



US 20210000555A1

(19) **United States**

(12) **Patent Application Publication**  
**Shelton, IV et al.**

(10) **Pub. No.: US 2021/0000555 A1**

(43) **Pub. Date: Jan. 7, 2021**

(54) **WIRELESS PAIRING OF A SURGICAL DEVICE WITH ANOTHER DEVICE WITHIN A STERILE SURGICAL FIELD BASED ON THE USAGE AND SITUATIONAL AWARENESS OF DEVICES**

341, filed on Dec. 28, 2017, provisional application No. 62/611,340, filed on Dec. 28, 2017, provisional application No. 62/611,339, filed on Dec. 28, 2017.

**Publication Classification**

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(51) **Int. Cl.**

- A61B 34/00* (2006.01)
- G16H 40/63* (2006.01)
- A61B 34/10* (2006.01)
- A61B 34/30* (2006.01)
- G16H 10/60* (2006.01)
- A61B 18/08* (2006.01)
- A61B 18/12* (2006.01)

(72) Inventors: **Frederick E. Shelton, IV**, Hillsboro, OH (US); **Jason L. Harris**, Lebanon, OH (US)

(21) Appl. No.: **16/931,712**

(22) Filed: **Jul. 17, 2020**

(52) **U.S. Cl.**

- CPC ..... *A61B 34/25* (2016.02); *G16H 40/63* (2018.01); *A61B 34/10* (2016.02); *A61B 34/30* (2016.02); *A61B 34/20* (2016.02); *G16H 10/60* (2018.01); *A61B 18/082* (2013.01); *A61B 18/1206* (2013.01); *A61B 2034/107* (2016.02); *A61B 34/76* (2016.02)

**Related U.S. Application Data**

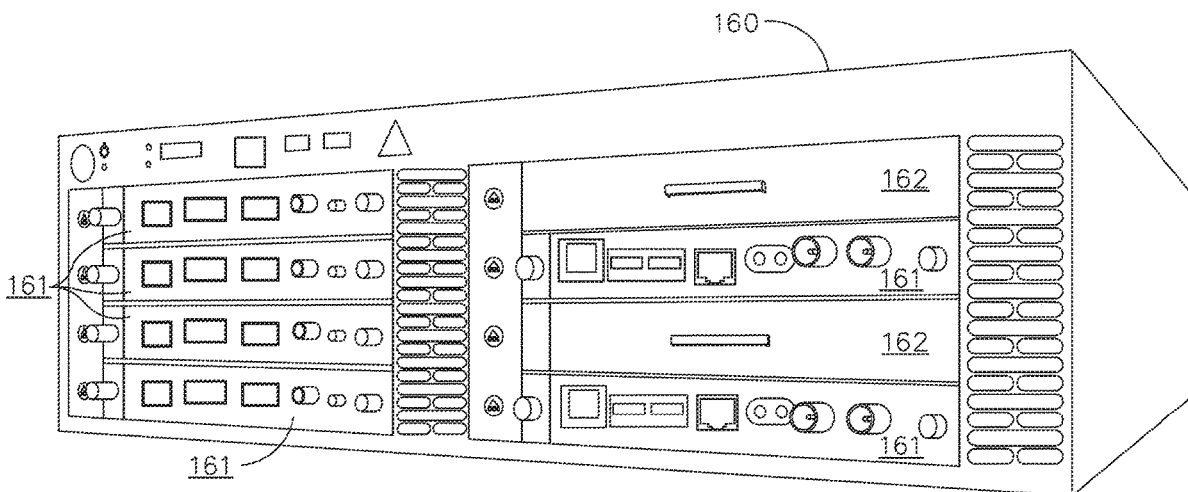
(63) Continuation of application No. 16/182,231, filed on Nov. 6, 2018, now Pat. No. 10,758,310.

(60) Provisional application No. 62/729,186, filed on Sep. 10, 2018, provisional application No. 62/692,747, filed on Jun. 30, 2018, provisional application No. 62/692,748, filed on Jun. 30, 2018, provisional application No. 62/692,768, filed on Jun. 30, 2018, provisional application No. 62/659,900, filed on Apr. 19, 2018, provisional application No. 62/650,898, filed on Mar. 30, 2018, provisional application No. 62/650,887, filed on Mar. 30, 2018, provisional application No. 62/650,882, filed on Mar. 30, 2018, provisional application No. 62/650,877, filed on Mar. 30, 2018, provisional application No. 62/640,417, filed on Mar. 8, 2018, provisional application No. 62/640,415, filed on Mar. 8, 2018, provisional application No. 62/611,

(57)

**ABSTRACT**

A surgical system includes a first surgical device comprising a control circuit. The control circuit is configured to be situationally aware of events occurring within the vicinity of the first surgical device according to data received from a database, a patient monitoring device, or a paired surgical device, or any combination of a database, patient monitoring device, or paired surgical device. The control circuit is configured to be wirelessly paired with a second surgical device according to usage of the first surgical device and the events of which the first surgical device is situationally aware.



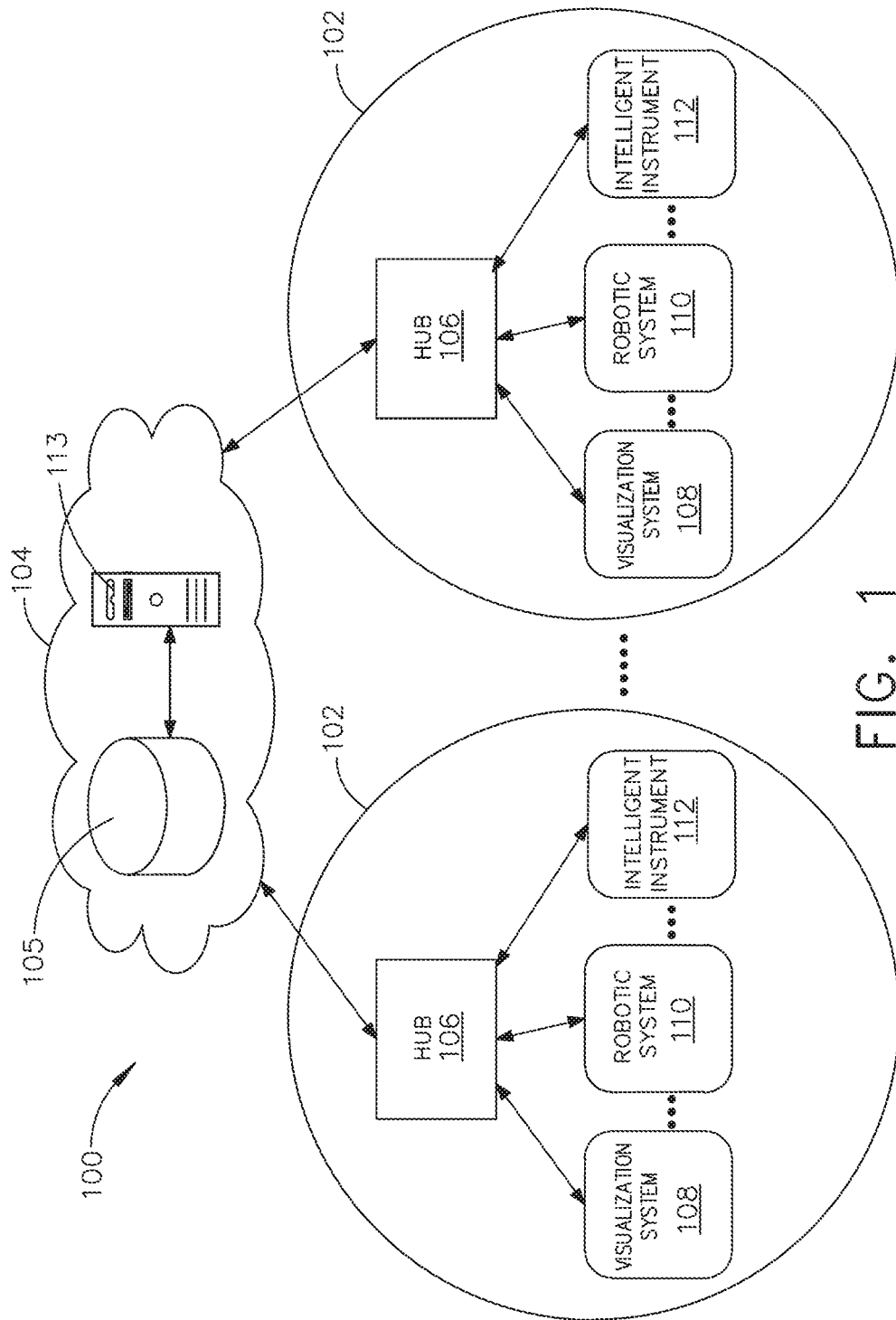
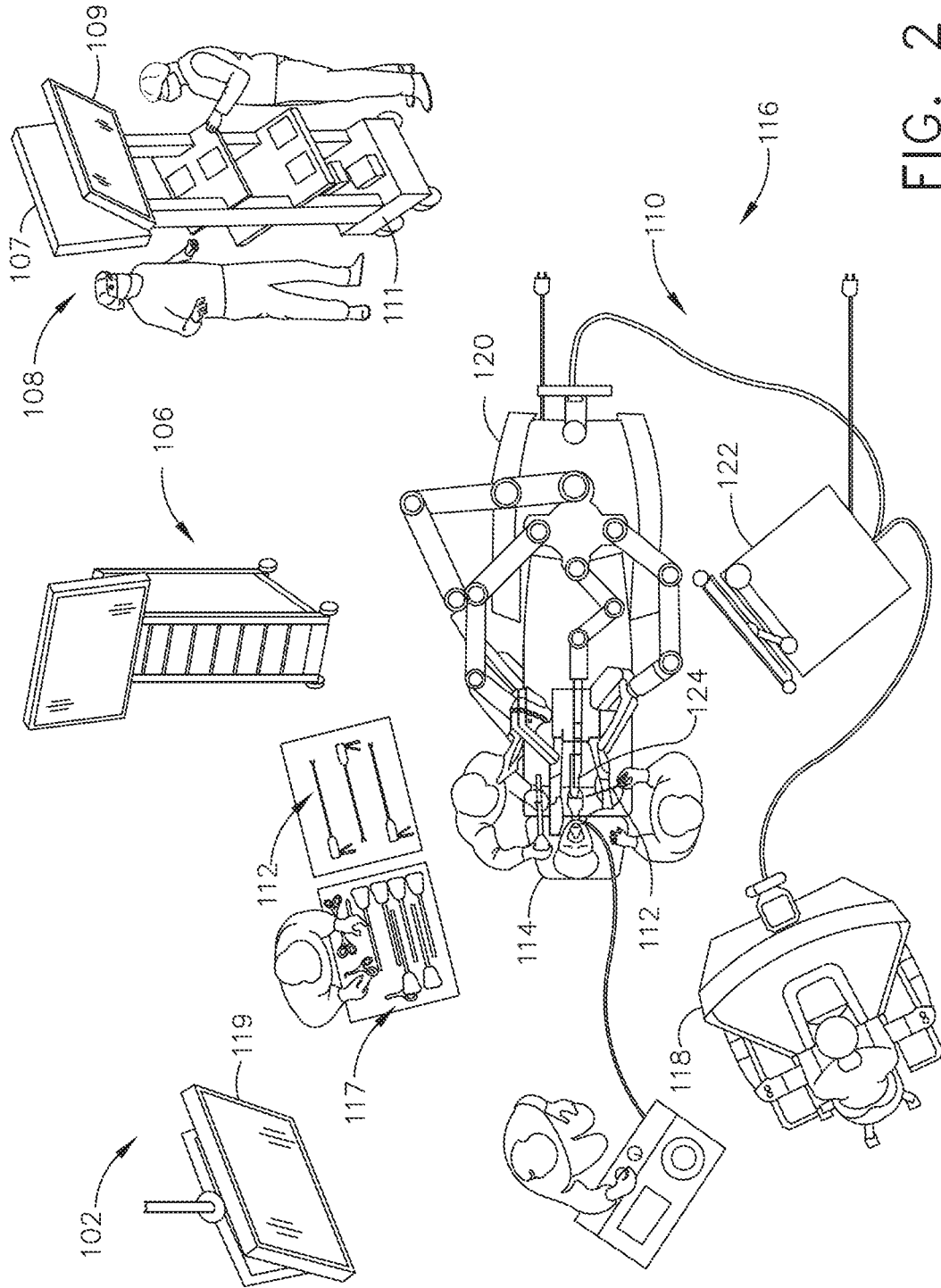


