 BLDC+GP8A Planetary Gearhead, or EC 6 BLDC+GP6A Planetary Gearhead, all of which are commercially available from Maxon Motors, located in Fall River, MA. There are many ways to actuate these motions, such as with DC motors, AC motors, permanent magnet DC motors, brushless motors, pneumatics, cables to remote motors, hydraulics, and the like. Further implementations can be used in conjunction with the various systems, methods and devices disclosed in U.S. patent application Ser. No. 15/227,813 filed Aug. 3, 2016 and entitled "Robotic Surgical Devices, Systems, and Related Methods," which is incorporated by reference in its entirety.
(167) In this implementation, joints **1-4** have both absolute position sensors (magnetic encoders) and incremental sensors (hall effect). Joints **5** & **6** only have incremental sensors. These sensors are used for motor control. It is understood that the joints could also contain many other types of sensors, as have been described in detail in the incorporated applications and references.
(168) According to one implementation, certain other internal components depicted in the implementation of FIGS. **15-16** are configured to actuate the rotation of the shoulder yaw joint **100** of the body **10**A around axis **1**, as shown in FIG. **14**. It is understood that two of each of the described components are used—one for each arm—but for ease of description, in certain depictions and descriptions, only one is used.
(169) As best shown in FIG. **15**, a shoulder yaw joint **100** motor **116** and gearhead combination drives a motor gear **117** first spur gear set **118**, which is best shown in FIG. **16**. The first spur gear set **118** drives a shaft supported by bearings **120** to drive a second spur gear set **122**. In turn, this second spur gear set **122** drives an output shaft **124** that is also supported by bearings **126**. This output shaft **124** then drives a turret **14**A, **16**A (representing the shoulder of the robot **10**) such that the shoulder **16**A rotates around axis **1**, as best shown in FIG. **14**.
(170) According to one implementation, certain internal components depicted in the implementation of FIGS. **17-19** are configured to actuate the shoulder pitch joint **102** of the body **10**A and/or shoulder **14**A, **16**A around axis **2**, as is shown in FIG. **14**. In these implementations, the pitch joint **102** is constructed and arranged to pivot the output link **140** so as to move the upper arm (not shown) relative to the shoulder **14**A, **16**A.
(171) In this implementation, a motor **130** and gearhead combination drives a motor gear **131** and spur gear **132** that in turn drives a first shaft **134**. This shaft **134** then drives a bevel (or miter) gear pair **136**, **137** inside the shoulder turret (depicted in FIG. **19**). The bevel (or miter) gear pair **136**, **137** accordingly drives a helical spur set **138**, **139** directly connected to the shoulder pitch joint **102** output link **140**, such that the upper arm **16**B rotates around axis **2**, as best shown in FIG. **14**. In this implementation, the shoulder yaw joint **100** and the shoulder pitch joint **102** therefore have coupled motion. In these implementations, a plurality of bearings **141** support the various gears and other components, as has been previously described.
(172) FIGS. **20-23** depict various internal components of the upper arm **16**B constructed and arranged for the movement and operation of the arm **16**. In various implementations, multiple actuators or motors **142**, **154** are disposed within the housing (not shown) of the forearm **16**C. FIGS. **24-27** depict various internal components of the forearm **16**C constructed and arranged for the movement and operation of the end effectors. In various implementations, multiple actuators or motors **175**, **178** are disposed within the housing (not shown) of the forearm **16**C.
(173) In one implementation, and as shown in FIG. **22** and elsewhere the various actuators or motors **116**, **130**, **154**, **178** described herein have at least one temperature sensor **101** disposed on the surface of the motor, for example by temperature-sensitive epoxy, such that the temperature sensors can collect temperature information from each actuator for transmission to the control unit, as discussed below. In one embodiment, any of the motors discussed and depicted herein can be

brush or brushless motors. Further, the motors can be, for example, 6 mm, 8 mm, or 10 mm diameter motors. Alternatively, any known size that can be integrated into a medical device can be used. In a further alternative, the actuators can be any known actuators used in medical devices to actuate movement or action of a component. Examples of motors that could be used for the motors described herein include the EC 10 BLDC+GP10A Planetary Gearhead, EC 8 BLDC+GP8A Planetary Gearhead, or EC 6 BLDC+GP6A Planetary Gearhead, all of which are commercially available from Maxon Motors, located in Fall River, MA. There are many ways to actuate these motions, such as with DC motors, AC motors, permanent magnet DC motors, brushless motors, pneumatics, cables to remote motors, hydraulics, and the like.

(174) One implementation of the internal components of the upper arm **16**B constructed and arranged to actuate the upper arm roll joint **104** is shown in FIGS. **20-21**. In this implementation, a motor **142** and gearhead combination controlled by a PCB **112** drives a motor gear **143** and corresponding spur gear **144** where the output spur gear **144** is supported by a shaft **148** and bearings **150**. The output shaft **152** and output spur gear **144** can have a mating feature **146** that mates to the shoulder pitch joint **102** output link **140** (shown in FIG. **17**).

(175) One implementation of the internal components of the upper arm **16**B configured to operate the elbow joint **106** is shown in FIGS. **22-23**. In this implementation, a base motor **154** directly drives a driven spur gear set that includes three gears **156**, **158**, **160**. This spur gear set **156**, **158**, **160** transfers the axis of rotation from the axis of the motor **154** to the axis of a worm gear **166**.

(176) As best shown in FIG. **23**, the output spur gear **160** from this set drives a motor gearhead **162** that drives a worm shaft **164** that has a worm gear **166** mounted on it. This worm gear **166** then drives a worm wheel **168** that is connected to the Joint **4** output shaft **170**. It should also be noted that the upper arm unit (as shown in FIG. **22**) shows a curved concave region **172** on the right side. It is understood that this region **172** is configured to allow for a larger motion of Joint **4** so as to allow the forearm to pass through the region **172**.

(177) One implementation of the internal components of the forearm **16**C configured or otherwise constructed and arranged to operate the tool roll joint **108** is shown in FIGS. **24-25**. In these implementations, the tool roll joint **108** drives a tool lumen **174** that holds the tool (shown, for example, at **18**, **20** in FIGS. **1**A-**1**B). The tool lumen **174** is designed to mesh with the roll features on the tool to cause the tool to rotate about its axis, as shown as axis **5** in FIG. **14**. In this implementation, a tool roll motor **175** with a gearhead is used to drive a motor gear **176** and spur gear chain with two gears **177**A, **177**B. The last gear of this chain **177**B is rigidly mounted to the tool lumen **174**, so as to rotate the inner surface **174**A of the tool lumen, and correspondingly any inserted end effector.