FIG. 1



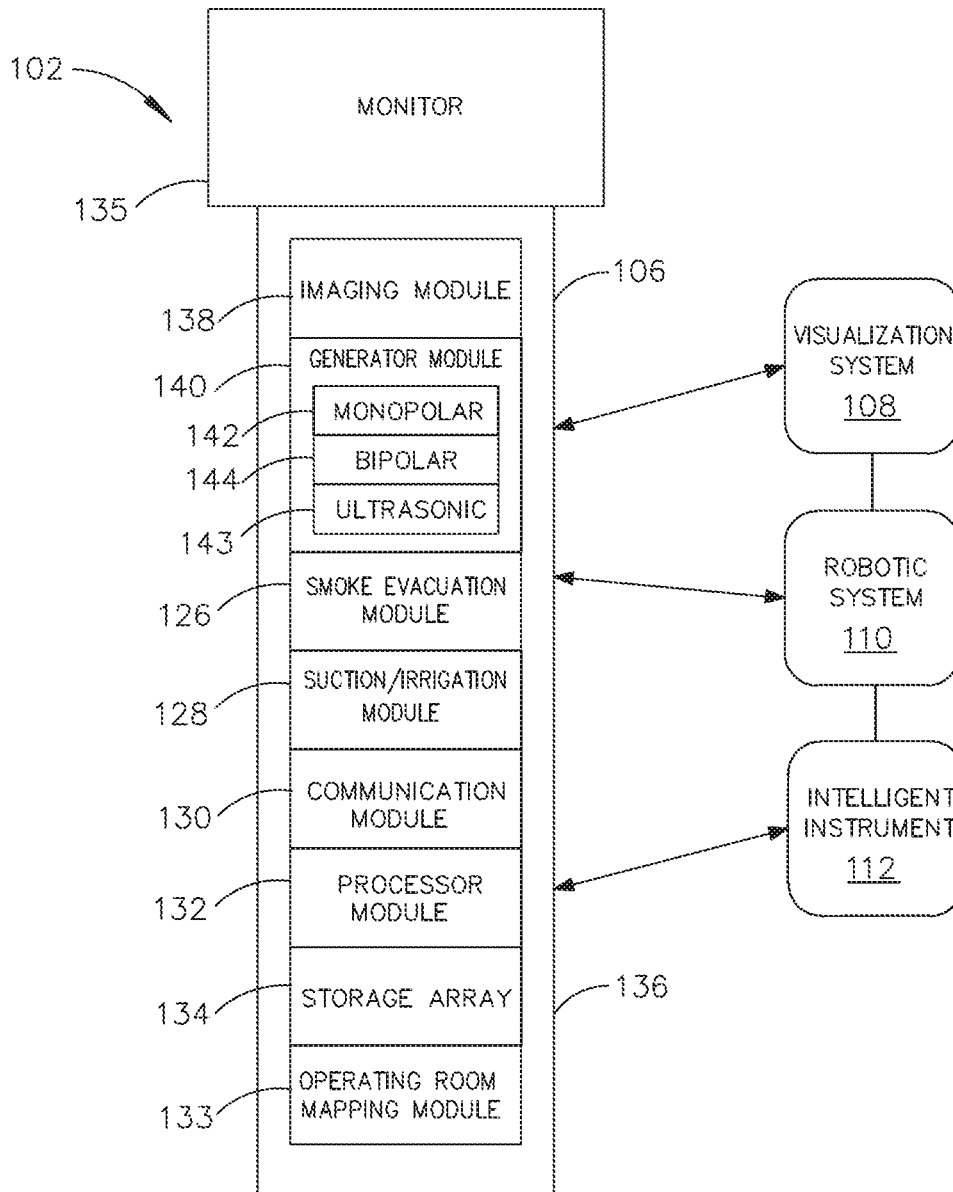


FIG. 3

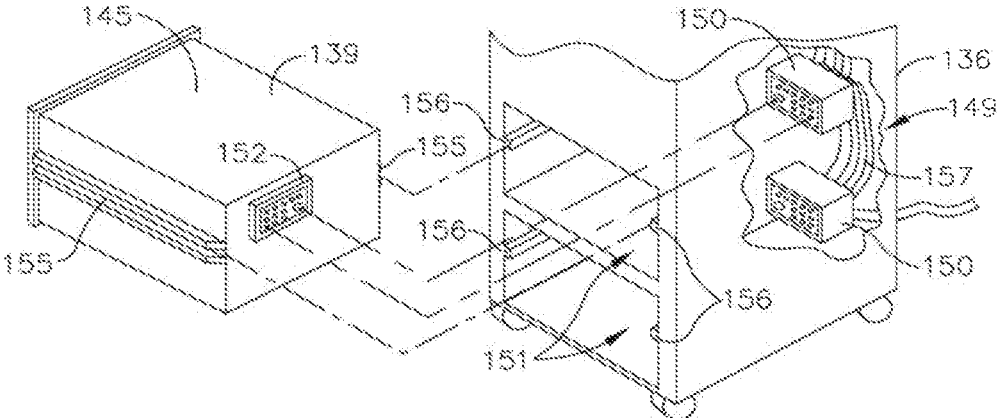


FIG. 4

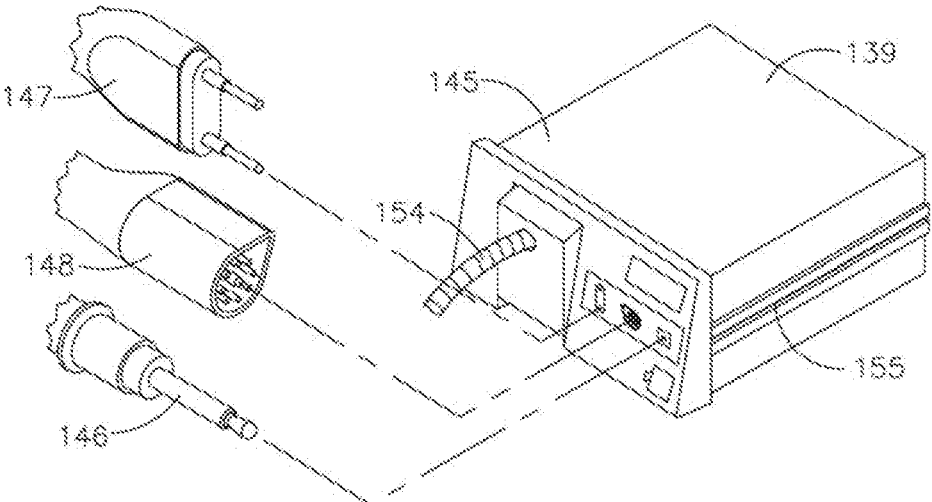


FIG. 5

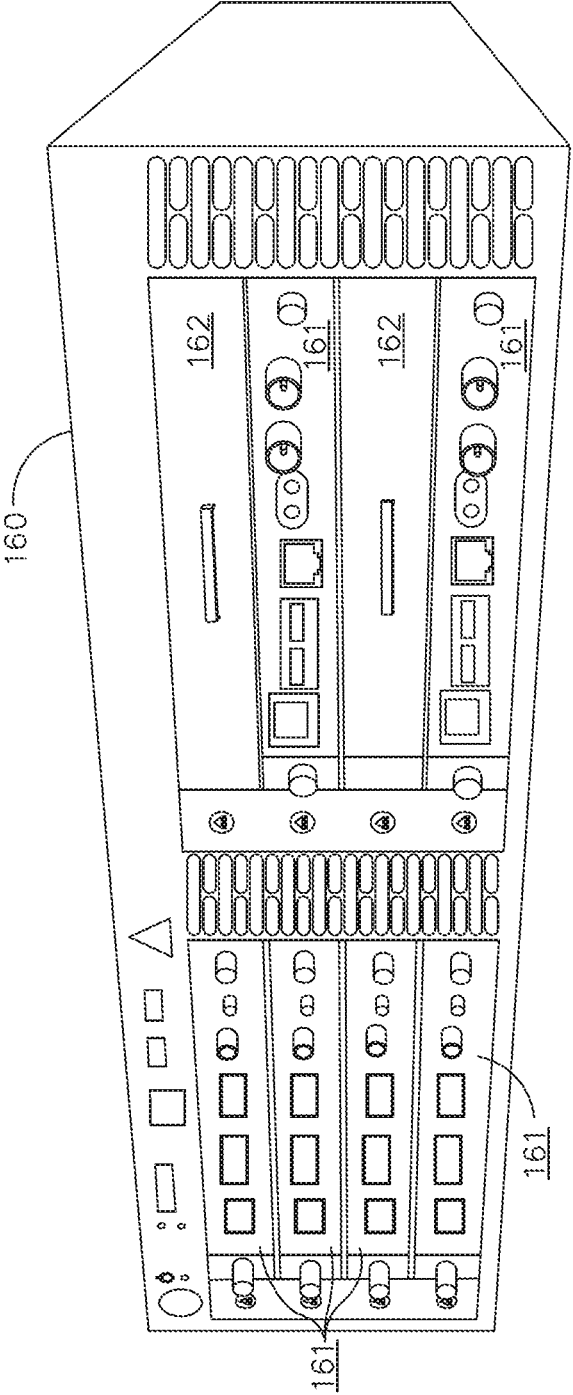


FIG. 6

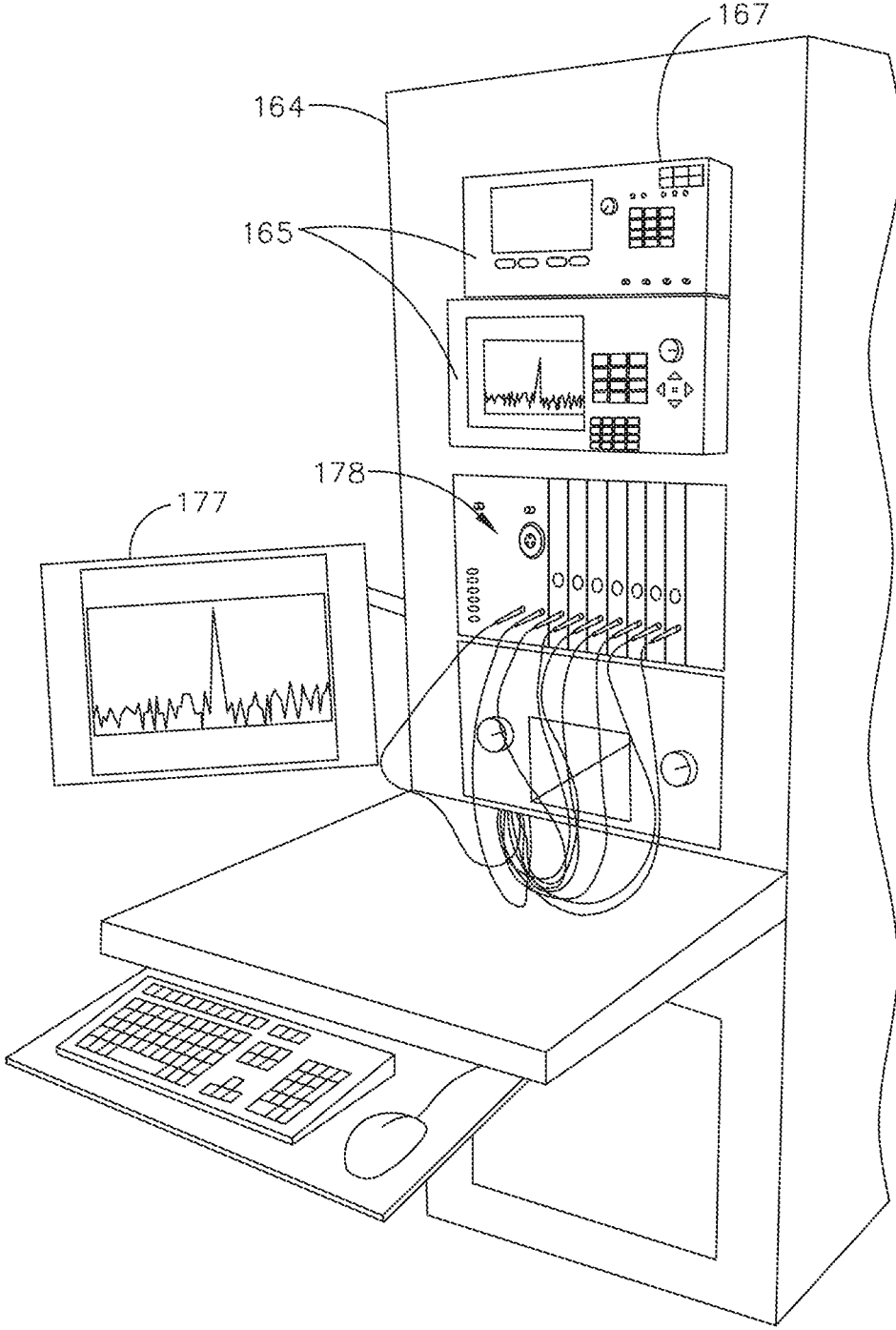


FIG. 7

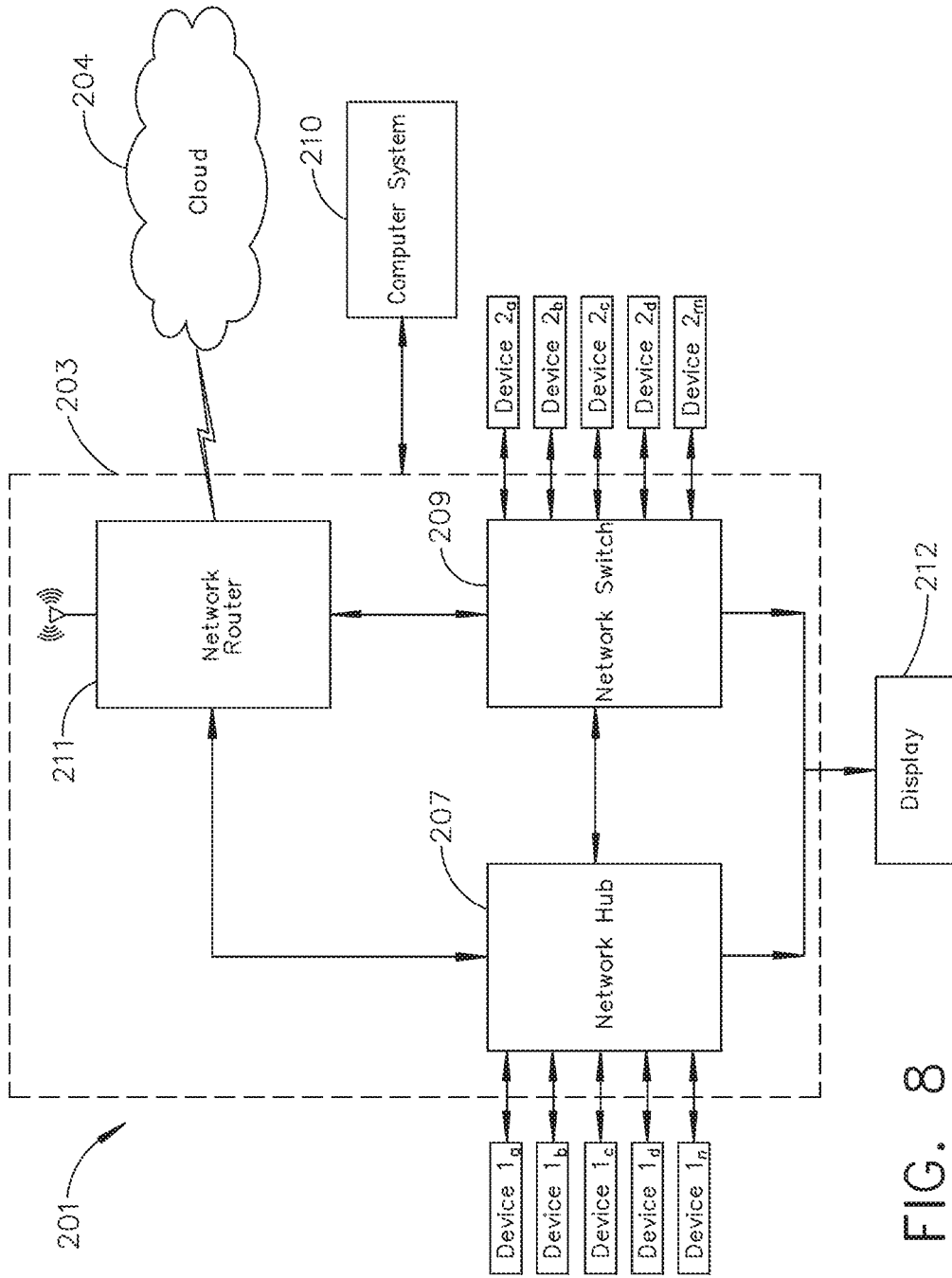


FIG. 8



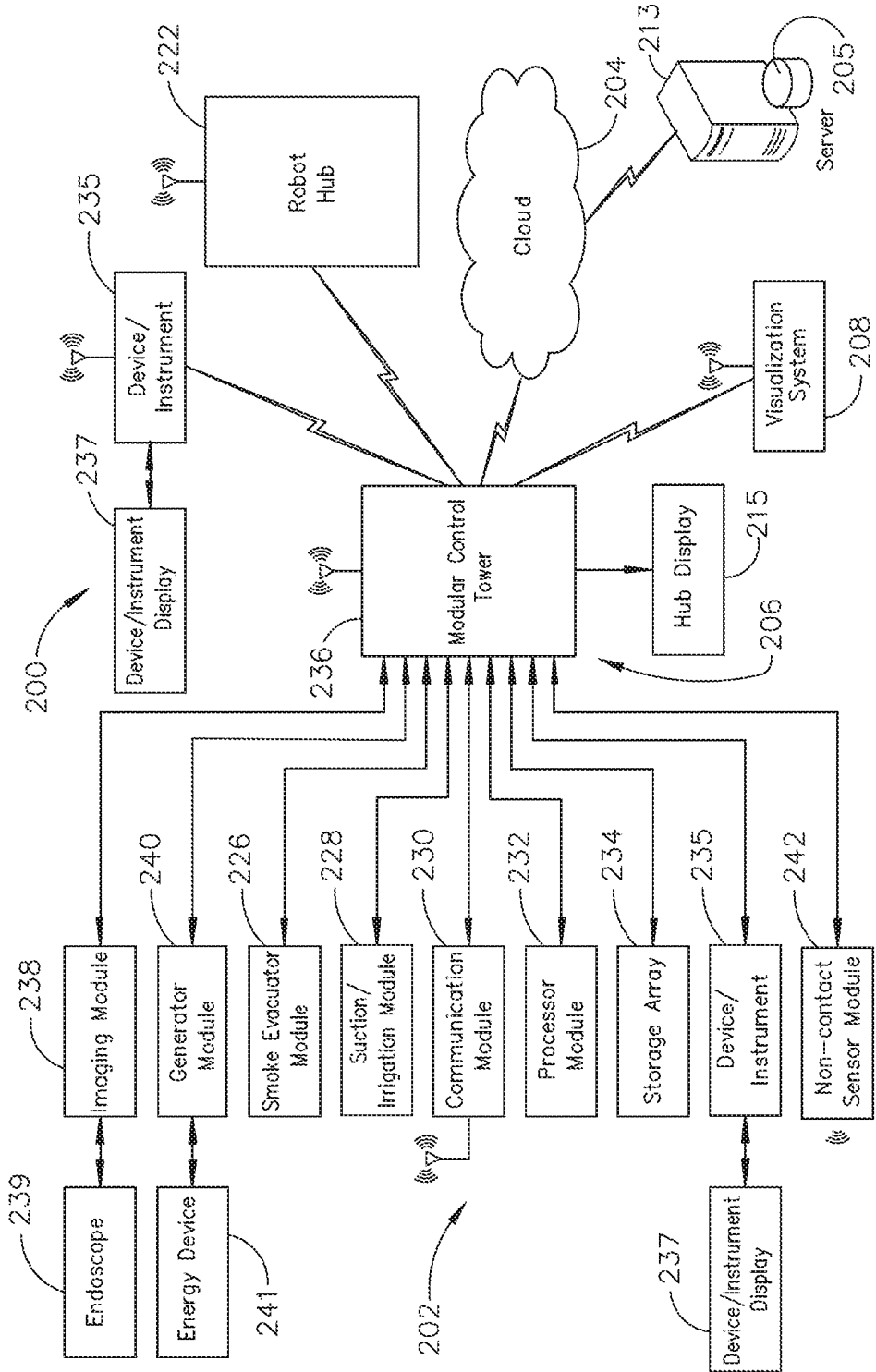


FIG. 9

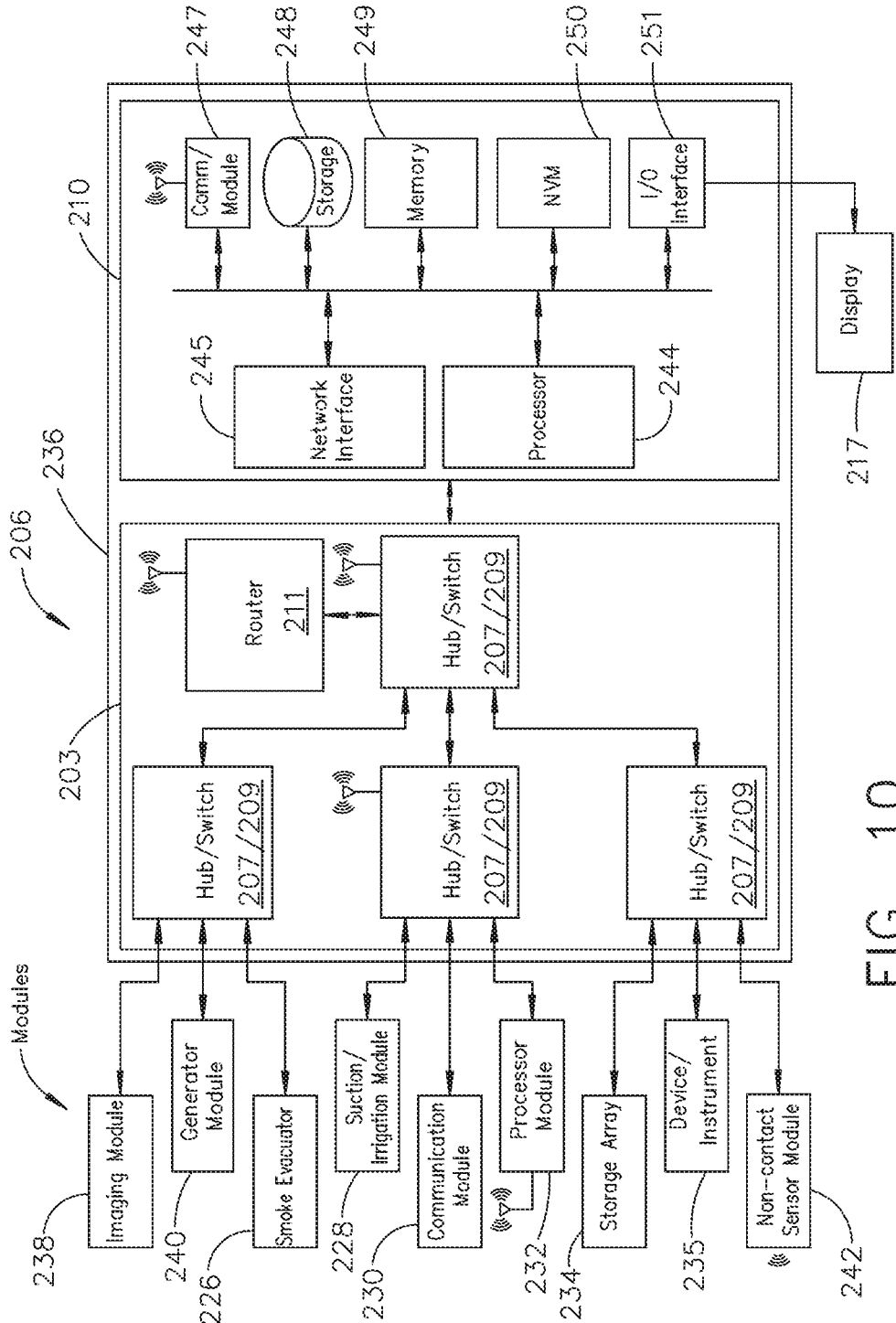


FIG. 10

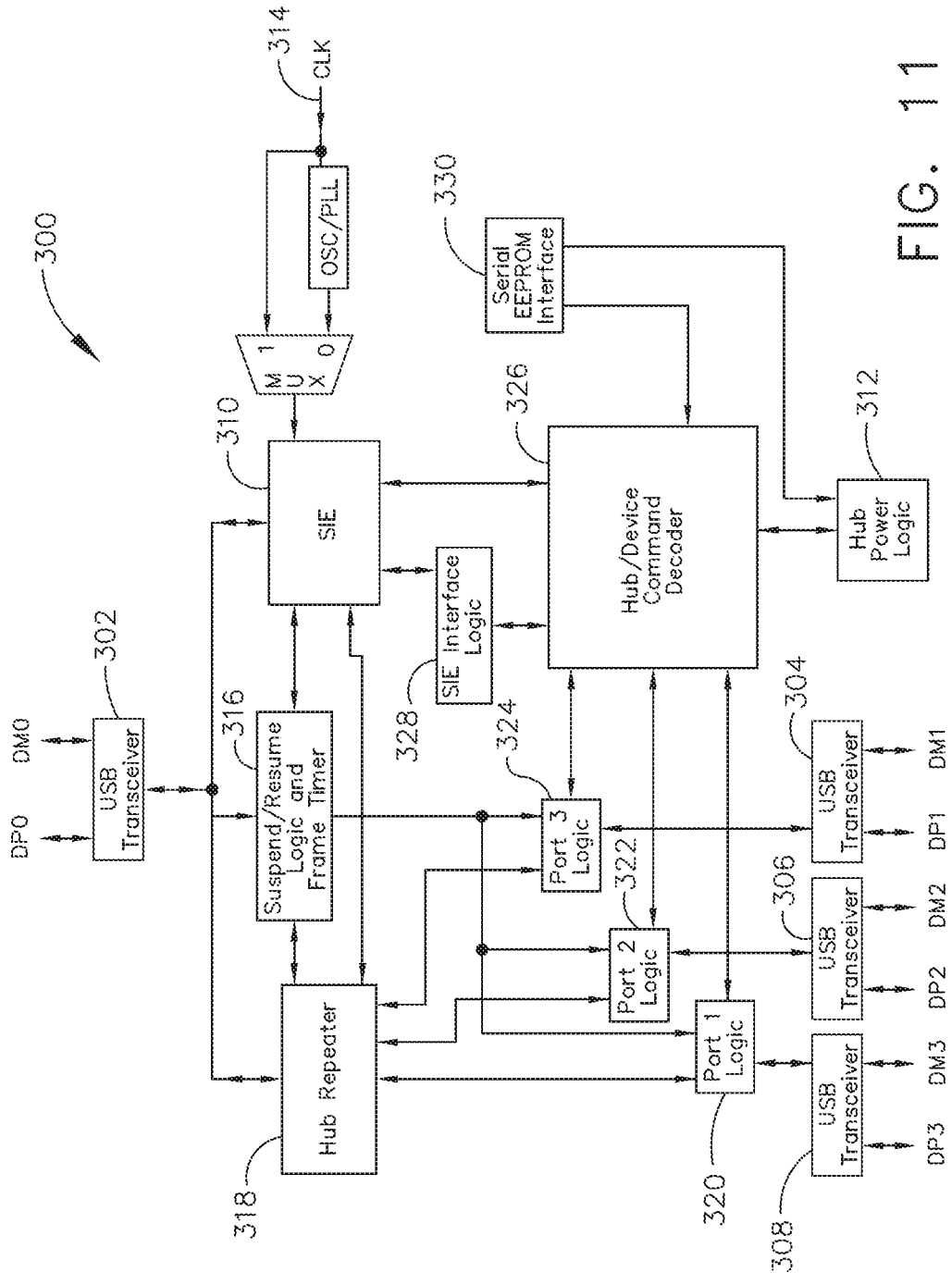


FIG. 11

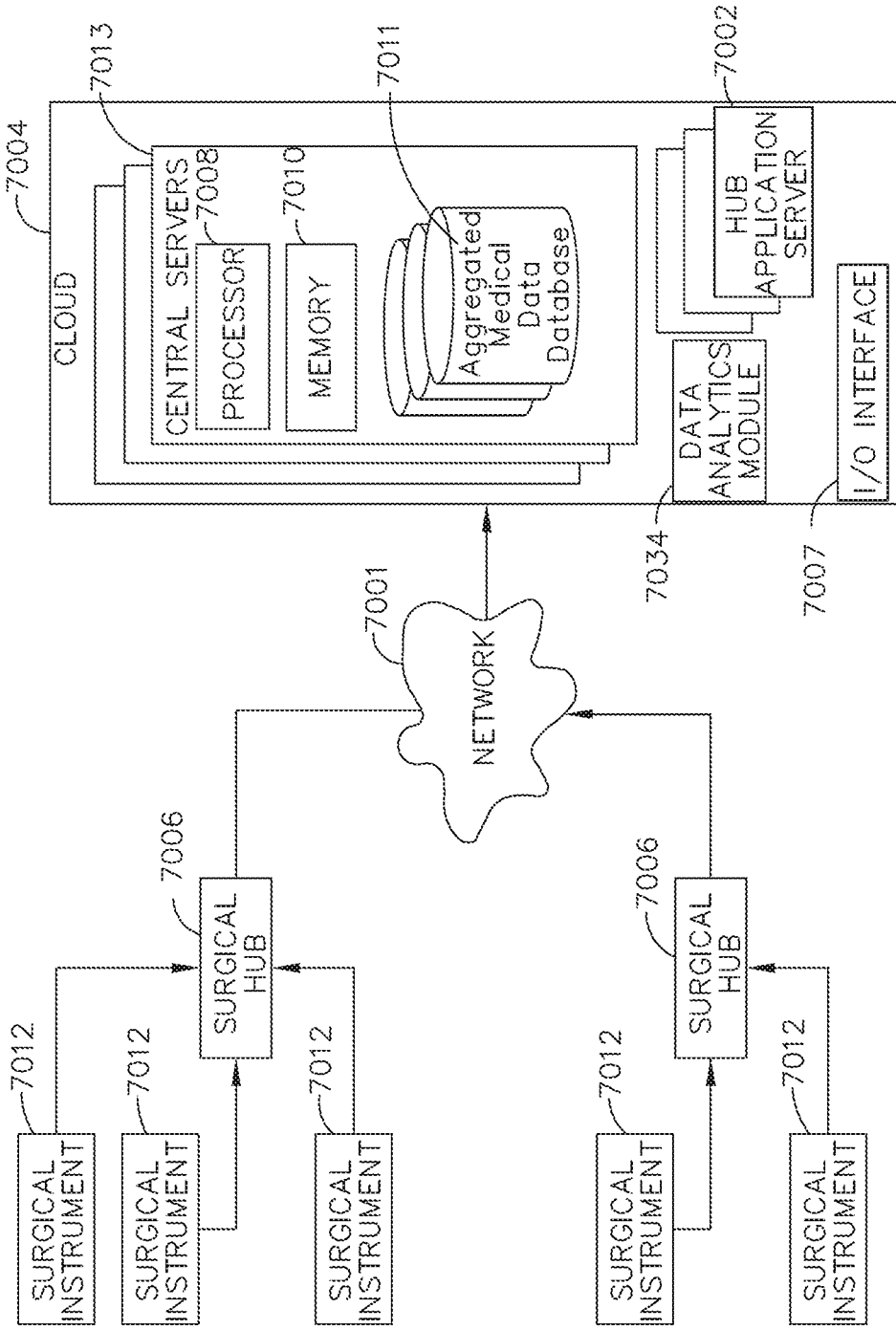


FIG. 12

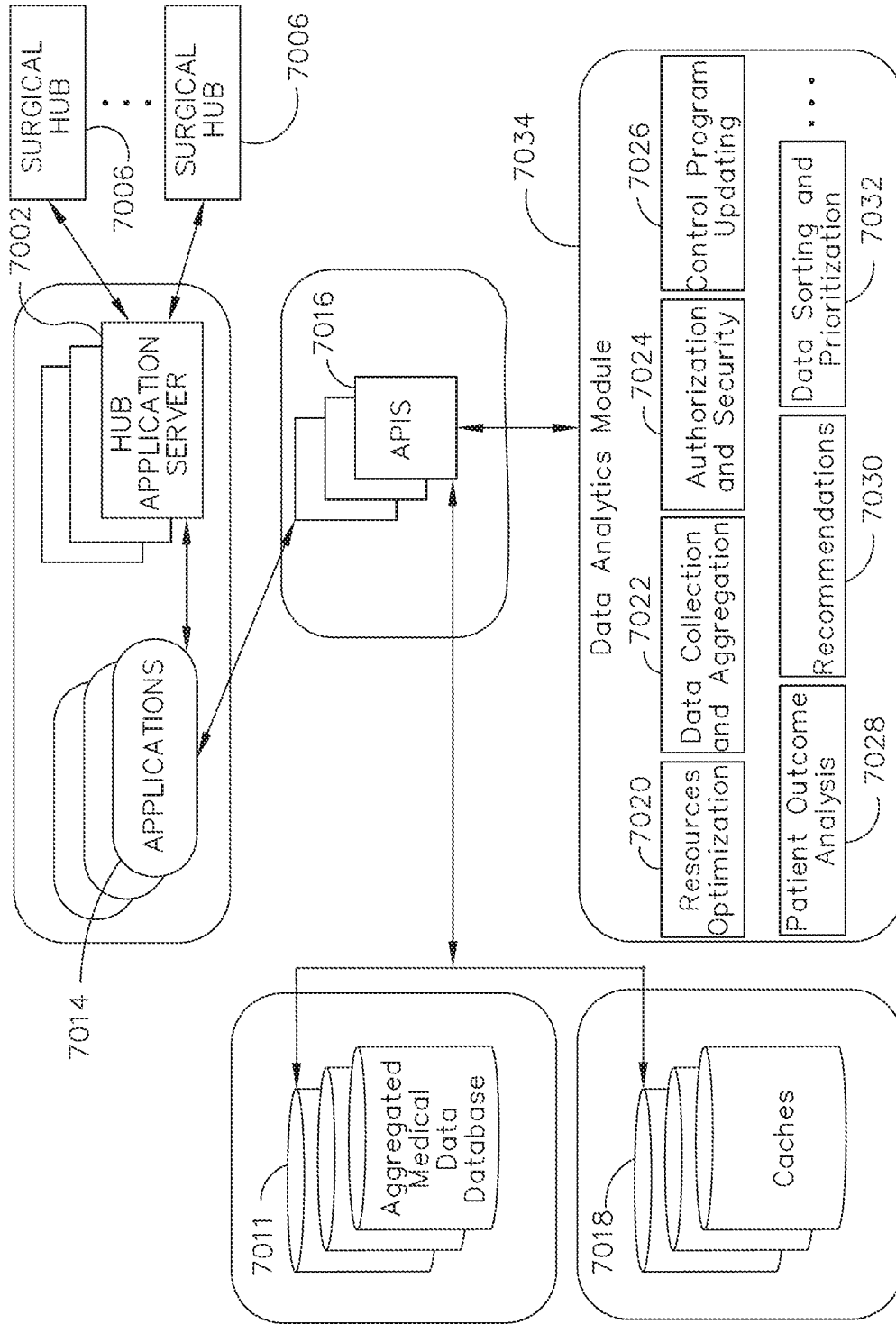


FIG. 13

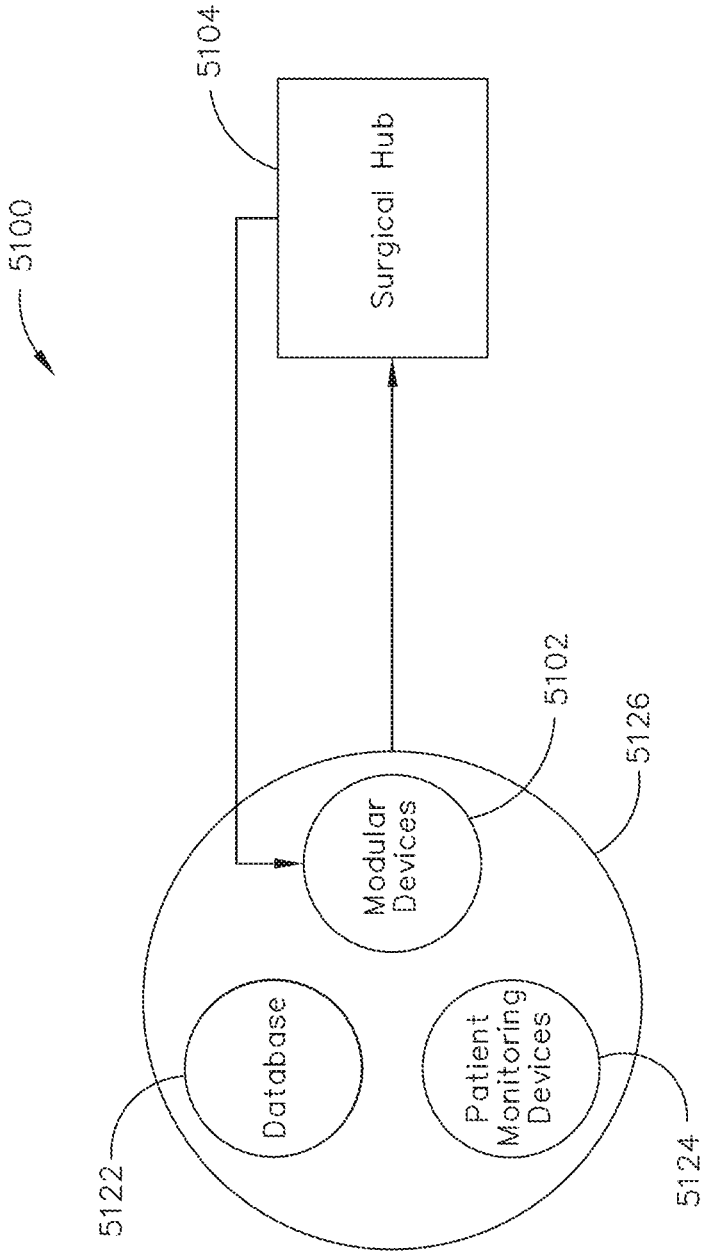
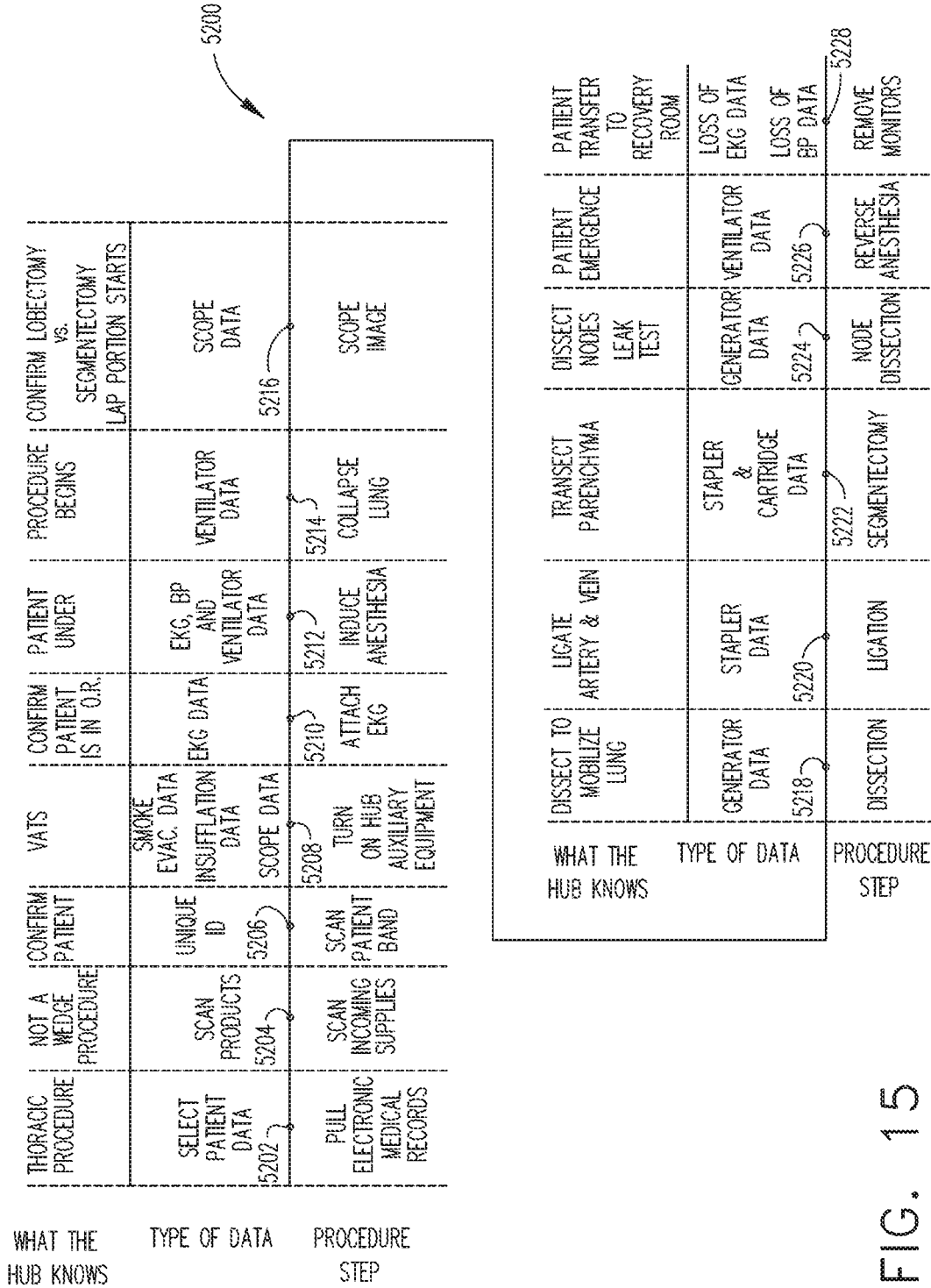