(178) One implementation of a tool actuation joint **109** is shown in FIGS. **26-27**. In this implementation, the Joint **6** motor **178** does not visibly move the robot. Instead, this tool actuation joint **109** drives a female spline **184** that interfaces with the tool (Shown, for example, at **18**, **20** in FIGS. **1**A-**1**B) and is configured to actuate the end effector to open and close. This rotation of the end effector arms such that the end effector opens and closes is also called “tool drive.” The actuation, in one aspect, is created as follows. An actuator **178** is provided that is, in this implementation, a motor assembly **178**. The motor assembly **178** is operably coupled to the motor gear **180**, which is a spur gear in this embodiment. The motor gear **180** is coupled to first **182** and second **183** driven gears such that rotation of the motor gear **180** causes rotation of the driven gears **182**, **183**. The driven gears **182**, **183** are fixedly coupled to a female tool spline **184**, which is supported by bearing pair **186**. The female tool spline **184** is configured to interface with a male tool spline feature on the end effector to open/close the tool as directed.

(179) According to one implementation, the end effector (shown at FIGS. **1**A-**1**B at **18**, **20**) can be quickly and easily coupled to and uncoupled from the forearm **16**C in the following fashion. With both the roll and drive axes fixed or held in position, the end effector **18**, **20** can be rotated, thereby coupling or uncoupling the threads (not shown). That is, if the end effector is rotated in one

direction, the end effector is coupled to the forearm **16**B, and if it is rotated in the other direction, the end effector is uncoupled from the forearm **16**B.

(180) Various implementations of the system **10** are also designed to deliver energy to the end effectors so as to cut and coagulate tissue during surgery. This is sometimes called cautery and can come in many electrical forms as well as thermal energy, ultrasonic energy, and RF energy all of which are intended for the robot.

(181) In exemplary implementations of the system **1** and various devices **10**, the camera **12** is configured or otherwise constructed and arranged to allow for both pitch (meaning "up" and "down") movements and yaw (meaning "side to side" movements) within the workspace **30**, and in exemplary implementations, the yaw or "pan" functionality is accomplished via mechanical articulation at the distal tip **12**C, rather than via rotating the camera shaft **12**D and/or handle **12**A, as has been done previously. Accordingly, various implementations of the camera component **12** of this implementation have two mechanical degrees of freedom: yaw (look left/right) and tilt (look up/down). In use, the camera component **12** has pan and tilt functionality powered and controlled by the actuators and electronics in the handle **12**A, as has been previously described in U.S. patent application Ser. No. 15/227,813. In these implementations of the system, the camera **12** is therefore able to allow the user to observe the device arms and end effectors throughout the expanded workspace. Several devices, systems and methods allowing for this improved range of vision and camera movement are described herein.

(182) Various implementations and components of the camera are shown in FIGS. **28**A-**36**C and elsewhere. As discussed above, the camera **12** of certain implementations is designed to function with the robot **10**, as is shown in FIG. **2**. The robot camera **12** can also be used independent of the robot, as shown FIG. **4**. In various implementations, the camera **12** is inserted into the proximal end **10**C of the robot body **10**A, and as is shown in FIG. **28**A, the camera tip **12**C exits through the distal end **10**B of the robot body **10**A near the attachment location between the body and arms, as described above in relation to FIG. **6**. In certain implementations, and as discussed in relation to FIG. **3**, a seal **10**E is included in the robot body **10**A so as not to lose insufflation when the camera **12** is removed from the robot **10**. Several diameters are possible, but one implementation has a 5 mm camera that is inserted into a 6 mm lumen **10**D in the robot, as is shown in FIG. **28**A.

(183) In the implementations of FIGS. **28**A-B, the camera **12** is designed to flex in two independent degrees of freedom at the distal end **12**C. This allows the user to visualize the robot tools at any position within the robot workspace via the imager **12**B, as shown at 1°-V° in FIG. **28**B. In these implementations, the robot lumen **10**D may be centered with respect to the robot body **10**A, as shown in FIGS. **28**A-B, allowing for symmetric points of view with respect to the robot arms, or it may be more anterior, as shown in the implementation of FIG. **1**A, or posterior or in other locations.

(184) Additionally, as shown in FIGS. **28**A-**28**B the camera **12** tip **12**C contains one or more lighting components **12**F to light the viewing target (as discussed in relation to FIG. **1**). In these implementations, the lighting components **12**F can be illuminated via an independent light box or some other known light source (not shown, but one non-limiting example is high bright LEDs) in the camera handle or other forms of light sources. The light can then be directed through the camera shaft **12** via fiber optic cables, as has been previously described, for example in relation to U.S. patent application Ser. No. 15/227,813 filed Aug. 3, 2016 and entitled "Robotic Surgical Devices, Systems, and Related Methods," which is incorporated by reference.

(185) An additional feature of certain implementations allows the camera **12** to be inserted into the body **10**A with various depths. These implementations allow for better visualization during various activities. For example, FIGS. **28**C-**28**E, **28**F-**28**H and FIG. **28**I show several implementations of a camera **12** that can be inserted at several depths, which can include fixed locations to hold the camera **12** using one ore more projections **70** such as spring balls **70** disposed on the exterior surface of the camera body **12**A, and corresponding fixed ring detents **72** (best shown in FIG. **28**I)

disposed at a variety of depths inside the body lumen **10**D. In use, the detents **72** that engage the balls **70** at various degrees of insertion depth (reference arrow H). This would allow the camera to be more proximal with respect to the robot arms (FIGS. **28**C-E) or more distal with respect to the robot arms (FIG. **28**F-**28**H). It is understood that in alternate implementations, other methods of disposing the camera **12** are possible, including a continuous movement and other systems actuated with various actuation and control mechanisms.
(186) In various implementations of the camera handle **12**, over molds may be provided for user comfort. Various connector and button and pigtail combinations are possible. In certain implementations, the camera handle **12**A holds at least one motor to actuate the flexible tip **12**C. In one version these motors can then be controlled via the surgeon console (as described below) or other input devices to control the motion of the camera **12**. This control could also include other camera functions such as zoom, brightness, contrast, light intensity, and many other features.
(187) As shown in FIGS. **29**A-**29**B, the camera system's flexible articulated tip **12**C allows the camera **12** to achieve fields of view (reference arrow V) over substantially all of the robot workspace **30**. In these implementations, a cross section of one possible workspace in the sagittal plane is shown. FIGS. **29**A-**29**B demonstrate the movement of the robot arms **14**, **16** can move about a large workspace **30** and the camera system **12** must be able to visualize the robot tools **18**, **20** at all times.
(188) FIGS. **30**A-**33**C depict several embodiments of the device **10**, wherein the camera **12** is alternately oriented to allow for consistent tool visualization throughout the surgical theater. It is understood that this visualization requirement can be met through various implementations, and that many imager configurations are possible.
(189) The imager **12**B-**1** of the implementations of FIGS. **30**A-**30**F is referred to as a “zero degree scope” imager **12**B-**1**, meaning that the line of viewing (shown with reference area V) is aligned normally with the distal tip **12**C of the camera **12**. FIGS. **30**A-**30**F depict the sagittal plane of a robot **10** design with the camera **12**C having a zero degree imager **12**B-**1** following the motion of the robot **10** from “behind” (at −90°) the robot **10** (FIG. **30**A) to “bellow” (at 0°) the robot (at FIG. **30**D) and in “front” (at 90°) of the robot **602** at FIG. **30**F. FIGS. **30**B, **30**C and **30**E depict the device **10** at −60°, −45°, and 45°, respectively. It is understood that in the implementation of FIGS. **30**A-**30**F, the camera tip **12**C is oriented so as to place the end effector **20** into the field of view V at each position.
(190) The imager **12**B-**2** of the implementations of FIGS. **31**A-**31**F is referred to as a “30 degree scope” imager **12**B-**2**, meaning that the line of viewing (shown with reference area V) is aligned 30° from the distal tip **12**C of the camera **12**, as would be understood by one of skill in the art. FIGS. **31**A-**31**F depict the sagittal plane of a robot **10** design with the camera **12**C having a zero degree imager **12**B following the motion of the robot **10** from “behind” (at −90°) the robot **10** (FIG. **31**A) to “bellow” (at 0°) the robot (at FIG. **31**D) and in “front” (at 90°) of the robot **602** at FIG. **31**F. FIGS. **31**B, **31**C and **31**E depict the device **10** at −60°, −45°, and 45°, respectively. It is understood that in the implementation of FIGS. **31**A-**31**F, the camera tip **12**C is oriented so as to place the end effector **20** into the field of view V at each position.
(191) The imager **12**B-**3** of the implementations of FIGS. **32**A-**32**F is referred to as a “60 degree scope” imager **12**B-**3**, meaning that the line of viewing (shown with reference area V) is aligned 60° from the distal tip **12**C of the camera **12**, as would be understood by one of skill in the art. FIGS. **32**A-**32**F depict the sagittal plane of a robot **10** design with the camera **12**C having a zero degree imager **12**B following the motion of the robot **10** from “behind” (at −90°) the robot **10** (FIG. **32**A) to “bellow” (at 0°) the robot (at FIG. **32**D) and in “front” (at 90°) of the robot **10** at FIG. **32**F. FIGS. **32**B, **32**C and **32**E depict the device **10** at −60°, −45°, and 45°, respectively. It is understood that in the implementation of FIGS. **32**A-**32**F, the camera tip **12**C is oriented so as to place the end effector **20** into the field of view V at each position.
(192) FIGS. **33**A-**33**B depict an alternate implementation of the robot **10** wherein the distal camera