FIG. 14



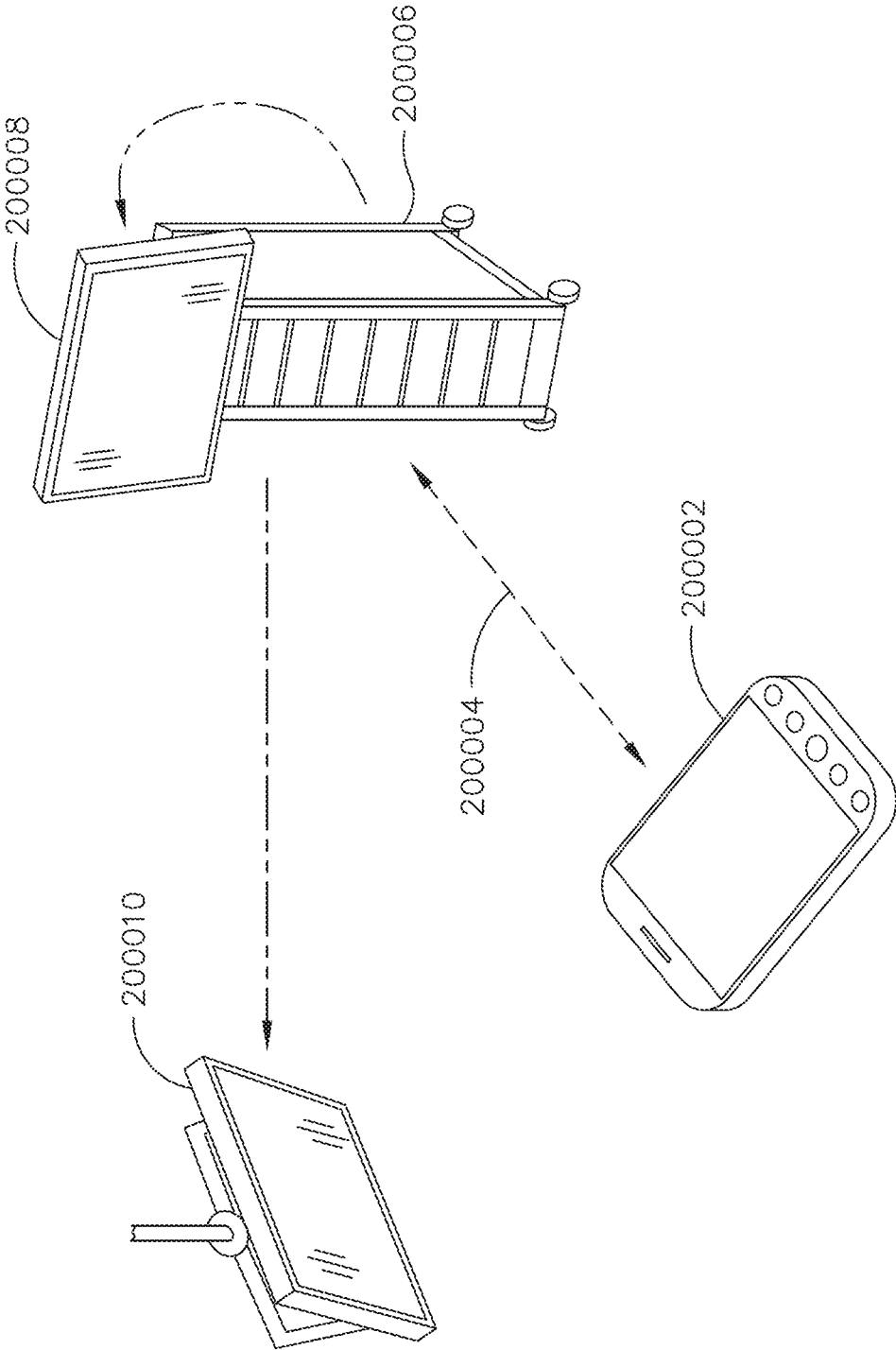


FIG. 16



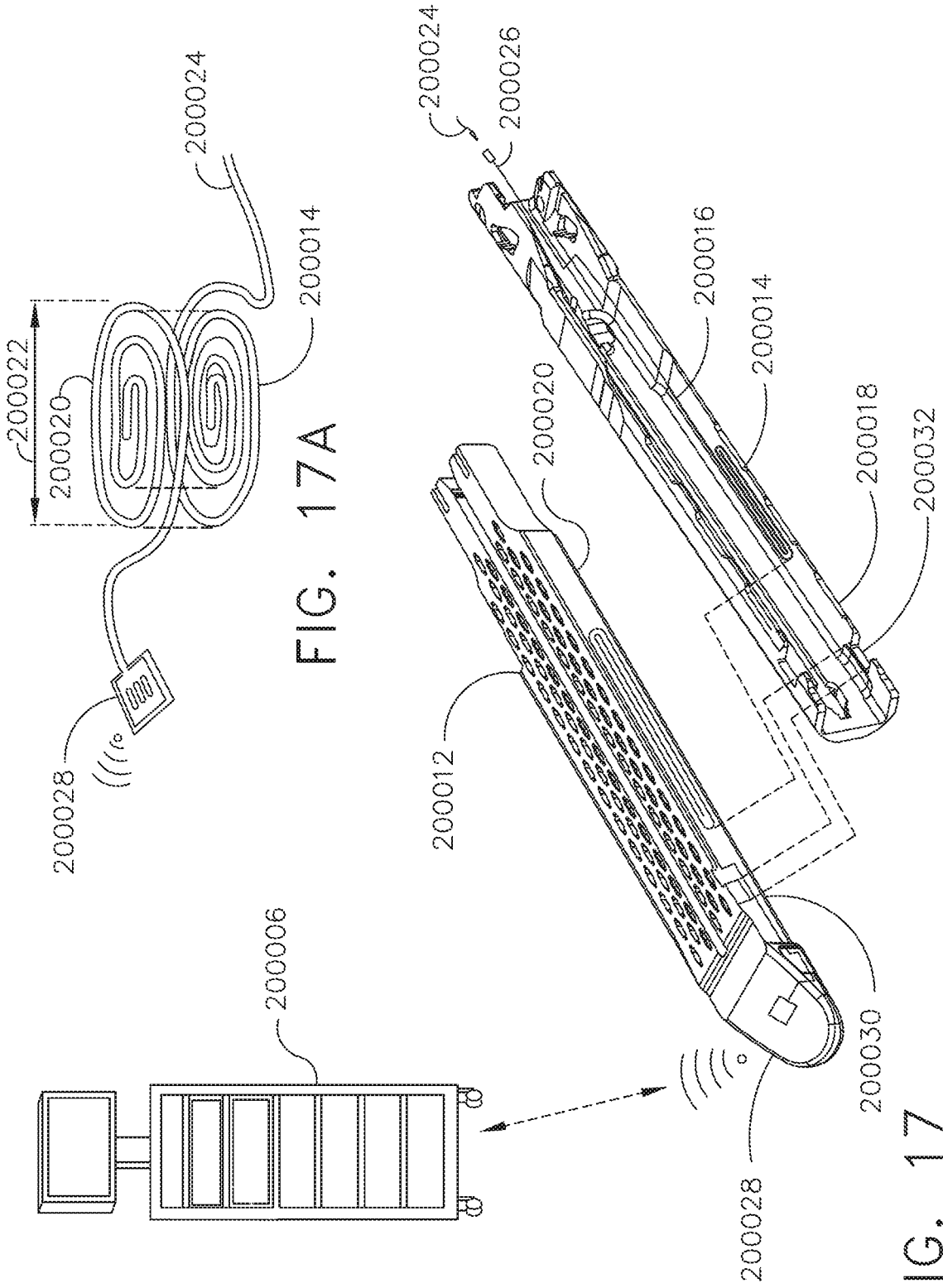


FIG. 17A

FIG. 17

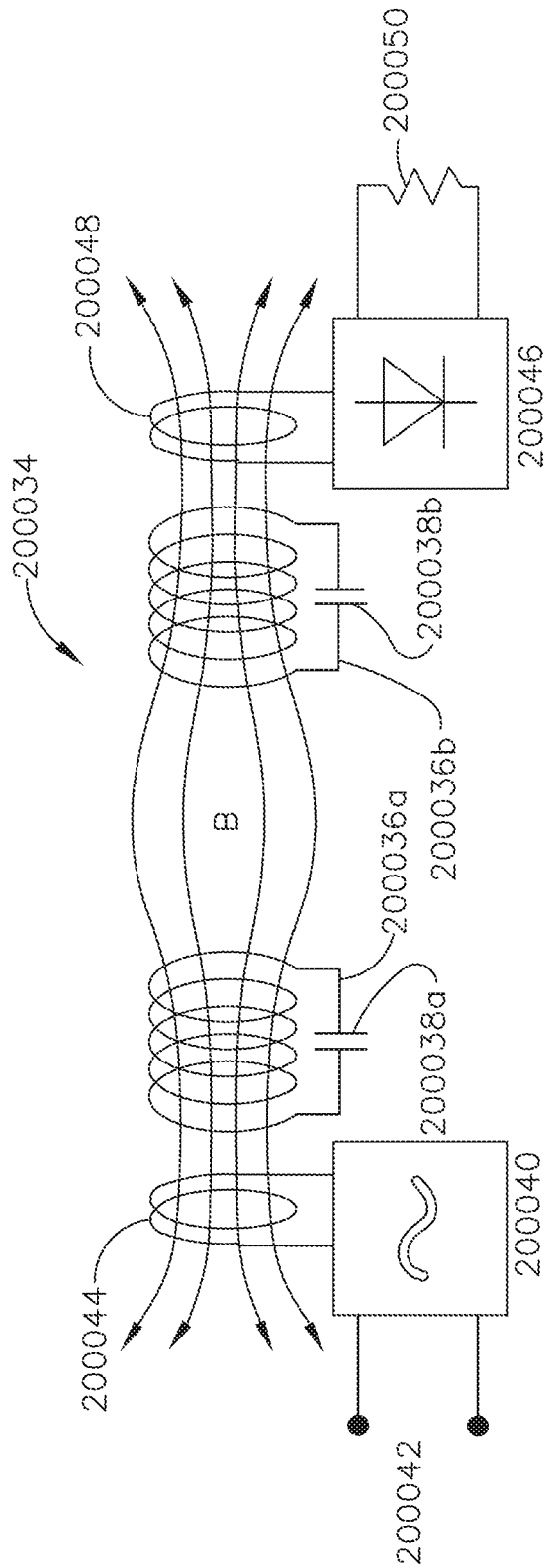


FIG. 18

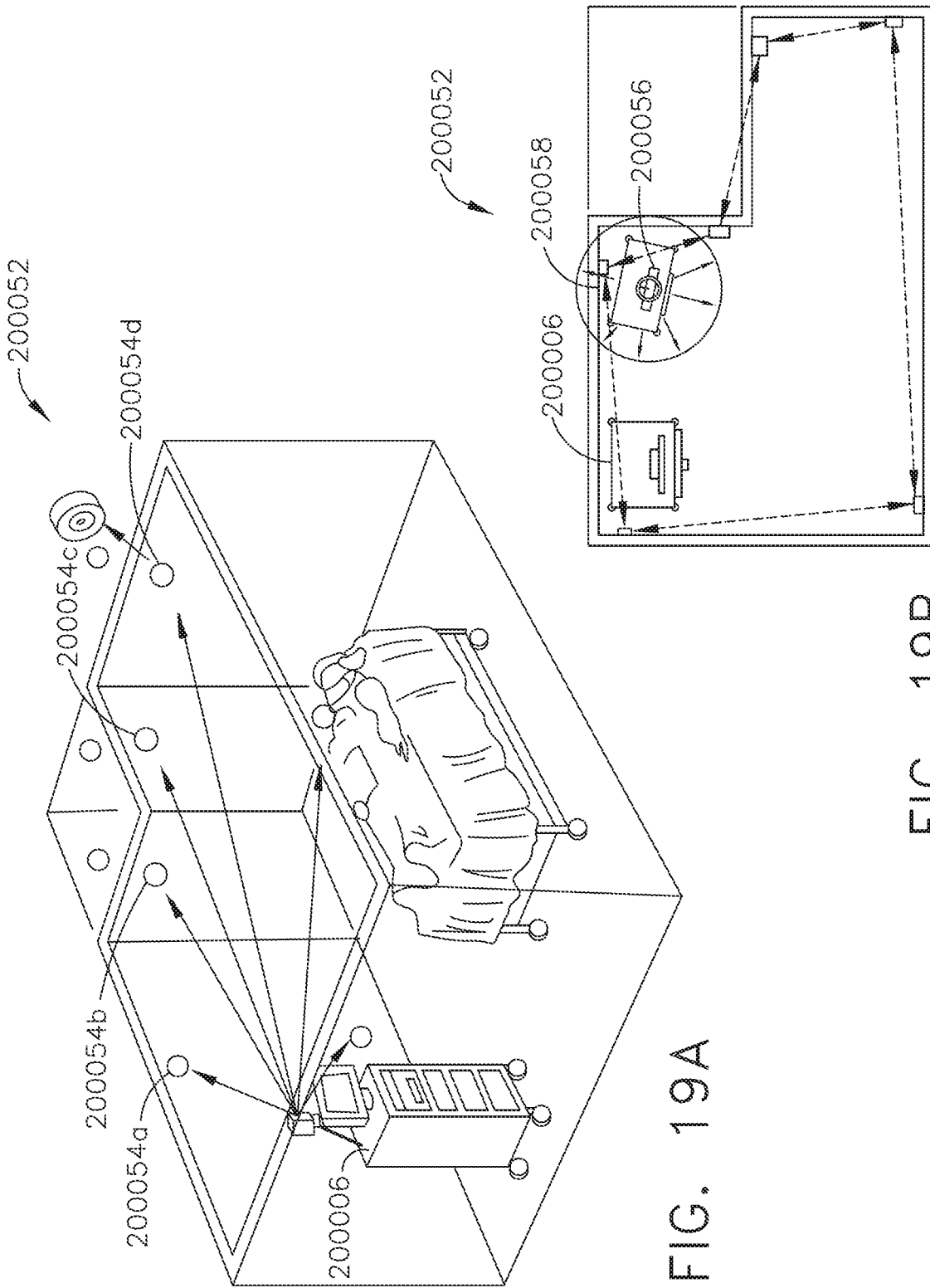


FIG. 19A

FIG. 19B

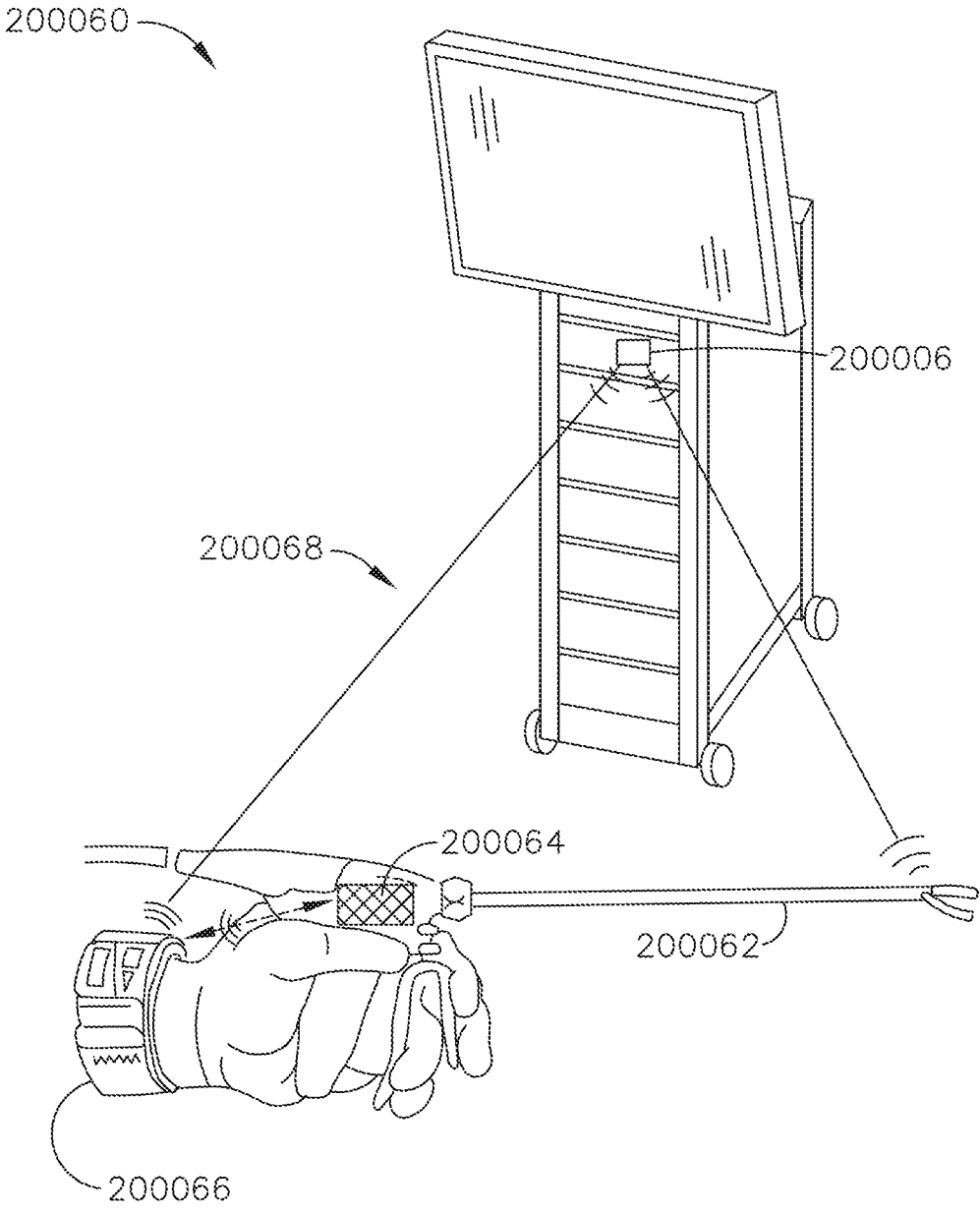


FIG. 20

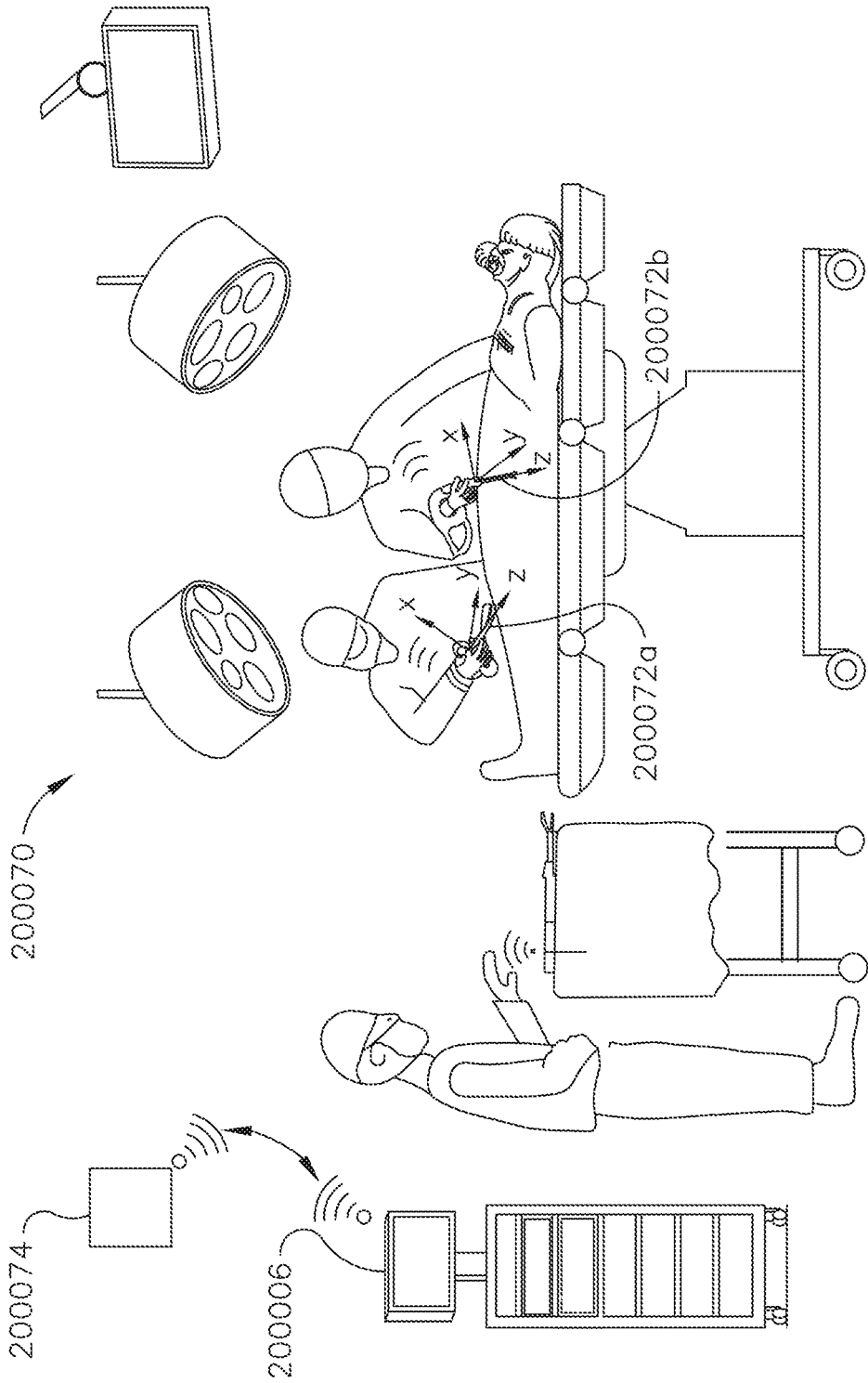


FIG. 21

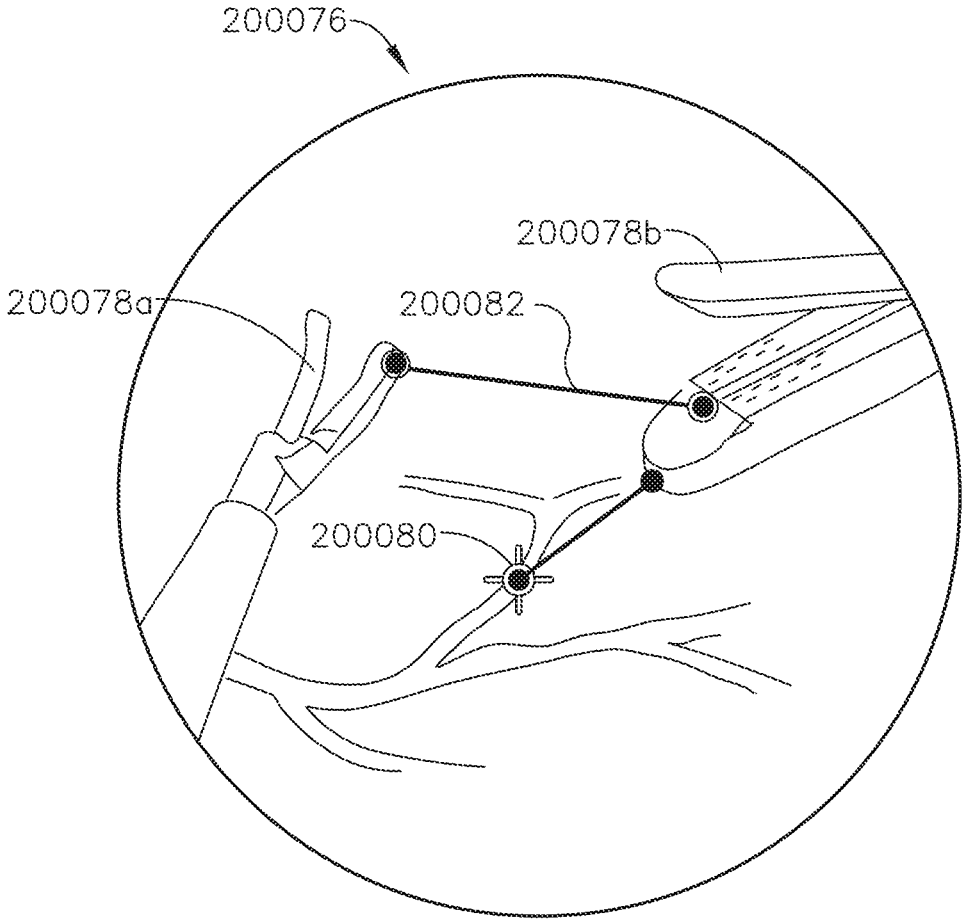


FIG. 22

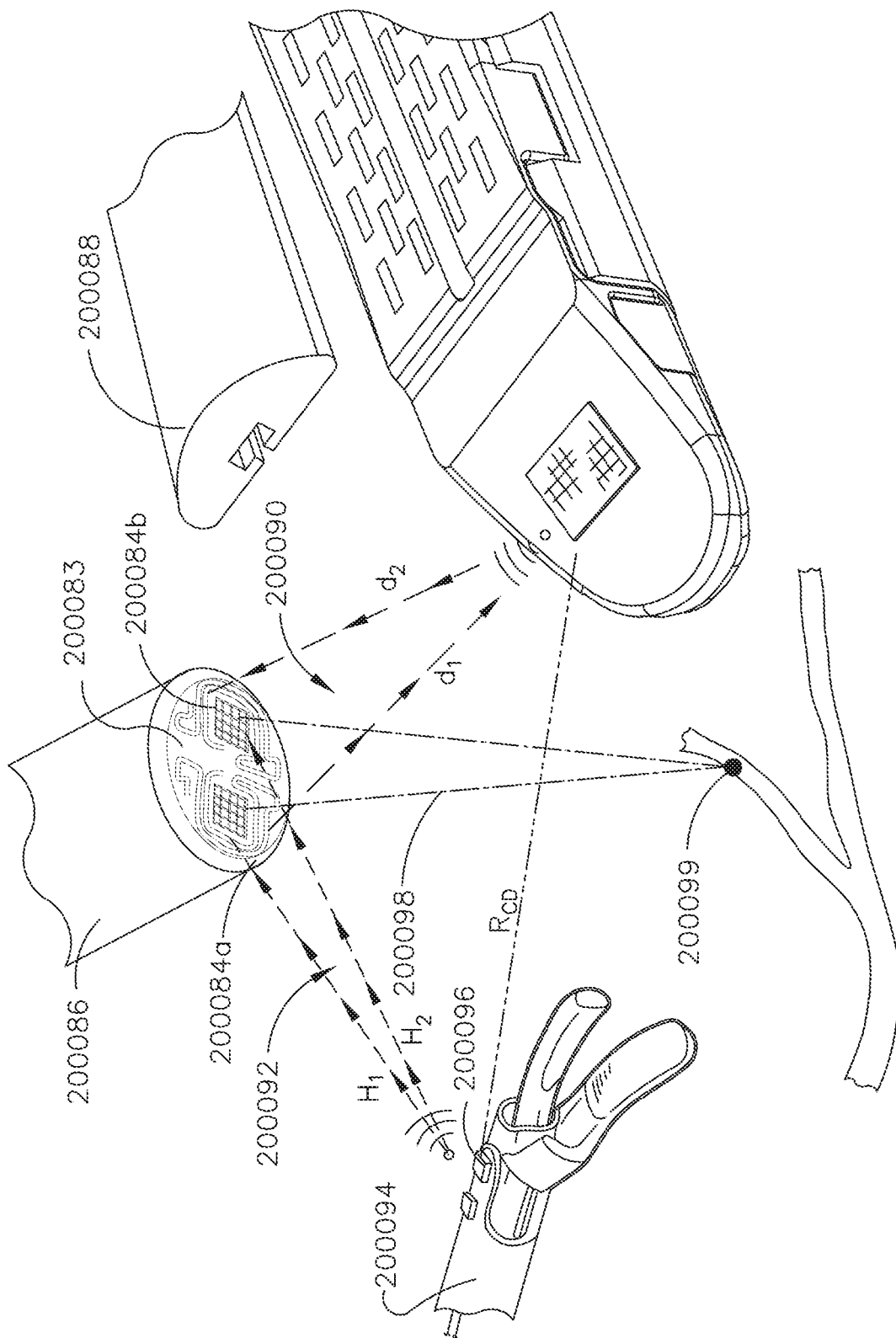


FIG. 23

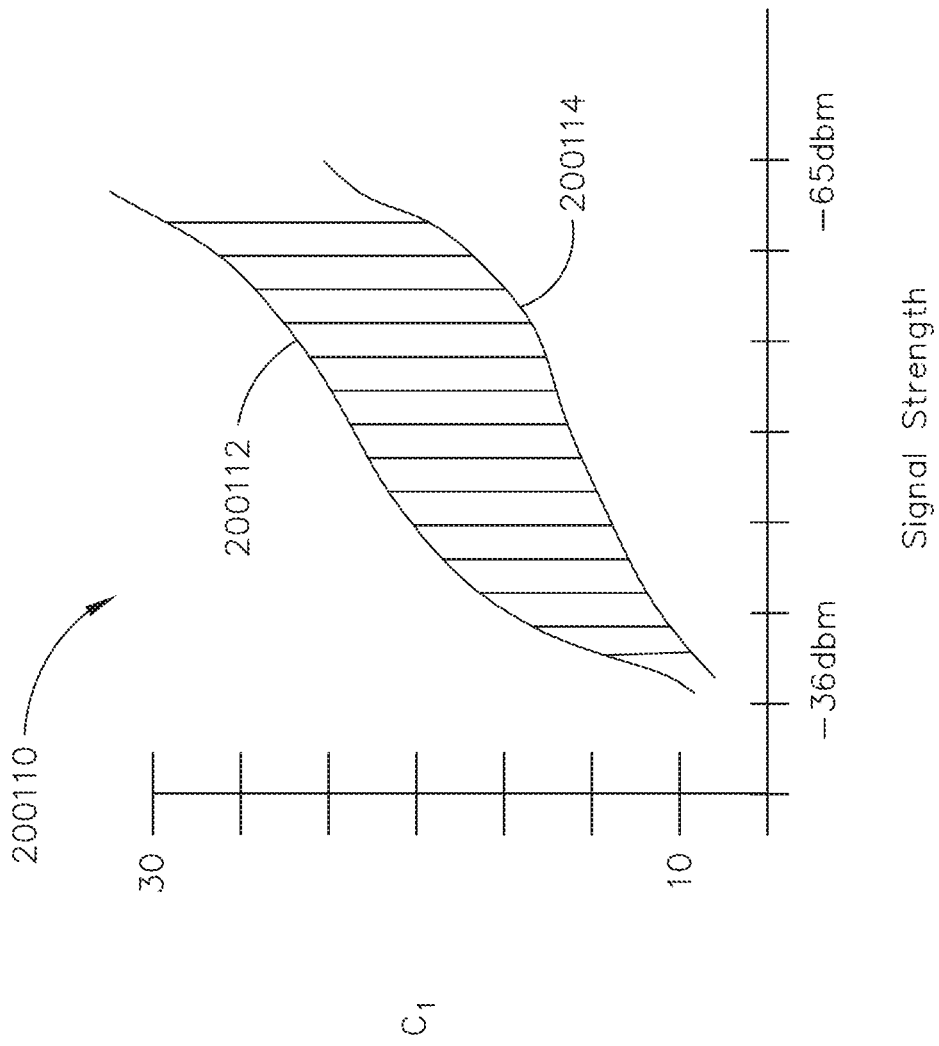


FIG. 24



**WIRELESS PAIRING OF A SURGICAL  
DEVICE WITH ANOTHER DEVICE WITHIN  
A STERILE SURGICAL FIELD BASED ON  
THE USAGE AND SITUATIONAL  
AWARENESS OF DEVICES**

**CROSS-REFERENCE TO RELATED  
APPLICATIONS**

**[0001]** The present application claims priority under 35 U.S.C. § 120 to U.S. patent application Ser. No. 16/182,231, titled WIRELESS PAIRING OF A SURGICAL DEVICE WITH ANOTHER DEVICE WITHIN A STERILE SURGICAL FIELD BASED ON THE USAGE AND SITUATIONAL AWARENESS OF DEVICES, filed on Nov. 6, 2018, now U.S. Patent Application Publication No. 2019/0201122, the disclosure of which is herein incorporated by reference in its entirety.

**[0002]** U.S. patent application Ser. No. 16/182,231 claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application No. 62/729,186, titled WIRELESS PAIRING OF A SURGICAL DEVICE WITH ANOTHER DEVICE WITHIN A STERILE SURGICAL FIELD BASED ON THE USAGE AND SITUATIONAL AWARENESS OF DEVICES, filed on Sep. 10, 2018, the disclosure of which is herein incorporated by reference in its entirety.

**[0003]** U.S. patent application Ser. No. 16/182,231 also claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application No. 62/692,747, titled SMART ACTIVATION OF AN ENERGY DEVICE BY ANOTHER DEVICE, filed on Jun. 30, 2018, to U.S. Provisional Patent Application No. 62/692,748, titled SMART ENERGY ARCHITECTURE, filed on Jun. 30, 2018, and to U.S. Provisional Patent Application No. 62/692,768, titled SMART ENERGY DEVICES, filed on Jun. 30, 2018, the disclosure of each of which is herein incorporated by reference in its entirety.

**[0004]** U.S. patent application Ser. No. 16/182,231 also claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application No. 62/659,900, titled METHOD OF HUB COMMUNICATION, filed on Apr. 19, 2018, the disclosure of each of which is herein incorporated by reference in its entirety.

**[0005]** U.S. patent application Ser. No. 16/182,231 also claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application No. 62/650,898 filed on Mar. 30, 2018, titled CAPACITIVE COUPLED RETURN PATH PAD WITH SEPARABLE ARRAY ELEMENTS, to U.S. Provisional Patent Application Ser. No. 62/650,887, titled SURGICAL SYSTEMS WITH OPTIMIZED SENSING CAPABILITIES, filed Mar. 30, 2018, to U.S. Provisional Patent Application Ser. No. 62/650,882, titled SMOKE EVACUATION MODULE FOR INTERACTIVE SURGICAL PLATFORM, filed Mar. 30, 2018, and to U.S. Provisional Patent Application Ser. No. 62/650,877, titled SURGICAL SMOKE EVACUATION SENSING AND CONTROLS, filed Mar. 30, 2018, the disclosure of each of which is herein incorporated by reference in its entirety.

**[0006]** U.S. patent application Ser. No. 16/182,231 also claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application Ser. No. 62/640,417, titled TEMPERATURE CONTROL IN ULTRASONIC DEVICE AND CONTROL SYSTEM THEREFOR, filed Mar. 8, 2018, and to U.S. Provisional Patent Application Ser. No. 62/640,415, titled ESTIMATING STATE OF ULTRASONIC END

EFFECTOR AND CONTROL SYSTEM THEREFOR, filed Mar. 8, 2018, the disclosure of each of which is herein incorporated by reference in its entirety.

**[0007]** U.S. patent application Ser. No. 16/182,231 also claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application Ser. No. 62/611,341, titled INTERACTIVE SURGICAL PLATFORM, filed Dec. 28, 2017, to U.S. Provisional Patent Application Ser. No. 62/611,340, titled CLOUD-BASED MEDICAL ANALYTICS, filed Dec. 28, 2017, and to U.S. Provisional Patent Application Ser. No. 62/611,339, titled ROBOT ASSISTED SURGICAL PLATFORM, filed Dec. 28, 2017, the disclosure of each of which is herein incorporated by reference in its entirety.

**BACKGROUND**

**[0008]** The present disclosure relates to various surgical systems. Surgical procedures are typically performed in surgical operating theaters or rooms in a healthcare facility such as, for example, a hospital. A sterile field is typically created around the patient. The sterile field may include the scrubbed team members, who are properly attired, and all furniture and fixtures in the area. Various surgical devices and systems are utilized in performance of a surgical procedure.

**SUMMARY**

**[0009]** An aspect of a surgical system may include a first surgical device having a control circuit configured to be situationally aware of events occurring within a vicinity of the first surgical device according to data received from a database, a patient monitoring device, or a paired surgical device, or any combination of the database, the patient monitoring device, or the paired surgical device, and wirelessly pair with a second surgical device according to a usage of the first surgical device and the events of which the first surgical device is situationally aware.

**[0010]** In one aspect of the surgical system, events of which the first surgical device is situationally aware include a first user using the first surgical device and a second user using the second surgical device.

**[0011]** In one aspect of the surgical system, the events consisting of the first user using the first surgical device include the first user grasping a handle of the first surgical device.

**[0012]** In one aspect of the surgical system, the events consisting of the first user grasping a handle of the first surgical device may include the first user grasping the handle of the first surgical device thereby allowing a transceiver in the handle of the first surgical device to communicate with an identifier worn by the first user and allowing, by the identifier, a communication between the first surgical device and a surgical hub.

**[0013]** In one aspect of the surgical system, events of which the first surgical device is situationally aware may include a location of the first surgical device and a location of the second surgical device.

**[0014]** In one aspect of the surgical system, the control circuit is configured to determine the location of the second surgical device based on a wireless signal transmitted by the second surgical device to the first surgical device.

**[0015]** In one aspect of the surgical system, the control circuit is further configured to simultaneously activate the

first surgical device and the second surgical device each for a predetermined period of time when no tissue or patient is sensed.

**[0016]** In one aspect of the surgical system, the first surgical device is located within a sterile field and the second surgical device is located outside the sterile field when the first surgical device wirelessly pairs with the second surgical device.

**[0017]** In one aspect of the surgical system, the control circuit is further configured to wireless pair with a communication device.

**[0018]** In one aspect of the surgical system, events of which the first surgical device is situationally aware may include a determination of a distance between the first surgical device and a tissue structure within a patient.

**[0019]** An aspect of a method may include being situationally aware, by a control circuit within a first surgical device, of events occurring within a vicinity of a first surgical device according to data received from a database, a patient monitoring device, or a paired surgical device, or any combination of the database, the patient monitoring device, or the paired surgical device, and wirelessly pairing, by the control circuit, with a second surgical device according to a usage of the first surgical device and the events of which the first surgical device is situationally aware.

**[0020]** In one aspect of the method, being situationally aware, by a control circuit within a first surgical device, may include being situationally aware, by a control circuit within a first surgical device, of a first user using the first surgical device and a second user using the second surgical device.

**[0021]** In one aspect of the method, being situationally aware, by a control circuit within a first surgical device, of a first user using the first surgical device may include being situationally aware, by a control circuit within a first surgical device, of a first user grasping a handle of the first surgical device.

**[0022]** In one aspect, the method may further include allowing a transceiver in the handle of the first surgical device to communicate with an identifier worn by the first user and allowing, by the identifier, a communication between the first surgical device and a surgical hub.

**[0023]** In one aspect of the method, being situationally aware, by a control circuit within a first surgical device, of a first user using the first surgical device and a second user using the second surgical device, may include being situationally aware, by a control circuit within a first surgical device, of a location of the first surgical device and a location of the second surgical device.

**[0024]** In one aspect, the method may further include determining, by the control circuit, the location of the second surgical device based on a wireless signal transmitted by the second surgical device to the first surgical device.