imager **12**B and tip **12**C can make an "S-curve" shape. This implementation may require an extra actuated degree of freedom in certain implementations, but it is understood that it has the ability to provide improved viewpoints (shown by reference area V) by allowing the camera **12**B to be moved from the plane of (or otherwise being coaxial with) the robot arms **16** and end effectors **20**. It is understood that there are various advantages to offsetting the camera tip **12**C axis from any individual arm **14**, **16** or end effector axis, such as to view various internal tissues, organs and the like within the surgical theater.

(193) Turning to the articulation of the camera tip **12**C, FIGS. **34**A-**34**C depict various internal components and devices used to achieve the camera **12** movements shown in FIGS. **31**A-**33**B and elsewhere. Again, because of the large workspaces possible in certain implementations (as discussed for example in relation to FIGS. **6**A-**6**B at **30**) exemplary implementations of the camera **12** are configured or otherwise constructed and arranged to allow for both pitch (meaning "up" and "down") movements and pan or yaw (meaning "side to side" movements) within the workspace **30**. In these implementations of the system, the camera is therefore able to allow the user to observe the device arms and end effectors throughout the expanded workspace. Several devices, systems and methods allowing for this improved range of vision and camera movement are described herein. As would be understood by one of skill in the art, the present examples are non-limiting, and are shown for purposes of illustration without the protective sheath (shown, for example, in FIG. **9**A at **15**).

(194) The pitch and yaw articulation of the camera tip **12**C can be achieved through various implementations, as shown in FIGS. **34**A-**34**C. FIGS. **34**A-**34**B show continuum mechanisms. In the implementation of FIG. **34**A, the camera is able to articulate at the tip **12**C. In this implementation, the camera tip **12**C via an articulating portion **202** defining a camera lumen **204** and comprising a plurality of openings **206**A, **206**B on either side of the portion so as to allow the device to flex in the possible directions (as shown by reference arrows A and B. It is understood that in these implementations, the articulating portion **202** can be caused to move or articulate in either direction (A or B) via cables **208**A, **208**B disposed through the camera lumen **204** and actuated via motors disposed within the camera handle **12**A. It is further understood that additional components such as wires, fiber optics and the like can also be disposed through this lumen **204**.

(195) In the implementation of FIG. **34**B, the articulating portion has several spacers **212** surrounding an internal tube **214** defining a camera lumen **204**. In these implementations, a plurality of cables **208**A, **208**B, **208**C, **208**D are disposed through openings **216**A, **216**B, **216**C, **216**D in the spacers **212**. As would be appreciated by one of skill in the art, in these implementations the cables are fixedly attached to the most distal spacer **212** and are allowed to pass through the more proximal spacers, such that proximal movement of the cables **208** results in articulation of the portion **202**. Various methods for urging the cables **208** proximally have been previously described, for example in relation to U.S. patent application Ser. No. 15/227,813 filed Aug. 3, 2016 and entitled "Robotic Surgical Devices, Systems, and Related Methods," which is incorporated by reference.

(196) The implementation of FIG. **34**C has a "stack" of interlocking linkages **220** disposed within the portion **202**. In these implementations, the linkages **220** have corresponding vertical **222**A and horizontal **222**B articulating links on adjacent links **220**A, **220**B that are configured to allow the proper degrees of freedom, as would be understood and appreciated by one of skill in the art. In these implementations, cables (not shown) can be run through openings **224** in the links **222**, as has been previously described. It is understood that these various implementations of the articulating portion allow for the adjustment of camera pitch and yaw in various degrees of freedom so as to enable the camera to view several fields of view within the workspace without repositioning the camera body or device.

(197) Further, the depth to which the camera **12** is inserted into the device **10** can be varied. FIGS. **35**A-C show how the depths of the camera **12** can be varied to change the vantage point (reference

arrow V). For example, as shown in FIG. **35**A, the camera **12** can be fully inserted into the robot **10**A with the imager **12**B coaxial with the lumen **10**D during insertion to "self visualize" the insertion process. In use, self visualization allows the user to view the tool tips during insertion. When in this "insertion" position, the imager **12**B reaches the maximum distance from the "plunge line" **230** (shown by reference arrow A).

(198) As shown in FIGS. **35**B-**35**C, a forward working position (FIG. **35**B) and a backward working position (FIG. **35**C) are also possible, with the field of view (reference area V) adjusted correspondingly. In the depicted implementation, the camera **12** motion can be manual or motorized and controlled. As is also shown in FIGS. **35**B-**35**C, in certain implementations of the device **10** where the camera extends from a portion on the front side of the device (like that shown in FIG. **1**A), the camera tip depth will vary between frontward and backward viewing positions, as is designated by reference arrow B. In certain implementations, and as is also described in relation to FIGS. **28**A-I, the height of the camera **12** within the workspace can also be adjusted to correct for this discrepancy.