**[0025]** In one aspect, the method may further include activating, by the control circuit, the first surgical device and the second surgical device each for a predetermined period of time when no tissue or patient is sensed.

**[0026]** In one aspect of the method, wirelessly pairing, by the control circuit, with a second surgical device according to a usage of the first surgical device may include wirelessly pairing, by the control circuit, with a second surgical device outside of a sterile field when the first surgical device is located within the sterile field.

**[0027]** In one aspect, the method may further include wirelessly pairing of the control circuit with a communication device.

**[0028]** In one aspect, the method may further include determining, by the control circuit, a distance between the first surgical device and a tissue structure within a patient.

## FIGURES

**[0029]** The various aspects described herein, both as to organization and methods of operation, together with further objects and advantages thereof, may best be understood by reference to the following description, taken in conjunction with the accompanying drawings as follows.

**[0030]** FIG. 1 is a block diagram of a computer-implemented interactive surgical system, in accordance with at least one aspect of the present disclosure.

**[0031]** FIG. 2 is a surgical system being used to perform a surgical procedure in an operating room, in accordance with at least one aspect of the present disclosure.

**[0032]** FIG. 3 is a surgical hub paired with a visualization system, a robotic system, and an intelligent instrument, in accordance with at least one aspect of the present disclosure.

**[0033]** FIG. 4 is a partial perspective view of a surgical hub enclosure, and of a combo generator module slidably receivable in a drawer of the surgical hub enclosure, in accordance with at least one aspect of the present disclosure.

**[0034]** FIG. 5 is a perspective view of a combo generator module with bipolar, ultrasonic, and monopolar contacts and a smoke evacuation component, in accordance with at least one aspect of the present disclosure.

**[0035]** FIG. 6 illustrates individual power bus attachments for a plurality of lateral docking ports of a lateral modular housing configured to receive a plurality of modules, in accordance with at least one aspect of the present disclosure.

**[0036]** FIG. 7 illustrates a vertical modular housing configured to receive a plurality of modules, in accordance with at least one aspect of the present disclosure.

**[0037]** FIG. 8 illustrates a surgical data network comprising a modular communication hub configured to connect modular devices located in one or more operating theaters of a healthcare facility, or any room in a healthcare facility specially equipped for surgical operations, to the cloud, in accordance with at least one aspect of the present disclosure.

**[0038]** FIG. 9 illustrates a computer-implemented interactive surgical system, in accordance with at least one aspect of the present disclosure.

**[0039]** FIG. 10 illustrates a surgical hub comprising a plurality of modules coupled to the modular control tower, in accordance with at least one aspect of the present disclosure.

**[0040]** FIG. 11 illustrates one aspect of a Universal Serial Bus (USB) network hub device, in accordance with at least one aspect of the present disclosure.

**[0041]** FIG. 12 is a block diagram of a cloud computing system comprising a plurality of smart surgical instruments coupled to surgical hubs that may connect to the cloud component of the cloud computing system, in accordance with at least one aspect of the present disclosure.

**[0042]** FIG. 13 is a functional module architecture of a cloud computing system, in accordance with at least one aspect of the present disclosure.

**[0043]** FIG. 14 illustrates a diagram of a situationally aware surgical system, in accordance with at least one aspect of the present disclosure.

[0044] FIG. 15 is a timeline depicting situational awareness of a surgical hub, in accordance with at least one aspect of the present disclosure.

[0045] FIG. 16 is a diagram of a pairing of a personally owned wireless device with a surgical hub, in accordance with at least one aspect of the present disclosure.

[0046] FIG. 17 is a diagram of a cartridge configured to wirelessly communicate with a surgical hub, in accordance with at least one aspect of the present disclosure.

[0047] FIG. 17A depicts inductive power coupling between adjacent coils, in accordance with at least one aspect of the present disclosure.

[0048] FIG. 18 is a block diagram of a resonant inductive wireless power system, in accordance with at least one aspect of the present disclosure.

[0049] FIG. 19A is a diagram of a surgical hub detecting a room perimeter, in accordance with at least one aspect of the present disclosure.

[0050] FIG. 19B is a diagram of a room perimeter including one or more jamming beacons, in accordance with at least one aspect of the present disclosure.

[0051] FIG. 20 is a diagram of interaction between a user-worn identifier and a surgical instrument, in accordance with at least one aspect of the present disclosure.

[0052] FIG. 21 is a diagram of a surgical system including a magnetic field generator for detecting the position and orientation of surgical devices relative thereto, in accordance with at least one aspect of the present disclosure.

[0053] FIG. 22 is a diagram depicting a system for utilizing lidar to determine the positions of devices relative to a user-selected measurement site, in accordance with at least one aspect of the present disclosure.

[0054] FIG. 23 is a diagram of a system for determining the relative position of devices via a dual-antenna receiver, in accordance with at least one aspect of the present disclosure.

[0055] FIG. 24 is a graph depicting viable detected signal strength, in accordance with at least one aspect of the present disclosure.

#### DESCRIPTION

[0056] Applicant of the present application owns the following U.S. patent applications, filed on Nov. 6, 2018, the disclosure of each of which is herein incorporated by reference in its entirety:

[0057] U.S. patent application Ser. No. 16/182,224, titled SURGICAL NETWORK, INSTRUMENT, AND CLOUD RESPONSES BASED ON VALIDATION OF RECEIVED DATASET AND AUTHENTICATION OF ITS SOURCE AND INTEGRITY, now U.S. Patent Application Publication No. 2019/0205441;

[0058] U.S. patent application Ser. No. 16/182,230, titled SURGICAL SYSTEM FOR PRESENTING INFORMATION INTERPRETED FROM EXTERNAL DATA, now U.S. Patent Application Publication No. 2019/0200980;

[0059] U.S. patent application Ser. No. 16/182,233, titled MODIFICATION OF SURGICAL SYSTEMS CONTROL PROGRAMS BASED ON MACHINE LEARNING, now U.S. Patent Application Publication No. 2019/0201123;

[0060] U.S. patent application Ser. No. 16/182,239, titled ADJUSTMENT OF DEVICE CONTROL PROGRAMS BASED ON STRATIFIED CONTEXTUAL

DATA IN ADDITION TO THE DATA, now U.S. Patent Application Publication No. 2019/0201124;

[0061] U.S. patent application Ser. No. 16/182,243, titled SURGICAL HUB AND MODULAR DEVICE RESPONSE ADJUSTMENT BASED ON SITUATIONAL AWARENESS, now U.S. Patent Application Publication No. 2019/0206542;

[0062] U.S. patent application Ser. No. 16/182,248, titled DETECTION AND ESCALATION OF SECURITY RESPONSES OF SURGICAL INSTRUMENTS TO INCREASING SEVERITY THREATS, now U.S. Patent Application Publication No. 2019/0206216;

[0063] U.S. patent application Ser. No. 16/182,251, titled INTERACTIVE SURGICAL SYSTEM, now U.S. Patent Application Publication No. 2019/0201125;

[0064] U.S. patent application Ser. No. 16/182,260, titled AUTOMATED DATA SCALING, ALIGNMENT, AND ORGANIZING BASED ON PRE-DEFINED PARAMETERS WITHIN SURGICAL NETWORKS, now U.S. Patent Application Publication No. 2019/0206576;

[0065] U.S. patent application Ser. No. 16/182,267, titled SENSING THE PATIENT POSITION AND CONTACT UTILIZING THE MONO-POLAR RETURN PAD ELECTRODE TO PROVIDE SITUATIONAL AWARENESS TO A SURGICAL NETWORK, now U.S. Patent Application Publication No. 2019/0201128;

[0066] U.S. patent application Ser. No. 16/182,249, titled POWERED SURGICAL TOOL WITH PRE-DEFINED ADJUSTABLE CONTROL ALGORITHM FOR CONTROLLING END EFFECTOR PARAMETER, now U.S. Patent Application Publication No. 2019/0201081;

[0067] U.S. patent application Ser. No. 16/182,246, titled ADJUSTMENTS BASED ON AIRBORNE PARTICLE PROPERTIES, now U.S. Patent Application Publication No. 2019/0204201;

[0068] U.S. patent application Ser. No. 16/182,256, titled ADJUSTMENT OF A SURGICAL DEVICE FUNCTION BASED ON SITUATIONAL AWARENESS, now U.S. Patent Application Publication No. 2019/0201127;

[0069] U.S. patent application Ser. No. 16/182,242, titled REAL-TIME ANALYSIS OF COMPREHENSIVE COST OF ALL INSTRUMENTATION USED IN SURGERY UTILIZING DATA FLUIDITY TO TRACK INSTRUMENTS THROUGH STOCKING AND IN-HOUSE PROCESSES, now U.S. Patent Application Publication No. 2019/0206556;

[0070] U.S. patent application Ser. No. 16/182,255, titled USAGE AND TECHNIQUE ANALYSIS OF SURGEON/STAFF PERFORMANCE AGAINST A BASELINE TO OPTIMIZE DEVICE UTILIZATION AND PERFORMANCE FOR BOTH CURRENT AND FUTURE PROCEDURES, now U.S. Patent Application Publication No. 2019/0201126;

[0071] U.S. patent application Ser. No. 16/182,269, titled IMAGE CAPTURING OF THE AREAS OUTSIDE THE ABDOMEN TO IMPROVE PLACEMENT AND CONTROL OF A SURGICAL DEVICE IN USE, now U.S. Patent Application Publication No. 2019/0201129;

- [0072] U.S. patent application Ser. No. 16/182,278, titled COMMUNICATION OF DATA WHERE A SURGICAL NETWORK IS USING CONTEXT OF THE DATA AND REQUIREMENTS OF A RECEIVING SYSTEM/USER TO INFLUENCE INCLUSION OR LINKAGE OF DATA AND METADATA TO ESTABLISH CONTINUITY, now U.S. Patent Application Publication No. 2019/0201130;
- [0073] U.S. patent application Ser. No. 16/182,290, titled SURGICAL NETWORK RECOMMENDATIONS FROM REAL TIME ANALYSIS OF PROCEDURE VARIABLES AGAINST A BASELINE HIGHLIGHTING DIFFERENCES FROM THE OPTIMAL SOLUTION, now U.S. Patent Application Publication No. 2019/0201102;
- [0074] U.S. patent application Ser. No. 16/182,232, titled CONTROL OF A SURGICAL SYSTEM THROUGH A SURGICAL BARRIER, now U.S. Patent Application Publication No. 2019/0201158;
- [0075] U.S. patent application Ser. No. 16/182,227, titled SURGICAL NETWORK DETERMINATION OF PRIORITIZATION OF COMMUNICATION, INTERACTION, OR PROCESSING BASED ON SYSTEM OR DEVICE NEEDS, now U.S. Patent Application Publication No. 2019/0207857;
- [0076] U.S. patent application Ser. No. 16/182,229, titled ADJUSTMENT OF STAPLE HEIGHT OF AT LEAST ONE ROW OF STAPLES BASED ON THE SENSED TISSUE THICKNESS OR FORCE IN CLOSING, now U.S. Patent Application Publication No. 2019/0200996;
- [0077] U.S. patent application Ser. No. 16/182,234, titled STAPLING DEVICE WITH BOTH COMPULSORY AND DISCRETIONARY LOCKOUTS BASED ON SENSED PARAMETERS, now U.S. Patent Application Publication No. 2019/0200997;
- [0078] U.S. patent application Ser. No. 16/182,240, titled POWERED STAPLING DEVICE CONFIGURED TO ADJUST FORCE, ADVANCEMENT SPEED, AND OVERALL STROKE OF CUTTING MEMBER BASED ON SENSED PARAMETER OF FIRING OR CLAMPING, now U.S. Patent Application Publication No. 2019/0201034;
- [0079] U.S. patent application Ser. No. 16/182,235, titled VARIATION OF RADIO FREQUENCY AND ULTRASONIC POWER LEVEL IN COOPERATION WITH VARYING CLAMP ARM PRESSURE TO ACHIEVE PREDEFINED HEAT FLUX OR POWER APPLIED TO TISSUE, now U.S. Patent Application Publication No. 2019/0201044; and
- [0080] U.S. patent application Ser. No. 16/182,238, titled ULTRASONIC ENERGY DEVICE WHICH VARIES PRESSURE APPLIED BY CLAMP ARM TO PROVIDE THRESHOLD CONTROL PRESSURE AT A CUT PROGRESSION LOCATION, now U.S. Patent Application Publication No. 2019/0201080.
- [0081] Applicant of the present application owns the following U.S. patent applications, filed on Sep. 10, 2018, the disclosure of each of which is herein incorporated by reference in its entirety:
- [0082] U.S. Provisional Patent Application No. 62/729,183, titled A CONTROL FOR A SURGICAL NETWORK OR SURGICAL NETWORK CONNECTED DEVICE THAT ADJUSTS ITS FUNCTION BASED ON A SENSED SITUATION OR USAGE;
- [0083] U.S. Provisional Patent Application No. 62/729,177, titled AUTOMATED DATA SCALING, ALIGNMENT, AND ORGANIZING BASED ON PREDEFINED PARAMETERS WITHIN A SURGICAL NETWORK BEFORE TRANSMISSION;
- [0084] U.S. Provisional Patent Application No. 62/729,176, titled INDIRECT COMMAND AND CONTROL OF A FIRST OPERATING ROOM SYSTEM THROUGH THE USE OF A SECOND OPERATING ROOM SYSTEM WITHIN A STERILE FIELD WHERE THE SECOND OPERATING ROOM SYSTEM HAS PRIMARY AND SECONDARY OPERATING MODES;
- [0085] U.S. Provisional Patent Application No. 62/729,185, titled POWERED STAPLING DEVICE THAT IS CAPABLE OF ADJUSTING FORCE, ADVANCEMENT SPEED, AND OVERALL STROKE OF CUTTING MEMBER OF THE DEVICE BASED ON SENSED PARAMETER OF FIRING OR CLAMPING;
- [0086] U.S. Provisional Patent Application No. 62/729,184, titled POWERED SURGICAL TOOL WITH A PREDEFINED ADJUSTABLE CONTROL ALGORITHM FOR CONTROLLING AT LEAST ONE END EFFECTOR PARAMETER AND A MEANS FOR LIMITING THE ADJUSTMENT;
- [0087] U.S. Provisional Patent Application No. 62/729,182, titled SENSING THE PATIENT POSITION AND CONTACT UTILIZING THE MONO POLAR RETURN PAD ELECTRODE TO PROVIDE SITUATIONAL AWARENESS TO THE HUB;
- [0088] U.S. Provisional Patent Application No. 62/729,191, titled SURGICAL NETWORK RECOMMENDATIONS FROM REAL TIME ANALYSIS OF PROCEDURE VARIABLES AGAINST A BASELINE HIGHLIGHTING DIFFERENCES FROM THE OPTIMAL SOLUTION;
- [0089] U.S. Provisional Patent Application No. 62/729,195, titled ULTRASONIC ENERGY DEVICE WHICH VARIES PRESSURE APPLIED BY CLAMP ARM TO PROVIDE THRESHOLD CONTROL PRESSURE AT A CUT PROGRESSION LOCATION; and
- [0090] U.S. Provisional Patent Application No. 62/729,186, titled WIRELESS PAIRING OF A SURGICAL DEVICE WITH ANOTHER DEVICE WITHIN A STERILE SURGICAL FIELD BASED ON THE USAGE AND SITUATIONAL AWARENESS OF DEVICES.
- [0091] Applicant of the present application owns the following U.S. patent applications, filed on Aug. 28, 2018, the disclosure of each of which is herein incorporated by reference in its entirety:
- [0092] U.S. patent application Ser. No. 16/115,214, titled ESTIMATING STATE OF ULTRASONIC END EFFECTOR AND CONTROL SYSTEM THEREFOR;
- [0093] U.S. patent application Ser. No. 16/115,205, titled TEMPERATURE CONTROL OF ULTRASONIC END EFFECTOR AND CONTROL SYSTEM THEREFOR;