(199) Various implementations of the system have a variety of tools, or end effectors **18**, **20** disposed at the distal ends of the arms. Exemplary implementations feature interchangeable end effectors or "hands". In these implementations, the robot "hands" can include various tools such as scissors, graspers, needle drivers, and the like. In various implementations, the tools are designed to be removable by a small twist of the tool knob **250**, such as via a ¼ turn bayonet connection. The tools generally have two actuated and controlled degrees of freedom with respect to the forearm. It is understood that in various implementations, the tools can also have no degrees of freedom or one or more degrees of freedom. In various implementations, the tools are controlled via the user input devices on the control console, as has been previously described. The first degree of freedom allows the tools to roll about their own axis (shown at reference arrow R). One type of tool used in this robot has one degree of freedom. This tool **18**, **20**, shown in FIG. **36**A-B, is based on hook cautery from manual laparoscopic tools, and has a roll interface **252** and monopolar slip ring **254**. Certain implementations of the tool **18**, **20** can roll (reference arrow R), but does not have an open close function. Many additional end effector implementations are contemplated herein, as are described in the several incorporated references.

(200) In use, according to certain implementations, the distal end **10**B of the device body **10**A and arms **14**, **16** are disposed within the patient body cavity, so as to be operated remotely by the user via console, as is described below. The user—typically a surgeon—positions the device **10** body within the cavity at a fixed initial starting position, and in some implementations, is thereafter able to re-position the device as desired. In certain implementations, and as described herein, the various support systems described herein utilize "remote center" or "point tracing" approaches to maintain the desired position and orientation of the robot relative to a specific point through re-positioning, such as a remote point and/or the incision or insertion point. In certain implementations, the remote centering is maintained by constraining the movements of the support structure as it moves through several degrees of freedom, while certain point tracing implementations impose additional movements onto the support structure to maintain the position. It is understood that certain implementations can involve combinations of these and other approaches. Several illustrative systems and methods for securing, positioning and repositioning the device **10** are described herein.

(201) As shown in FIG. **37**, in various implementations the robot **10** can be supported in place with FIG. **37** shows one method or device for supporting the robot **10** with a known clamp/support system **302** attached to the operating room table **303**. The clamp system **302** allows for significant adjustment of the location of the robot in all six degrees of freedom possible for the robot body. It is understood that other known, commercially-available support systems can be used to hold any robotic device embodiment disclosed or contemplated herein (such as, for example, robot **10**). Such known devices typically hold manual laparoscopic instruments such as scopes, tools, and retractors, and can similarly be used to clamp to or otherwise support the robot **10** or other such robotic device

embodiments.

(202) FIGS. **38-39** show one embodiment of a remote center mechanism **304**, sometimes called a “point tracing mechanism,” or “positioning system” that could be used to support the robot **10**. One advantage of the remote center mechanism **304**, in accordance with one implementation, is that the mechanism **304** can be used to move the device **10** while a single point of the robot **10** assembly remains in the same location: the remote center **318** of the mechanism **304** as best shown in FIG. **38**. In use, the mechanism **304** is typically positioned such that the remote center **318** is positioned at the insertion point **315** in the patient, as best shown in FIG. **39**. With the remote center **318** at the insertion point **315**, the robot **10** has about three degrees of freedom about this insertion point **318** and one in/out translation through the insertion point **315** and port **301**. In these implementations, the insertion point **315** can be adjusted in several ways such as by moving the mechanism **304** with respect to the operating room bed rail to align the remote center **318** with the insertion point **315** on the patient. The remote center **318** results, in one embodiment, from all joints of the mechanism **304** (shown at Joint **1**, **2**, **3**, & **4** in FIG. **38**), being designed to intersect with that remote center **318**. As shown in FIG. **38** according to one implementation, joints **1-3** are rotational joints (in which Joint **2** is a special parallelogram mechanism) and joint **4** is a translational joint that controls the robot insertion depth into the abdominal cavity. According to any remote center mechanism implementation as disclosed or contemplated herein, the remote center **318** can eliminate or reduce mechanical interference between the robot **10** and the abdominal wall **316** that might be created when the robot **10** is being moved.

(203) FIGS. **40**A and **40**B show the positioning of the robot **10** with respect to the abdominal wall **316**, according to certain implementations. In these implementations, a remote center positioning device **304** (and any other positioning device embodiment disclosed or contemplated herein) allow the robotic device **10** to access the full extent of the workspace **30** within the cavity **316**. In these implementations, the positioning device **304** has several linkages and links **305**, **306**, **307**, **308**, **309** including a support link **310** in mechanical communication with the device **10** and joints **311**, **312**, **313** including a support joint **314** in mechanical communication with the support link **310**. In these implementations, the links **305**, **306**, **307**, **308**, **309**, **310** and joints **311**, **312**, **313**, **314** are in mechanical communication with one another and with a support pivot **319**, so as to be capable of movement in at least three degrees of freedom, and with the rotation of the device **10**, a fourth degree of freedom.

(204) That is, the positioning device **304** makes it possible to position the robotic device **10** within the patient's cavity **316** with the body **10**A of the device **10** positioned through the incision **315** (or port disposed in the incision **315**) such that the end effectors **18**, **20** attached to the arms **14**, **16** of the robotic device **10** can reach any desired location in the workspace **30** while the links **305**, **306**, **307**, **308**, **309**, **310** and joints **311**, **312**, **313**, **314** of the positioning device **304** function to create the remote center **318** where the device body **10**A passes through the incision **315** such that all movements of the robotic device **22** pass through the remote center **318** at a single point, such as the insertion point **315**. In other words, regardless of the positioning of the links **305**, **306**, **307**, **308**, **309**, **310** and joints **311**, **312**, **313**, **314** and the resulting positioning of the robotic device **10** within the patient's cavity **316**, the portion of the device body **10**A at the incision **315** (the remote center **318**) remains in the same position in all three axes (through the incision **315**) as a result of the positioning device **304**. This allows operation of a robotic device (such as robotic device **10**) within a cavity (such as cavity **316**) such that the end effectors (such as end effectors **18**, **20**) can reach any desired location within the cavity while the entire device **10** is connected to the positioning device **304** via a device body **10**A that passes through and never moves from a single point (remote center **318**) at the incision **315**, thereby making it possible to operate and position the device **10** through that single incision (such as incision **315**). Another advantage is that the positioning device **304** makes it possible to use the single in vivo robotic device within the patient's cavity instead of the multiple arms of the known Da Vinci™ system extending from the patient's

cavity and thereby taking up a great deal of workspace outside the body of the patient.
(205) FIGS. **41**A and **41**B show further implementations of the support device **304** that can be used to support the robot **10**. In these implementations, one or more motors **301**A, **301**B can be operationally integrated with a support mechanism **304** such that the links **305**, **306**, **307**, **308**, **309**, **310** and joints **311**, **312**, **313**, **314**. It is understood that in these implementations, the motors **301**A, **301**B are able to drive the linkages into various controlled positions, that is to "point trace" on the incision point **318** through three or four (including device roll) degrees of freedom. That is, the actuators or motors **301**A, **301**B can be configured to drive the links **305**, **306**, **307**, **308**, **309**, **310** and joints **311**, **312**, **313**, **314** in a coordinated fashion through yaw, pitch and rotational degrees of freedom, so as to maintain the position the robot **10** relative to the remote point **318**.
(206) The support structure **304** of FIGS. **42**A-**42**C also utilizes one or more motors **301**A, **301**B to maintain the position of the device **10** relative to the remote point **318**, according to certain implementations. Again, in these implementations, the support structure **304** has links **305**, **306**, **307**, **308**, **309**, **310** and joints **311**, **312**, **313**, **314**, including a tracked joint **326** that is in operational communication with a pitch track **322** having a track opening **324**. It is understood that in these implementations, the movement of the links **305**, **306**, **307**, **308**, **309**, **310** urges the support joint **326** through various positions on the track opening **324** to reposition the device **10** while point tracing at the remote point **318**. It is understood that many implementations of the linkages and/or joints are possible.
(207) The implementations of FIGS. **43** and **44** depict a positioning and support structure embodiment referred to as the "desk lamp" **304**. It is understood that this implementation has similar kinematics to a desk lamp, in that in these implementations, the links **330**, **332**, **334**, **336**, **338**, **340**, **342**, **344**, **346** are able to move in a controlled fashion relative to the handle **12**A and/or robot **10**, so as to adjust the pitch or other position of the robot **10** while maintaining a consistent position relative to the insertion point **318**. In certain implementations, springs can be used to counterbalance the weight of the robot **10**. As shown in FIG. **44**, in certain of these support devices **304**, a plurality of cables **350**, **352**, **354** can be used to drive the linkages, such as via an actuated spindle **360** or other device. That is, various implementations, actuators **301**A, **301**B can be operationally connected to a cables **350**, **352**, **354** to drive these motions of the links **330**, **332**, **334**, **336**, **338**, **340**, **342**, **344**, **346**.
(208) Of course all of the support mechanisms described herein can be actuated with electric motors or other actuators. Each joint, or any combination of the joints, could be driven by an electric motor. Sensors could also be used at some or all of the joints to create a control system. This control system can then be connected to the robot control system so that the support mechanism control and the robot control could be coordinated to allow both systems to work together so as to extend the workspace of the robotic device through the robot controls (or other controls) on the console or in a separate control system.
(209) As shown in FIG. **45**, in further alternate implementations, the robotic device **10** can be supported by an exterior robot **360**. Here, the robotic device **10** is supported by an external robot arm **362** having several links **362**, **364**, **366** that have one or more degrees of freedom each, and can be used to remote center or point trace the robot during the surgical procedure. In various implementations, the arm(s) are actively controlled by motors, sensors, and a control system, such as that described herein. It is understood that this external robot **360** in certain implementations can be another surgical robot **360**, an industrial robot, or a custom robot. It is further understood that the external robot **360** in this system **1** could be used in conjunction with other surgical devices and robotic surgical systems, such as laparoscopes **3365** or other known surgical tools and devices. Another version of the external robot support robot **360** could be a parallel linkage external robot **370**, as is shown in the implementation of FIG. **46**.
(210) The parallel linkage external robot **370** of FIG. **46** has an above-mounted robot **370** that in certain implementations is mounted to the ceiling above the surgical theater. In various

implementations, a plurality of radially-disposed proximal links **372** that are actuated by the robot **370** viat actuation joints **371**. These proximal links **372** are in mechanical communication with corresponding joints **374** that are in turn supporting or otherwise positioning support arms **376**. In these implementations, the support arms are in mechanical and/or operational communication with the surgical robot **10** by way of a support joint **378**, such that the movement of the actuation joints **371** is sufficient to urge the support joint laterally, rotationally and/or vertically so as to urge the robot **10** into various additional positions.

(211) FIG. **47** depicts a further alternative embodiment using a ball-like joint **380** supported by a support bar **382** to provide adequate degrees of freedom to the robot **10** near the insertion point **318**. In this implementation, the ball-like joint can be used to adjust the three rotations and one translation (in/out) of the robot **10**, as would be understood by one of skill. It is further understood that in certain implementations, a lever lock could be used to unclamp the ball and allow all four degrees of freedom to move.

(212) As shown in FIGS. **48**A-**48**D-**2**, in further alternate implementations, a “hangman” support structure **400** is used to support the robot **10**. In this implementation, a curved, pivoting support staff **402** is attached to the operating room table **303** and extends above the patient cavity **316**. In this implementation, the support staff **404** is in operational communication with a suspended, articulating “J-hook” **404** that extends over the patient. In this implementation, the J-hook has an additional telescoping link **406** withball joints **408**, **410** at either end and is used to support and position the robot **10**. In various implementations, and as shown in FIGS. **48**B-**1** through **48**D-**2**, rotational movement of the support staff causes corresponding movement of the J-hook **404** and associated link **406** and joints **408**, **410** so as to “swing” the hangman **400** and, in turn, the device **10** about a central position **318**. It is understood that many alternate constructions are possible.

(213) FIG. **49** shows a further alternate implementation showing a rotating support (also referred to as a “Lazy Susan support”) **420** for the robot. In these implementations, the robot (not shown) is supported by a support arm **422** (similar to FIG. **37**, for example) that allows for positioning or adjustment of the support **420** in relation to the insertion point **424** in the patient. That is, a support ring **425** is coupled to a distal end of the support arm **422** and can be positioned adjacent to or on the insertion point **424** of the patient. As is understood in the art, the insertion point **424** can be an incision or a natural orifice in the patient. The support **420** has a “yaw” degree of freedom in the form of a rotational ring **426** that is rotatable in relation to the support ring **425** around the insertion point **424**. Further, the support **420** has a “pitch” degree of freedom by way of the cross-links **428** that are rotatable around an axis that is transverse to the axis of the rotatable ring **426**. Coupling plates **430** are rotatably attached to the cross-links **428** and are configured to couple to the sides of a robotic device (such as, for example, device **10**). According to one implementation, the coupling plates **430** can be any coupling components capable of coupling to a robotic device. The robot (not shown) can be inserted at different depths using the plates **430**, which are attached to the cross-links **428** with a passive joint that allows for errors in acting about the insertion point **424** introduced by variations in the abdominal wall thickness. More specifically, each of the cross-links **428** are rotatably coupled at one end to the rotational ring **426** and rotatably coupled at the other end to the plates **430**, thereby making it possible for the robot (such as robot **10**) to be moveable so as to address any unknown abdominal wall thickness. In one embodiment, the cross-links **428** can be any elongate members that can be rotatably coupled to the rotational ring **426** and the coupling plates **430**.

(214) An alternate rotating support **440** implementation for a device (such as device **10**) is shown in FIGS. **50**A-D. Here, a support ring **444** supported by two support arms **448** and an open arc pitch track (also referred to herein as a “pitch frame”) **446** moveably coupled to the ring **444** provides both yaw (y) and pitch (p) degrees of freedom as shown in FIG. **50**A. More specifically, the pitch track **446** has a coupling component **447** that is slidably coupled to the support ring **444** such that the pitch track **446** can slide along the ring **444** to different positions around the ring **444** as best

shown in FIGS. **50**B-**50**D, thereby providing the yaw (y) degree of freedom for the device **10** in which the device **10** can be rotated around as shown. It is understood that the coupling component **447** can be any mechanism or device that can be slidably coupled to the support ring **444** to allow the pitch track **446** to coupleably slide along the ring **444** as described herein.