- [0094] U.S. patent application Ser. No. 16/115,233, titled RADIO FREQUENCY ENERGY DEVICE FOR DELIVERING COMBINED ELECTRICAL SIGNALS;
- [0095] U.S. patent application Ser. No. 16/115,208, titled CONTROLLING AN ULTRASONIC SURGICAL INSTRUMENT ACCORDING TO TISSUE LOCATION;
- [0096] U.S. patent application Ser. No. 16/115,220, titled CONTROLLING ACTIVATION OF AN ULTRASONIC SURGICAL INSTRUMENT ACCORDING TO THE PRESENCE OF TISSUE;
- [0097] U.S. patent application Ser. No. 16/115,232, titled DETERMINING TISSUE COMPOSITION VIA AN ULTRASONIC SYSTEM;
- [0098] U.S. patent application Ser. No. 16/115,239, titled DETERMINING THE STATE OF AN ULTRASONIC ELECTROMECHANICAL SYSTEM ACCORDING TO FREQUENCY SHIFT;
- [0099] U.S. patent application Ser. No. 16/115,247, titled DETERMINING THE STATE OF AN ULTRASONIC END EFFECTOR;
- [0100] U.S. patent application Ser. No. 16/115,211, titled SITUATIONAL AWARENESS OF ELECTROSURGICAL SYSTEMS;
- [0101] U.S. patent application Ser. No. 16/115,226, titled MECHANISMS FOR CONTROLLING DIFFERENT ELECTROMECHANICAL SYSTEMS OF AN ELECTROSURGICAL INSTRUMENT;
- [0102] U.S. patent application Ser. No. 16/115,240, titled DETECTION OF END EFFECTOR IMMERSION IN LIQUID;
- [0103] U.S. patent application Ser. No. 16/115,249, titled INTERRUPTION OF ENERGY DUE TO INADVERTENT CAPACITIVE COUPLING;
- [0104] U.S. patent application Ser. No. 16/115,256, titled INCREASING RADIO FREQUENCY TO CREATE PAD-LESS MONOPOLAR LOOP;
- [0105] U.S. patent application Ser. No. 16/115,223, titled BIPOLAR COMBINATION DEVICE THAT AUTOMATICALLY ADJUSTS PRESSURE BASED ON ENERGY MODALITY; and
- [0106] U.S. patent application Ser. No. 16/115,238, titled ACTIVATION OF ENERGY DEVICES.
- [0107] Applicant of the present application owns the following U.S. patent applications, filed on Aug. 23, 2018, the disclosure of each of which is herein incorporated by reference in its entirety:
- [0108] U.S. Provisional Patent Application No. 62/721,995, titled CONTROLLING AN ULTRASONIC SURGICAL INSTRUMENT ACCORDING TO TISSUE LOCATION;
- [0109] U.S. Provisional Patent Application No. 62/721,998, titled SITUATIONAL AWARENESS OF ELECTROSURGICAL SYSTEMS;
- [0110] U.S. Provisional Patent Application No. 62/721,999, titled INTERRUPTION OF ENERGY DUE TO INADVERTENT CAPACITIVE COUPLING;
- [0111] U.S. Provisional Patent Application No. 62/721,994, titled BIPOLAR COMBINATION DEVICE THAT AUTOMATICALLY ADJUSTS PRESSURE BASED ON ENERGY MODALITY; and
- [0112] U.S. Provisional Patent Application No. 62/721,996, titled RADIO FREQUENCY ENERGY DEVICE FOR DELIVERING COMBINED ELECTRICAL SIGNALS.
- [0113] Applicant of the present application owns the following U.S. patent applications, filed on Jun. 30, 2018, the disclosure of each of which is herein incorporated by reference in its entirety:
- [0114] U.S. Provisional Patent Application No. 62/692,747, titled SMART ACTIVATION OF AN ENERGY DEVICE BY ANOTHER DEVICE;
- [0115] U.S. Provisional Patent Application No. 62/692,748, titled SMART ENERGY ARCHITECTURE; and
- [0116] U.S. Provisional Patent Application No. 62/692,768, titled SMART ENERGY DEVICES.
- [0117] Applicant of the present application owns the following U.S. patent applications, filed on Jun. 29, 2018, the disclosure of each of which is herein incorporated by reference in its entirety:
- [0118] U.S. patent application Ser. No. 16/024,090, titled CAPACITIVE COUPLED RETURN PATH PAD WITH SEPARABLE ARRAY ELEMENTS;
- [0119] U.S. patent application Ser. No. 16/024,057, titled CONTROLLING A SURGICAL INSTRUMENT ACCORDING TO SENSED CLOSURE PARAMETERS;
- [0120] U.S. patent application Ser. No. 16/024,067, titled SYSTEMS FOR ADJUSTING END EFFECTOR PARAMETERS BASED ON PERIOPERATIVE INFORMATION;
- [0121] U.S. patent application Ser. No. 16/024,075, titled SAFETY SYSTEMS FOR SMART POWERED SURGICAL STAPLING;
- [0122] U.S. patent application Ser. No. 16/024,083, titled SAFETY SYSTEMS FOR SMART POWERED SURGICAL STAPLING;
- [0123] U.S. patent application Ser. No. 16/024,094, titled SURGICAL SYSTEMS FOR DETECTING END EFFECTOR TISSUE DISTRIBUTION IRREGULARITIES;
- [0124] U.S. patent application Ser. No. 16/024,138, titled SYSTEMS FOR DETECTING PROXIMITY OF SURGICAL END EFFECTOR TO CANCEROUS TISSUE;
- [0125] U.S. patent application Ser. No. 16/024,150, titled SURGICAL INSTRUMENT CARTRIDGE SENSOR ASSEMBLIES;
- [0126] U.S. patent application Ser. No. 16/024,160, titled VARIABLE OUTPUT CARTRIDGE SENSOR ASSEMBLY;
- [0127] U.S. patent application Ser. No. 16/024,124, titled SURGICAL INSTRUMENT HAVING A FLEXIBLE ELECTRODE;
- [0128] U.S. patent application Ser. No. 16/024,132, titled SURGICAL INSTRUMENT HAVING A FLEXIBLE CIRCUIT;
- [0129] U.S. patent application Ser. No. 16/024,141, titled SURGICAL INSTRUMENT WITH A TISSUE MARKING ASSEMBLY;
- [0130] U.S. patent application Ser. No. 16/024,162, titled SURGICAL SYSTEMS WITH PRIORITIZED DATA TRANSMISSION CAPABILITIES;

- [0131] U.S. patent application Ser. No. 16/024,066, titled SURGICAL EVACUATION SENSING AND MOTOR CONTROL;
- [0132] U.S. patent application Ser. No. 16/024,096, titled SURGICAL EVACUATION SENSOR ARRANGEMENTS;
- [0133] U.S. patent application Ser. No. 16/024,116, titled SURGICAL EVACUATION FLOW PATHS;
- [0134] U.S. patent application Ser. No. 16/024,149, titled SURGICAL EVACUATION SENSING AND GENERATOR CONTROL;
- [0135] U.S. patent application Ser. No. 16/024,180, titled SURGICAL EVACUATION SENSING AND DISPLAY;
- [0136] U.S. patent application Ser. No. 16/024,245, titled COMMUNICATION OF SMOKE EVACUATION SYSTEM PARAMETERS TO HUB OR CLOUD IN SMOKE EVACUATION MODULE FOR INTERACTIVE SURGICAL PLATFORM;
- [0137] U.S. patent application Ser. No. 16/024,258, titled SMOKE EVACUATION SYSTEM INCLUDING A SEGMENTED CONTROL CIRCUIT FOR INTERACTIVE SURGICAL PLATFORM;
- [0138] U.S. patent application Ser. No. 16/024,265, titled SURGICAL EVACUATION SYSTEM WITH A COMMUNICATION CIRCUIT FOR COMMUNICATION BETWEEN A FILTER AND A SMOKE EVACUATION DEVICE; and
- [0139] U.S. patent application Ser. No. 16/024,273, titled DUAL IN-SERIES LARGE AND SMALL DROPLET FILTERS.
- [0140] Applicant of the present application owns the following U.S. Provisional Patent Applications, filed on Jun. 28, 2018, the disclosure of each of which is herein incorporated by reference in its entirety:
- [0141] U.S. Provisional Patent Application Ser. No. 62/691,228, titled A METHOD OF USING REINFORCED FLEX CIRCUITS WITH MULTIPLE SENSORS WITH ELECTROSURGICAL DEVICES;
- [0142] U.S. Provisional Patent Application Ser. No. 62/691,227, titled CONTROLLING A SURGICAL INSTRUMENT ACCORDING TO SENSED CLOSURE PARAMETERS;
- [0143] U.S. Provisional Patent Application Ser. No. 62/691,230, titled SURGICAL INSTRUMENT HAVING A FLEXIBLE ELECTRODE;
- [0144] U.S. Provisional Patent Application Ser. No. 62/691,219, titled SURGICAL EVACUATION SENSING AND MOTOR CONTROL;
- [0145] U.S. Provisional Patent Application Ser. No. 62/691,257, titled COMMUNICATION OF SMOKE EVACUATION SYSTEM PARAMETERS TO HUB OR CLOUD IN SMOKE EVACUATION MODULE FOR INTERACTIVE SURGICAL PLATFORM;
- [0146] U.S. Provisional Patent Application Ser. No. 62/691,262, titled SURGICAL EVACUATION SYSTEM WITH A COMMUNICATION CIRCUIT FOR COMMUNICATION BETWEEN A FILTER AND A SMOKE EVACUATION DEVICE; and
- [0147] U.S. Provisional Patent Application Ser. No. 62/691,251, titled DUAL IN-SERIES LARGE AND SMALL DROPLET FILTERS.
- [0148] Applicant of the present application owns the following U.S. Provisional Patent Application, filed on Apr. 19, 2018, the disclosure of which is herein incorporated by reference in its entirety:
- [0149] U.S. Provisional Patent Application Ser. No. 62/659,900, titled METHOD OF HUB COMMUNICATION.
- [0150] Applicant of the present application owns the following U.S. Provisional Patent Applications, filed on Mar. 30, 2018, the disclosure of each of which is herein incorporated by reference in its entirety:
- [0151] U.S. Provisional Patent Application No. 62/650,898 filed on Mar. 30, 2018, titled CAPACITIVE COUPLED RETURN PATH PAD WITH SEPARABLE ARRAY ELEMENTS;
- [0152] U.S. Provisional Patent Application Ser. No. 62/650,887, titled SURGICAL SYSTEMS WITH OPTIMIZED SENSING CAPABILITIES;
- [0153] U.S. Provisional Patent Application Ser. No. 62/650,882, titled SMOKE EVACUATION MODULE FOR INTERACTIVE SURGICAL PLATFORM; and
- [0154] U.S. Provisional Patent Application Ser. No. 62/650,877, titled SURGICAL SMOKE EVACUATION SENSING AND CONTROLS.
- [0155] Applicant of the present application owns the following U.S. patent applications, filed on Mar. 29, 2018, the disclosure of each of which is herein incorporated by reference in its entirety:
- [0156] U.S. patent application Ser. No. 15/940,641, titled INTERACTIVE SURGICAL SYSTEMS WITH ENCRYPTED COMMUNICATION CAPABILITIES;
- [0157] U.S. patent application Ser. No. 15/940,648, titled INTERACTIVE SURGICAL SYSTEMS WITH CONDITION HANDLING OF DEVICES AND DATA CAPABILITIES;
- [0158] U.S. patent application Ser. No. 15/940,656, titled SURGICAL HUB COORDINATION OF CONTROL AND COMMUNICATION OF OPERATING ROOM DEVICES;
- [0159] U.S. patent application Ser. No. 15/940,666, titled SPATIAL AWARENESS OF SURGICAL HUBS IN OPERATING ROOMS;
- [0160] U.S. patent application Ser. No. 15/940,670, titled COOPERATIVE UTILIZATION OF DATA DERIVED FROM SECONDARY SOURCES BY INTELLIGENT SURGICAL HUBS;
- [0161] U.S. patent application Ser. No. 15/940,677, titled SURGICAL HUB CONTROL ARRANGEMENTS;
- [0162] U.S. patent application Ser. No. 15/940,632, titled DATA STRIPPING METHOD TO INTERROGATE PATIENT RECORDS AND CREATE ANONYMIZED RECORD;
- [0163] U.S. patent application Ser. No. 15/940,640, titled COMMUNICATION HUB AND STORAGE DEVICE FOR STORING PARAMETERS AND STATUS OF A SURGICAL DEVICE TO BE SHARED WITH CLOUD BASED ANALYTICS SYSTEMS;
- [0164] U.S. patent application Ser. No. 15/940,645, titled SELF DESCRIBING DATA PACKETS GENERATED AT AN ISSUING INSTRUMENT;

- [0165] U.S. patent application Ser. No. 15/940,649, titled DATA PAIRING TO INTERCONNECT A DEVICE MEASURED PARAMETER WITH AN OUTCOME;
- [0166] U.S. patent application Ser. No. 15/940,654, titled SURGICAL HUB SITUATIONAL AWARENESS;
- [0167] U.S. patent application Ser. No. 15/940,663, titled SURGICAL SYSTEM DISTRIBUTED PROCESSING;
- [0168] U.S. patent application Ser. No. 15/940,668, titled AGGREGATION AND REPORTING OF SURGICAL HUB DATA;
- [0169] U.S. patent application Ser. No. 15/940,671, titled SURGICAL HUB SPATIAL AWARENESS TO DETERMINE DEVICES IN OPERATING THEATER;
- [0170] U.S. patent application Ser. No. 15/940,686, titled DISPLAY OF ALIGNMENT OF STAPLE CARTRIDGE TO PRIOR LINEAR STAPLE LINE;
- [0171] U.S. patent application Ser. No. 15/940,700, titled STERILE FIELD INTERACTIVE CONTROL DISPLAYS;
- [0172] U.S. patent application Ser. No. 15/940,629, titled COMPUTER IMPLEMENTED INTERACTIVE SURGICAL SYSTEMS;
- [0173] U.S. patent application Ser. No. 15/940,704, titled USE OF LASER LIGHT AND RED-GREEN-BLUE COLORATION TO DETERMINE PROPERTIES OF BACK SCATTERED LIGHT;
- [0174] U.S. patent application Ser. No. 15/940,722, titled CHARACTERIZATION OF TISSUE IRREGULARITIES THROUGH THE USE OF MONO-CHROMATIC LIGHT REFRACTIVITY;
- [0175] U.S. patent application Ser. No. 15/940,742, titled DUAL CMOS ARRAY IMAGING;
- [0176] U.S. patent application Ser. No. 15/940,636, titled ADAPTIVE CONTROL PROGRAM UPDATES FOR SURGICAL DEVICES;
- [0177] U.S. patent application Ser. No. 15/940,653, titled ADAPTIVE CONTROL PROGRAM UPDATES FOR SURGICAL HUBS;
- [0178] U.S. patent application Ser. No. 15/940,660, titled CLOUD-BASED MEDICAL ANALYTICS FOR CUSTOMIZATION AND RECOMMENDATIONS TO A USER;
- [0179] U.S. patent application Ser. No. 15/940,679, titled CLOUD-BASED MEDICAL ANALYTICS FOR LINKING OF LOCAL USAGE TRENDS WITH THE RESOURCE ACQUISITION BEHAVIORS OF LARGER DATA SET;
- [0180] U.S. patent application Ser. No. 15/940,694, titled CLOUD-BASED MEDICAL ANALYTICS FOR MEDICAL FACILITY SEGMENTED INDIVIDUALIZATION OF INSTRUMENT FUNCTION;
- [0181] U.S. patent application Ser. No. 15/940,634, titled CLOUD-BASED MEDICAL ANALYTICS FOR SECURITY AND AUTHENTICATION TRENDS AND REACTIVE MEASURES;
- [0182] U.S. patent application Ser. No. 15/940,706, titled DATA HANDLING AND PRIORITIZATION IN A CLOUD ANALYTICS NETWORK;
- [0183] U.S. patent application Ser. No. 15/940,675, titled CLOUD INTERFACE FOR COUPLED SURGICAL DEVICES;
- [0184] U.S. patent application Ser. No. 15/940,627, titled DRIVE ARRANGEMENTS FOR ROBOT-ASSISTED SURGICAL PLATFORMS;
- [0185] U.S. patent application Ser. No. 15/940,637, titled COMMUNICATION ARRANGEMENTS FOR ROBOT-ASSISTED SURGICAL PLATFORMS;
- [0186] U.S. patent application Ser. No. 15/940,642, titled CONTROLS FOR ROBOT-ASSISTED SURGICAL PLATFORMS;
- [0187] U.S. patent application Ser. No. 15/940,676, titled AUTOMATIC TOOL ADJUSTMENTS FOR ROBOT-ASSISTED SURGICAL PLATFORMS;
- [0188] U.S. patent application Ser. No. 15/940,680, titled CONTROLLERS FOR ROBOT-ASSISTED SURGICAL PLATFORMS;
- [0189] U.S. patent application Ser. No. 15/940,683, titled COOPERATIVE SURGICAL ACTIONS FOR ROBOT-ASSISTED SURGICAL PLATFORMS;
- [0190] U.S. patent application Ser. No. 15/940,690, titled DISPLAY ARRANGEMENTS FOR ROBOT-ASSISTED SURGICAL PLATFORMS; and
- [0191] U.S. patent application Ser. No. 15/940,711, titled SENSING ARRANGEMENTS FOR ROBOT-ASSISTED SURGICAL PLATFORMS.
- [0192] Applicant of the present application owns the following U.S. Provisional Patent Applications, filed on Mar. 28, 2018, the disclosure of each of which is herein incorporated by reference in its entirety:
- [0193] U.S. Provisional Patent Application Ser. No. 62/649,302, titled INTERACTIVE SURGICAL SYSTEMS WITH ENCRYPTED COMMUNICATION CAPABILITIES;
- [0194] U.S. Provisional Patent Application Ser. No. 62/649,294, titled DATA STRIPPING METHOD TO INTERROGATE PATIENT RECORDS AND CREATE ANONYMIZED RECORD;
- [0195] U.S. Provisional Patent Application Ser. No. 62/649,300, titled SURGICAL HUB SITUATIONAL AWARENESS;
- [0196] U.S. Provisional Patent Application Ser. No. 62/649,309, titled SURGICAL HUB SPATIAL AWARENESS TO DETERMINE DEVICES IN OPERATING THEATER;
- [0197] U.S. Provisional Patent Application Ser. No. 62/649,310, titled COMPUTER IMPLEMENTED INTERACTIVE SURGICAL SYSTEMS;
- [0198] U.S. Provisional Patent Application Ser. No. 62/649,291, titled USE OF LASER LIGHT AND RED-GREEN-BLUE COLORATION TO DETERMINE PROPERTIES OF BACK SCATTERED LIGHT;
- [0199] U.S. Provisional Patent Application Ser. No. 62/649,296, titled ADAPTIVE CONTROL PROGRAM UPDATES FOR SURGICAL DEVICES;
- [0200] U.S. Provisional Patent Application Ser. No. 62/649,333, titled CLOUD-BASED MEDICAL ANALYTICS FOR CUSTOMIZATION AND RECOMMENDATIONS TO A USER;
- [0201] U.S. Provisional Patent Application Ser. No. 62/649,327, titled CLOUD-BASED MEDICAL ANALYTICS FOR SECURITY AND AUTHENTICATION TRENDS AND REACTIVE MEASURES;

- [0202] U.S. Provisional Patent Application Ser. No. 62/649,315, titled DATA HANDLING AND PRIORITIZATION IN A CLOUD ANALYTICS NETWORK;
- [0203] U.S. Provisional Patent Application Ser. No. 62/649,313, titled CLOUD INTERFACE FOR COUPLED SURGICAL DEVICES;
- [0204] U.S. Provisional Patent Application Ser. No. 62/649,320, titled DRIVE ARRANGEMENTS FOR ROBOT-ASSISTED SURGICAL PLATFORMS;
- [0205] U.S. Provisional Patent Application Ser. No. 62/649,307, titled AUTOMATIC TOOL ADJUSTMENTS FOR ROBOT-ASSISTED SURGICAL PLATFORMS; and
- [0206] U.S. Provisional Patent Application Ser. No. 62/649,323, titled SENSING ARRANGEMENTS FOR ROBOT-ASSISTED SURGICAL PLATFORMS.
- [0207] Applicant of the present application owns the following U.S. Provisional Patent Applications, filed on Mar. 8, 2018, the disclosure of each of which is herein incorporated by reference in its entirety:
- [0208] U.S. Provisional Patent Application Ser. No. 62/640,417, titled TEMPERATURE CONTROL IN ULTRASONIC DEVICE AND CONTROL SYSTEM THEREFOR; and
- [0209] U.S. Provisional Patent Application Ser. No. 62/640,415, titled ESTIMATING STATE OF ULTRASONIC END EFFECTOR AND CONTROL SYSTEM THEREFOR.
- [0210] Applicant of the present application owns the following U.S. Provisional Patent Applications, filed on Dec. 28, 2017, the disclosure of each of which is herein incorporated by reference in its entirety:
- [0211] U.S. Provisional Patent Application Ser. No. 62/611,341, titled INTERACTIVE SURGICAL PLATFORM;
- [0212] U.S. Provisional Patent Application Ser. No. 62/611,340, titled CLOUD-BASED MEDICAL ANALYTICS; and
- [0213] U.S. Provisional Patent Application Ser. No. 62/611,339, titled ROBOT ASSISTED SURGICAL PLATFORM.
- [0214] Before explaining various aspects of surgical devices and generators in detail, it should be noted that the illustrative examples are not limited in application or use to the details of construction and arrangement of parts illustrated in the accompanying drawings and description. The illustrative examples may be implemented or incorporated in other aspects, variations and modifications, and may be practiced or carried out in various ways. Further, unless otherwise indicated, the terms and expressions employed herein have been chosen for the purpose of describing the illustrative examples for the convenience of the reader and are not for the purpose of limitation thereof. Also, it will be appreciated that one or more of the following-described aspects, expressions of aspects, and/or examples, can be combined with any one or more of the other following-described aspects, expressions of aspects and/or examples.