(215) The pitch frame **446** can be slidably positioned on the ring **444** and selectively locked into the desired position or location on the ring **444**. Further, a carriage **452** is provided that is slidably coupled to the pitch track **446** and which receives the robotic device **10**. That is, the robotic device **10** can be slidably coupled to the carriage **452**. The carriage **452** can slide along the pitch track **446** in the direction indicated by reference letter p and can be selectively locked into the desired position or location on the track **446**, thereby providing the pitch degree of freedom for the device **10** when coupled thereto. Further, because the device **10** is coupled to the carriage **452** such that it can be slidably positioned in the carriage **452** and selectively locked into the desired position in the carriage, the carriage **452** provides the translational degree of freedom for the device **10**. The pitch track **446**, according to one embodiment, can be any mechanism or device to which the carriage **452** or the robotic device **10** can be slidably coupled so as to provide the pitch degree of freedom. In this implementation, the pitch track **446** has a first arm **446**A and a second arm **446**B that are positioned to define a track space **449** therebetween such that the carriage **452** can be slidably coupled to the first and second arms **446**A, **446**B and slide along the track space **449**. In various embodiments, the two arms **446**A, **446**B are curved in an arc as shown to provide for the pitch degree of freedom such that the carriage **452** moves along the arc and thereby transfers the pitch degree of freedom to the device **10**.

(216) In certain alternative embodiments, the ring **44** can be supported by one support arm or three or more support arms. In this implementation, the two support arms **448** are positioned to align the ring **444** with the insertion point **450** (which can, as with other embodiments, be an incision or a natural orifice).

(217) Another implementation of a robotic device support **460** can be seen in FIG. **51**. In this embodiment, the device support **460** has two frames: a first frame ("first track," "pitch frame," or "pitch track") **462** and a second frame ("second track," "roll frame," or "roll track") **464**. The first track **462** is made up of two arms **462**A, **462**B that are positioned to define a track space **463** therebetween such that the second track **464** can be moveably coupled to the first and second arms **462**A, **462**B and move along the track space **463**. In various embodiments, the two arms **462**A, **462**B are curved in an arc as shown such that the second track **464** moves along the arc. In this implementation, each of the two arms **462**A, **462**B has a gear track **465**A, **465**B coupled to the arms **462**A, **462**B as shown such that the second track **464** can couple at each end to the gear tracks **465**A, **465**B and thereby move along the two arms **462**A, **462**B.

(218) The second track **464** is made up of two arms **464**A, **464**B that are positioned to define a track space **467** therebetween such that a carriage **466** can be moveably coupled to the first and second arms **464**A, **464**B and move along the track space **467**. In various embodiments, the two arms **464**A, **464**B are curved in an arc as shown such that the carriage **466** moves along the arc. In this implementation, each of the two arms **464**A, **464**B has a gear track **469**A, **469**B coupled to the arms **464**A, **464**B as shown such that the carriage **466** can couple to the gear tracks **469**A, **469**B and thereby move along the two arms **464**A, **464**B. The two arms **464**A, **464**B have coupling components **468**A, **468**B at each end thereof that are configured to couple to the arms **462**A, **462**B (and related gear tracks **465**A, **465**B) of the first frame **462**. More specifically, in this embodiment, the coupling components **468**A, **468**B have motors and gears (not shown) that allow for the coupling components **468**A, **468**B to move along the gear tracks **465**A, **465**B. That is, the gears (not shown) in the coupling components **468**A, **468**B are coupled to the gear tracks **465**A, **465**B respectively and the motors (not shown) can actuate those gears to turn in the appropriate direction to cause the second track **464** to move along the two arms **462**A, **462**B of the first track **462**.

(219) The carriage **466** is configured to receive the robotic device **10** in a fashion similar to the

carriage **452** discussed above with respect to FIGS. **50**A-**50**D. That is, the carriage **466** is moveably coupled to the second track **464** and receives the robotic device **10** such that the robotic device **10** can be slidably coupled to the carriage **466**. The carriage **466** in this embodiment has motors and gears (not shown) that allow for the carriage **466** to move along the gear tracks **469**A, **469**B of the second track **464** in a fashion similar to the coupling components **468**A, **468**B described above. Alternatively, the first and second tracks **462**, **464** can each be any mechanism or device to which the second track **464** or carriage **466** can be slidably coupled.
(220) According to one implementation, the two frames **462**, **464** can provide for three degrees of freedom. That is, the second frame **464** can move along the first track space **463** via the coupling components **468**A, **468**B moving along the first and second arms **462**A, **462**B, thereby providing the pitch degree of freedom for the device **10** as represented by the arrow P. Further, the carriage **466** can move along the second track space **467** by moving along the first and second arms **464**A, **464**B, thereby providing the roll degree of freedom for the device **10** as represented by the arrow R. In addition, the device **10** is slideably positioned in the carriage **466** such that it can moved translationally toward and away from the surgical space, thereby providing the translational degree of freedom for the device **10**. It is also understood that a fourth degree of freedom can be provided by coupling this support **460** to a rotatable support ring (such as the ring **444** discussed above) to achieve a yaw degree of freedom, thereby providing for positioning the robot **10** in three degrees of freedom (pitch, roll, and yaw as described herein) around a center of rotation **470**, along with the translational degree of freedom.
(221) FIG. **52** depicts another support embodiment **500** having a track **502** along which the robotic device **10** can move in a similar fashion to the carriage embodiments discussed above. It is understood that the track **502** can have any of the features described above with respect to other track embodiments. A handle **504** is coupled to one end of the track **502** and can slide the track **502** translationally or rotate the track **502**. More specifically, the handle **504** has an inner component **504**B and an outer component **504**A that is slideable in relation to the inner component **504**B. Further, the handle **504** is coupled to the track **502** such that when the outer component **504**A is slid in relation to the inner component **504**B, the outer component **504**A moves the track **502** in the same translational direction as indicated by arrow T. For example, when the outer component **504**A is urged distally toward the surgical space (represented by the sphere S), the track **502** is also urged toward the surgical space in the direction reflected by arrow T, and when the outer component **504**A is urged away, the track **502** is also urged away. In addition, the entire handle **504** can also be rotated around its own longitudinal axis, thereby urging the track **502** to rotate in the same direction as arrow P, thereby resulting in the pitch degree of freedom. Further, the device **10** can be slidably or otherwise moveably coupled to the track **502** such that it can be urged translationally toward or away from the surgical space and can be rotated around its own longitudinal axis.
(222) A further support embodiment **520** is depicted in FIG. **52**B. In this embodiment, the support **520** has two tracks **522**, **524** that are coupled or “in parallel.” That is, the support **520** has a single carriage **526** that is coupled to both the first and second tracks **522**, **524**, thereby resulting in coupled movement of the carriage **526** in relation to the two tracks **522**, **524**. It is understood that the two tracks **522**, **524** can be structured in a similar fashion to and have similar features to the previous track embodiments discussed above. Further, the carriage **526** can be similar to the previously described carriage embodiments, except with respect to the fact that the instant carriage **526** is directly coupled to both of the tracks **522**, **524** as depicted. That is, in this implementation, the carriage **526** has two portions (or segments): a top or first portion **526**A that is moveably coupled to the second track **524** and a bottom or second portion **526**B that is moveably coupled to the first track **522**.
(223) When the carriage **526** slides along the first track **522**, the second track **524** and the robot **10** rotate as reflected in arrow A. When the carriage **526** slides along the second track **524**, the first track **522** and the robot **10** rotate as reflected in arrow B. Further, as in other carriage embodiments

discussed above, the carriage **526** receives the robotic device **10** such that the robotic device **10** can be slidably coupled to the carriage **526**, thereby providing the translational degree of freedom for the device **10**. In addition, according to certain embodiments, the two tracks **522**, **524** can be coupled to a rotational support ring **528** such that both the tracks **522**, **524** (along with the carriage **526** and device **10**) can rotate with the ring **528** or in relation to the ring **528** in a fashion similar to the rotational ring embodiments discussed above.

(224) FIG. **52**C depicts a further implementation of a support **540**. In this implementation, the support **540** has a single track **542** that is rotatably positioned on a ring support **544**. A carriage **546** is moveably coupled to the track **542**. It is understood that the track **542** can be structured in a similar fashion to and have similar features to the previous track embodiments discussed above. Further, the carriage **546** can be similar to the previously described carriage embodiments.

(225) When the carriage **546** slides along the track **542**, the robot **10** rotates as reflected by arrow A. When the track **542** is rotated in relation to the support ring **544** (or, alternatively, the ring **544** is rotated), the carriage **546** and the robot **10** rotate as reflected in arrow B. Further, as in other carriage embodiments discussed above, the carriage **546** receives the robotic device **10** such that the robotic device **10** can be slidably coupled to the carriage **546**, thereby providing the translational degree of freedom for the device **10**.

(226) Another embodiment of a robotic device support **560** can be seen in FIG. **52**D. In this embodiment, the device support **560** has two frames: a first frame or track **562** and a second frame or track **564**. The two frames **562**, **564** are coupled to each other in a fashion similar to the frames **462**, **464** in the support **460** discussed in detail above. That is, the second track **564** can be moveably coupled to and move along the first track **562**. Either or both of the tracks **562**, **564** can have gear tracks as described above. Alternatively, the tracks **562**, **564** can have any configuration disclosed or contemplated herein with respect to tracks. In certain implementations, the second track **564** has coupling components (not shown) at each end that are configured to moveably couple to the first frame **562**. Alternatively, the second track **546** can be moveably coupled to the first track **562** in any fashion.

(227) According to one embodiment, the device **10** can be coupled to the support **560** via a carriage (not shown), which can be configured according to any carriage embodiment disclosed or contemplated herein. Alternatively, the device **10** can be coupled directly to the track **564** such that the device **10** can be movably coupled to the track **564**. As such, the device **10** can move along the track **564** as reflected by arrow A, can move toward or away from the surgical space, resulting in the translational degree of freedom as reflected by arrow T, and can rotate around its own longitudinal axis as reflected by arrow R. In addition, the second track **564** can move along the first track **562**, as reflected by arrow B. It is also understood that a further degree of freedom can be provided by coupling this support **560** to a rotatable support ring (such as any of the support ring embodiments discussed above).

(228) FIG. **52**E depicts another embodiment of a support **580**. In this implementation, the support **580** utilizes ball joints. That is, the support has a first or upper ring **582** and a second or lower ring **584** that are coupled by three arms **586**A, **586**B, **586**C. Each of the three arms **586**A, **586**B, **586**C has ball joints **588** at each end, such that the three arms **586**A, **586**B, **586**C are coupled at one end to the first ring **582** via ball joints **588** and at the other end to the second ring **584** via ball joints **588**. The robot **10** is coupled to the second ring **584** as shown. In one embodiment, the robot **10** is slidably coupled to the second ring **584** in a fashion similar to the carriage embodiments above such that the robot **10** can be slid toward or away from the surgical space, thereby resulting in a translational degree of freedom.

(229) It is understood that the configuration of the three arms **586**A-C coupled to the two rings **582**, **584** via ball joints can result in a single center of rotation for the robotic device **10** at some point below the second ring **584**. As such, if the support **580** is positioned above a patient, the center of rotation can be aligned with the surgical insertion point (such as an incision) in a fashion similar to

above support embodiments.

(230) A further implementation of a robotic device support **600** is shown in FIG. **52**F. In this embodiment, the device support **600** has two frames: a first frame or track **602** and a second frame or track **604**. The two frames **602**, **604** are coupled to each other in a fashion similar to the frames **462**, **464** in the support **460** or the frames **562**, **564** in the support **560**, both of which are discussed in detail above. That is, the second track **604** can be moveably coupled to and move along the first track **602**. A carriage **606** is moveably coupled to move along the second track **604**. Either or both of the tracks **602**, **604** can have gear tracks as described above. Alternatively, the frames **602**, **604** can have any configuration disclosed or contemplated herein with respect to frames. In certain implementations, the second track **604** has coupling components **608**A, **608**B at each end that are configured to moveably couple to the first frame **602**. Alternatively, the second track **604** can be moveably coupled to the first track **602** in any fashion.

(231) The carriage **606** (and thus the device **10**) can move along the second frame **604** as reflected by arrow A, can move toward or away from the surgical space in relation to the carriage **606**, resulting in the translational degree of freedom as reflected by arrow T, and can rotate around its own longitudinal axis as reflected by arrow R. In addition, the second track **604** can move along the first track **602**, as reflected by arrow B. It is also understood that a further degree of freedom can be provided by coupling this support **600** to a rotatable support ring (such as any of the support ring embodiments discussed above).

(232) One control console **720** implementation is shown in FIG. **53**, with a main display **722** that shows the view from the robot camera (such as robotic device **10**). A secondary touch screen **724** below the main display is used to interface with various functions of the robot, camera, and system. Two haptic hand controllers **726**, **728** are used as user input devices in this embodiment. These haptic hand controllers **726**, **728** are capable of measuring the motion of the surgeon's hands as applied at the controllers **726**, **728** and applying forces and torques to those hands so as to indicate various information to the surgeon through this haptic feedback. The console **720** also has pedals **730** to control various functions of the robot. The height of the surgeon console **720** can be varied to allow the surgeon to sit or stand. Further discussion of the operation of the haptic feedback can be found in relation to U.S. patent application Ser. No. 15/227,813 and the other applications incorporated by reference herein.

(233) FIG. **54** shows various interoperability and wiring possibilities for the system **1**. Many concepts are possible, but three exemplary embodiments are given here in the context of FIG. **54**. In one wiring implementation, the surgeon console **720** (or any other console disclosed or contemplated herein) interfaces with the electrosurgical generator **740**. Then a “monster cable” **742** connects the surgeon console **720** to a breakout connector **744** near the surgical environment. The camera **746** and robot **10** are then connected to the breakout connector **744**. In this scenario, the energy of the electrosurgical unit **740** is routed through the surgeon console **720** prior to being sent to the robot **10**. In this implementation, no return pad is provided.

(234) Alternatively, according to another wiring concept, a return pad **748** is provided that is coupled to the breakout connector **744** such that the monopolar electrosurgical energy is routed through the breakout connector **744**, the monster cable **742**, and the console **720** before returning to the electrosurgical generator **740**.

(235) In a further wiring alternative, the return pad **748** is coupled to the electrosurgical generator **740** such that the energy of the electrosurgical unit is routed through the surgeon console **720** prior to being sent to the robot **10** as a result of the monopolar electrosurgical energy being routed directly back to the electrosurgical generator **740**.

(236) In other embodiments, the system **1** can have a cabling connector enclosure or cluster with an interface box positioned at one of several possible locations on the system **1**. For example, FIG. **55** depicts the system **1** with an interface box (also referred to herein as a “pod”) **760** hung on the table rail of the surgical table **762**. In this embodiment, the system **1** has support electronics and

equipment such as cautery, light, and other functions **764** that are coupled to the interface box **760**. The console **720** is also coupled to the interface box **760**. The pod **760** simplifies connections of the robot **1** in the surgical area. The pod **760** can be sterile, or not sterile and covered with a sterile drape, or not sterile at all. The function of the pod **760** is to simplify the cabling required in the surgical space and to simplify the connection of the robot and camera **1** to the surgeon console **720**. The interface box **760** can be hung on the surgical table **762** inside or outside the sterile field. The box **760** in some embodiments has indicators such as lights or screens (not shown) that inform the user that a proper connection has been made and give other forms of feedback to the user. The pod **760** can also have an interface in the form of buttons, touchscreens, or other interface mechanisms to receive input from the user.
(237) In certain alternative embodiments, the pod **760** can be placed on the floor next to or at some distance from the surgical table **762**. Alternatively, the pod **760** can be hung or connected to other locations or placed on the floor outside the sterile field.
(238) One use of this can be to mount the pod to the bed rail and then at a later time to bring in the sterile robot and camera. The robot and camera pigtails can then be handed to a non-sterile person to connect to the pod. This allows for a clean interface between the sterile and non-sterile field. The pod end could also be draped so that it could enter the sterile field and be robot and camera connections can be assembled at a sterile table so it can then be brought fully functional and sterile to the surgeon at the bedside.
(239) The interface box can also be connected to other support electronics and equipment such as cautery, light, and other functions, and the an interface box can be designed to be on the floor or another location outside the sterile field with support electronics.
(240) Although the disclosure has been described with reference to preferred embodiments, persons skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the disclosed apparatus, systems and methods.

Claims

1. A robotic surgical device, comprising: a) a device body; b) a first shoulder operably coupled to a distal end of the device body, the first shoulder comprising: i) a first shaft; ii) a first gear pair wherein rotation of the first shaft drives the first gear pair; and iii) a second gear pair wherein the first gear pair drives the second gear pair; c) a second shoulder operably coupled to the distal end of the device body, the second shoulder comprising: i) a second shaft; ii) a third gear pair wherein rotation of the second shaft drives the third gear pair; and iii) a fourth gear pair wherein the third gear pair drives the fourth gear pair; and d) a first robotic arm operably coupled to the first shoulder; and e) a second robotic arm operably coupled to the second shoulder.
2. The robotic surgical device of claim 1, wherein the first and second robotic arms are moveable in a workspace extending from a front side to a back side of the device body.
3. The robotic surgical device of claim 2, wherein the workspace extends 180 degrees from the front side to the back side of the device body.
4. The robotic surgical device of claim 1, further comprising at least one actuator.
5. The robotic surgical device of claim 1, wherein the first and second robotic arms comprise at least one motor disposed within each of the first and second robotic arms.
6. The robotic surgical device of claim 1, further comprising a camera component disposed through a lumen defined in the device body.
7. The robotic surgical device of claim 6, wherein the camera component is configured to be an adjustable height camera.
8. The robotic surgical device of claim 6, wherein the camera component is constructed and arranged to be capable of pitch and yaw.
9. The robotic surgical device of claim 6, wherein the camera comprises a distal tip configured to

orient to a defined workspace.
10. The robotic surgical device of claim 6, wherein the camera component comprises at least one light.
11. The robotic surgical device of claim 1, further comprising first and second end effectors.
12. A robotic surgical device comprising: a) a device body; b) a first shoulder operably coupled to a distal end of the device body, the first shoulder comprising: i) a first shaft; ii) a first gear pair wherein rotation of the first shaft drives the first gear pair; and iii) a second gear pair wherein the first gear pair drives the second gear pair; c) a second shoulder operably coupled to the distal end of the device body, the second shoulder comprising: i) a second shaft; ii) a third gear pair wherein rotation of the second shaft drives the third gear pair; and iii) a fourth gear pair wherein the third gear pair drives the fourth gear pair; d) a first robotic arm operably coupled to the first shoulder; and e) a second robotic arm operably coupled to the second shoulder; and f) a camera component disposable through a lumen in the device body.
13. The robotic surgical device of claim 12, wherein the first and second shoulders are configured to allow the first and second robotic arms to be extendable to a front side and a back side of the device body.
14. The robotic surgical device of claim 12, wherein the first robotic arm further comprises an upper arm and a forearm.
15. The surgical robotic device of claim 12, wherein the first robotic arm further comprises at least one first arm actuator disposed within the first robotic arm.
16. The surgical robotic device of claim 12, wherein the second robotic arm further comprises at least one second arm actuator disposed within the second robotic arm.
17. A robotic surgical system, comprising: a. a robotic surgical device comprising: i. an elongate body comprising a lumen defined within the body; ii. a first shoulder operably coupled to the elongate body, the first shoulder comprising: (A) a first shaft; (B) a first gear pair, wherein rotation of the first shaft drives the first gear pair; and (C) a second gear pair, wherein the first gear pair drives the second gear pair; iii. a second shoulder operably coupled to the elongate body, the second shoulder comprising: (A) a second shaft; (B) a third gear pair, wherein rotation of the second shaft drives the third gear pair; and (C) a fourth gear pair, wherein the third gear pair drives the fourth gear pair; iv. a first robotic arm operably coupled to the first shoulder; and V. a second robotic arm operably coupled to the second shoulder; and b. a camera component removably disposable through the lumen, the camera component comprising: (A) a rigid section; (B) an optical section; and (C) a flexible section operably coupling the optical section to the rigid section.
18. The surgical robotic system of claim 17, wherein the robotic surgical device further comprises a robotic arm workspace extending from a front side to a back side of the elongate body.
19. The surgical robotic system of claim 17, wherein the first and second arms comprise at least one motor disposed in each arm.
20. The robotic surgical system of claim 17, further comprising a surgical console operably coupled to the robotic surgical device and the camera component.