#### Surgical Hubs

[0215] Referring to FIG. 1, a computer-implemented interactive surgical system 100 includes one or more surgical systems 102 and a cloud-based system (e.g., the cloud 104 that may include a remote server 113 coupled to a storage device 105). Each surgical system 102 includes at least one

surgical hub 106 in communication with the cloud 104 that may include a remote server 113. In one example, as illustrated in FIG. 1, the surgical system 102 includes a visualization system 108, a robotic system 110, and a handheld intelligent surgical instrument 112, which are configured to communicate with one another and/or the hub 106. In some aspects, a surgical system 102 may include an M number of hubs 106, an N number of visualization systems 108, an O number of robotic systems 110, and a P number of handheld intelligent surgical instruments 112, where M, N, O, and P are integers greater than or equal to one.

[0216] In various aspects, the intelligent instruments 112 as described herein with reference to FIGS. 1-7 may be implemented as surgical instruments 200018 (FIG. 17), 200062 (FIG. 20), 200072<sub>a,b</sub> (FIG. 21) 200088 and 200078<sub>a,b</sub> (FIG. 23), surgical device 200078<sub>a,b</sub> (FIG. 22), and visualization system 200086 (FIG. 23). The intelligent instruments 112 (e.g. devices 1<sub>a</sub>-1<sub>n</sub>) such as the surgical instruments 200018 (FIG. 17), 200062 (FIG. 20), 200072<sub>a,b</sub> (FIG. 21) 200088 and 200078<sub>a,b</sub> (FIG. 23), surgical device 200078<sub>a,b</sub> (FIG. 22), and visualization system 200086 (FIG. 23) are configured to operate in a surgical data network 201 as described with reference to FIG. 8.

[0217] FIG. 2 depicts an example of a surgical system 102 being used to perform a surgical procedure on a patient who is lying down on an operating table 114 in a surgical operating room 116. A robotic system 110 is used in the surgical procedure as a part of the surgical system 102. The robotic system 110 includes a surgeon's console 118, a patient side cart 120 (surgical robot), and a surgical robotic hub 122. The patient side cart 120 can manipulate at least one removably coupled surgical tool 117 through a minimally invasive incision in the body of the patient while the surgeon views the surgical site through the surgeon's console 118. An image of the surgical site can be obtained by a medical imaging device 124, which can be manipulated by the patient side cart 120 to orient the imaging device 124. The robotic hub 122 can be used to process the images of the surgical site for subsequent display to the surgeon through the surgeon's console 118.

[0218] Other types of robotic systems can be readily adapted for use with the surgical system 102. Various examples of robotic systems and surgical tools that are suitable for use with the present disclosure are described in U.S. Provisional Patent Application Ser. No. 62/611,339, titled ROBOT ASSISTED SURGICAL PLATFORM, filed Dec. 28, 2017, the disclosure of which is herein incorporated by reference in its entirety.

[0219] Various examples of cloud-based analytics that are performed by the cloud 104, and are suitable for use with the present disclosure, are described in U.S. Provisional Patent Application Ser. No. 62/611,340, titled CLOUD-BASED MEDICAL ANALYTICS, filed Dec. 28, 2017, the disclosure of which is herein incorporated by reference in its entirety.

[0220] In various aspects, the imaging device 124 includes at least one image sensor and one or more optical components. Suitable image sensors include, but are not limited to, Charge-Coupled Device (CCD) sensors and Complementary Metal-Oxide Semiconductor (CMOS) sensors.

[0221] The optical components of the imaging device 124 may include one or more illumination sources and/or one or more lenses. The one or more illumination sources may be



directed to illuminate portions of the surgical field. The one or more image sensors may receive light reflected or refracted from the surgical field, including light reflected or refracted from tissue and/or surgical instruments.

[0222] The one or more illumination sources may be configured to radiate electromagnetic energy in the visible spectrum as well as the invisible spectrum. The visible spectrum, sometimes referred to as the optical spectrum or luminous spectrum, is that portion of the electromagnetic spectrum that is visible to (i.e., can be detected by) the human eye and may be referred to as visible light or simply light. A typical human eye will respond to wavelengths in air that are from about 380 nm to about 750 nm.

[0223] The invisible spectrum (i.e., the non-luminous spectrum) is that portion of the electromagnetic spectrum that lies below and above the visible spectrum (i.e., wavelengths below about 380 nm and above about 750 nm). The invisible spectrum is not detectable by the human eye. Wavelengths greater than about 750 nm are longer than the red visible spectrum, and they become invisible infrared (IR), microwave, and radio electromagnetic radiation. Wavelengths less than about 380 nm are shorter than the violet spectrum, and they become invisible ultraviolet, x-ray, and gamma ray electromagnetic radiation.

[0224] In various aspects, the imaging device 124 is configured for use in a minimally invasive procedure. Examples of imaging devices suitable for use with the present disclosure include, but not limited to, an arthroscope, angioscope, bronchoscope, choledochoscope, colonoscope, cytoscope, duodenoscope, enteroscope, esophago-gastro-duodenoscope (gastroscope), endoscope, laryngoscope, nasopharyngo-neproscope, sigmoidoscope, thoracoscope, and ureteroscopy.

[0225] In one aspect, the imaging device employs multi-spectrum monitoring to discriminate topography and underlying structures. A multi-spectral image is one that captures image data within specific wavelength ranges across the electromagnetic spectrum. The wavelengths may be separated by filters or by the use of instruments that are sensitive to particular wavelengths, including light from frequencies beyond the visible light range, e.g., IR and ultraviolet. Spectral imaging can allow extraction of additional information the human eye fails to capture with its receptors for red, green, and blue. The use of multi-spectral imaging is described in greater detail under the heading “Advanced Imaging Acquisition Module” in U.S. Provisional Patent Application Ser. No. 62/611,341, titled INTERACTIVE SURGICAL PLATFORM, filed Dec. 28, 2017, the disclosure of which is herein incorporated by reference in its entirety. Multi-spectrum monitoring can be a useful tool in relocating a surgical field after a surgical task is completed to perform one or more of the previously described tests on the treated tissue.

[0226] It is axiomatic that strict sterilization of the operating room and surgical equipment is required during any surgery. The strict hygiene and sterilization conditions required in a “surgical theater,” i.e., an operating or treatment room, necessitate the highest possible sterility of all medical devices and equipment. Part of that sterilization process is the need to sterilize anything that comes in contact with the patient or penetrates the sterile field, including the imaging device 124 and its attachments and components. It will be appreciated that the sterile field may be considered a specified area, such as within a tray or on a sterile towel,

that is considered free of microorganisms, or the sterile field may be considered an area, immediately around a patient, who has been prepared for a surgical procedure. The sterile field may include the scrubbed team members, who are properly attired, and all furniture and fixtures in the area.

[0227] In various aspects, the visualization system 108 includes one or more imaging sensors, one or more image-processing units, one or more storage arrays, and one or more displays that are strategically arranged with respect to the sterile field, as illustrated in FIG. 2. In one aspect, the visualization system 108 includes an interface for HL7, PACS, and EMR. Various components of the visualization system 108 are described under the heading “Advanced Imaging Acquisition Module” in U.S. Provisional Patent Application Ser. No. 62/611,341, titled INTERACTIVE SURGICAL PLATFORM, filed Dec. 28, 2017, the disclosure of which is herein incorporated by reference in its entirety.

[0228] As illustrated in FIG. 2, a primary display 119 is positioned in the sterile field to be visible to an operator at the operating table 114. In addition, a visualization tower 111 is positioned outside the sterile field. The visualization tower 111 includes a first non-sterile display 107 and a second non-sterile display 109, which face away from each other. The visualization system 108, guided by the hub 106, is configured to utilize the displays 107, 109, and 119 to coordinate information flow to operators inside and outside the sterile field. For example, the hub 106 may cause the visualization system 108 to display a snapshot of a surgical site, as recorded by an imaging device 124, on a non-sterile display 107 or 109, while maintaining a live feed of the surgical site on the primary display 119. The snapshot on the non-sterile display 107 or 109 can permit a non-sterile operator to perform a diagnostic step relevant to the surgical procedure, for example.

[0229] In one aspect, the hub 106 is also configured to route a diagnostic input or feedback entered by a non-sterile operator at the visualization tower 111 to the primary display 119 within the sterile field, where it can be viewed by a sterile operator at the operating table. In one example, the input can be in the form of a modification to the snapshot displayed on the non-sterile display 107 or 109, which can be routed to the primary display 119 by the hub 106.

[0230] Referring to FIG. 2, a surgical instrument 112 is being used in the surgical procedure as part of the surgical system 102. The hub 106 is also configured to coordinate information flow to a display of the surgical instrument 112. For example, coordinate information flow is further described in U.S. Provisional Patent Application Ser. No. 62/611,341, titled INTERACTIVE SURGICAL PLATFORM, filed Dec. 28, 2017, the disclosure of which is herein incorporated by reference in its entirety. A diagnostic input or feedback entered by a non-sterile operator at the visualization tower 111 can be routed by the hub 106 to the surgical instrument display 115 within the sterile field, where it can be viewed by the operator of the surgical instrument 112. Example surgical instruments that are suitable for use with the surgical system 102 are described under the heading “Surgical Instrument Hardware” in U.S. Provisional Patent Application Ser. No. 62/611,341, titled INTERACTIVE SURGICAL PLATFORM, filed Dec. 28, 2017, the disclosure of which is herein incorporated by reference in its entirety, for example.

[0231] Referring now to FIG. 3, a hub 106 is depicted in communication with a visualization system 108, a robotic system 110, and a handheld intelligent surgical instrument 112. The hub 106 includes a hub display 135, an imaging module 138, a generator module 140 (which can include a monopolar generator 142, a bipolar generator 144, and/or an ultrasonic generator 143), a communication module 130, a processor module 132, and a storage array 134. In certain aspects, as illustrated in FIG. 3, the hub 106 further includes a smoke evacuation module 126, a suction/irrigation module 128, and/or an OR mapping module 133.

[0232] During a surgical procedure, energy application to tissue, for sealing and/or cutting, is generally associated with smoke evacuation, suction of excess fluid, and/or irrigation of the tissue. Fluid, power, and/or data lines from different sources are often entangled during the surgical procedure. Valuable time can be lost addressing this issue during a surgical procedure. Detangling the lines may necessitate disconnecting the lines from their respective modules, which may require resetting the modules. The hub modular enclosure 136 offers a unified environment for managing the power, data, and fluid lines, which reduces the frequency of entanglement between such lines.

[0233] Aspects of the present disclosure present a surgical hub for use in a surgical procedure that involves energy application to tissue at a surgical site. The surgical hub includes a hub enclosure and a combo generator module slidably receivable in a docking station of the hub enclosure. The docking station includes data and power contacts. The combo generator module includes two or more of an ultrasonic energy generator component, a bipolar RF energy generator component, and a monopolar RF energy generator component that are housed in a single unit. In one aspect, the combo generator module also includes a smoke evacuation component, at least one energy delivery cable for connecting the combo generator module to a surgical instrument, at least one smoke evacuation component configured to evacuate smoke, fluid, and/or particulates generated by the application of therapeutic energy to the tissue, and a fluid line extending from the remote surgical site to the smoke evacuation component.

[0234] In one aspect, the fluid line is a first fluid line and a second fluid line extends from the remote surgical site to a suction and irrigation module slidably received in the hub enclosure. In one aspect, the hub enclosure comprises a fluid interface.

[0235] Certain surgical procedures may require the application of more than one energy type to the tissue. One energy type may be more beneficial for cutting the tissue, while another different energy type may be more beneficial for sealing the tissue. For example, a bipolar generator can be used to seal the tissue while an ultrasonic generator can be used to cut the sealed tissue. Aspects of the present disclosure present a solution where a hub modular enclosure 136 is configured to accommodate different generators, and facilitate an interactive communication therebetween. One of the advantages of the hub modular enclosure 136 is enabling the quick removal and/or replacement of various modules.

[0236] Aspects of the present disclosure present a modular surgical enclosure for use in a surgical procedure that involves energy application to tissue. The modular surgical enclosure includes a first energy-generator module, configured to generate a first energy for application to the tissue,

and a first docking station comprising a first docking port that includes first data and power contacts, wherein the first energy-generator module is slidably movable into an electrical engagement with the power and data contacts and wherein the first energy-generator module is slidably movable out of the electrical engagement with the first power and data contacts,

[0237] Further to the above, the modular surgical enclosure also includes a second energy-generator module configured to generate a second energy, different than the first energy, for application to the tissue, and a second docking station comprising a second docking port that includes second data and power contacts, wherein the second energy-generator module is slidably movable into an electrical engagement with the power and data contacts, and wherein the second energy-generator module is slidably movable out of the electrical engagement with the second power and data contacts.

[0238] In addition, the modular surgical enclosure also includes a communication bus between the first docking port and the second docking port, configured to facilitate communication between the first energy-generator module and the second energy-generator module.

[0239] Referring to FIGS. 3-7, aspects of the present disclosure are presented for a hub modular enclosure 136 that allows the modular integration of a generator module 140, a smoke evacuation module 126, and a suction/irrigation module 128. The hub modular enclosure 136 further facilitates interactive communication between the modules 140, 126, 128. As illustrated in FIG. 5, the generator module 140 can be a generator module with integrated monopolar, bipolar, and ultrasonic components supported in a single housing unit 139 slidably insertable into the hub modular enclosure 136. As illustrated in FIG. 5, the generator module 140 can be configured to connect to a monopolar device 146, a bipolar device 147, and an ultrasonic device 148. Alternatively, the generator module 140 may comprise a series of monopolar, bipolar, and/or ultrasonic generator modules that interact through the hub modular enclosure 136. The hub modular enclosure 136 can be configured to facilitate the insertion of multiple generators and interactive communication between the generators docked into the hub modular enclosure 136 so that the generators would act as a single generator.

[0240] In one aspect, the hub modular enclosure 136 comprises a modular power and communication backplane 149 with external and wireless communication headers to enable the removable attachment of the modules 140, 126, 128 and interactive communication therebetween.

[0241] In one aspect, the hub modular enclosure 136 includes docking stations, or drawers, 151, herein also referred to as drawers, which are configured to slidably receive the modules 140, 126, 128. FIG. 4 illustrates a partial perspective view of a surgical hub enclosure 136, and a combo generator module 145 slidably receivable in a docking station 151 of the surgical hub enclosure 136. A docking port 152 with power and data contacts on a rear side of the combo generator module 145 is configured to engage a corresponding docking port 150 with power and data contacts of a corresponding docking station 151 of the hub modular enclosure 136 as the combo generator module 145 is slid into position within the corresponding docking station 151 of the hub module enclosure 136. In one aspect, the combo generator module 145 includes a bipolar, ultrasonic,

and monopolar module and a smoke evacuation module integrated together into a single housing unit **139**, as illustrated in FIG. 5.

[0242] In various aspects, the smoke evacuation module **126** includes a fluid line **154** that conveys captured/collected smoke and/or fluid away from a surgical site and to, for example, the smoke evacuation module **126**. Vacuum suction originating from the smoke evacuation module **126** can draw the smoke into an opening of a utility conduit at the surgical site. The utility conduit, coupled to the fluid line, can be in the form of a flexible tube terminating at the smoke evacuation module **126**. The utility conduit and the fluid line define a fluid path extending toward the smoke evacuation module **126** that is received in the hub enclosure **136**.

[0243] In various aspects, the suction/irrigation module **128** is coupled to a surgical tool comprising an aspiration fluid line and a suction fluid line. In one example, the aspiration and suction fluid lines are in the form of flexible tubes extending from the surgical site toward the suction/irrigation module **128**. One or more drive systems can be configured to cause irrigation and aspiration of fluids to and from the surgical site.

[0244] In one aspect, the surgical tool includes a shaft having an end effector at a distal end thereof and at least one energy treatment associated with the end effector, an aspiration tube, and an irrigation tube. The aspiration tube can have an inlet port at a distal end thereof and the aspiration tube extends through the shaft. Similarly, an irrigation tube can extend through the shaft and can have an inlet port in proximity to the energy deliver implement. The energy deliver implement is configured to deliver ultrasonic and/or RF energy to the surgical site and is coupled to the generator module **140** by a cable extending initially through the shaft.

[0245] The irrigation tube can be in fluid communication with a fluid source, and the aspiration tube can be in fluid communication with a vacuum source. The fluid source and/or the vacuum source can be housed in the suction/irrigation module **128**. In one example, the fluid source and/or the vacuum source can be housed in the hub enclosure **136** separately from the suction/irrigation module **128**. In such example, a fluid interface can be configured to connect the suction/irrigation module **128** to the fluid source and/or the vacuum source.

[0246] In one aspect, the modules **140**, **126**, **128** and/or their corresponding docking stations on the hub modular enclosure **136** may include alignment features that are configured to align the docking ports of the modules into engagement with their counterparts in the docking stations of the hub modular enclosure **136**. For example, as illustrated in FIG. 4, the combo generator module **145** includes side brackets **155** that are configured to slidably engage with corresponding brackets **156** of the corresponding docking station **151** of the hub modular enclosure **136**. The brackets cooperate to guide the docking port contacts of the combo generator module **145** into an electrical engagement with the docking port contacts of the hub modular enclosure **136**.

[0247] In some aspects, the drawers **151** of the hub modular enclosure **136** are the same, or substantially the same size, and the modules are adjusted in size to be received in the drawers **151**. For example, the side brackets **155** and/or **156** can be larger or smaller depending on the size of the module. In other aspects, the drawers **151** are different in size and are each designed to accommodate a particular module.

[0248] Furthermore, the contacts of a particular module can be keyed for engagement with the contacts of a particular drawer to avoid inserting a module into a drawer with mismatching contacts.

[0249] As illustrated in FIG. 4, the docking port **150** of one drawer **151** can be coupled to the docking port **150** of another drawer **151** through a communications link **157** to facilitate an interactive communication between the modules housed in the hub modular enclosure **136**. The docking ports **150** of the hub modular enclosure **136** may alternatively, or additionally, facilitate a wireless interactive communication between the modules housed in the hub modular enclosure **136**. Any suitable wireless communication can be employed, such as for example Air Titan-Bluetooth.

[0250] FIG. 6 illustrates individual power bus attachments for a plurality of lateral docking ports of a lateral modular housing **160** configured to receive a plurality of modules of a surgical hub **206**. The lateral modular housing **160** is configured to laterally receive and interconnect the modules **161**. The modules **161** are slidably inserted into docking stations **162** of lateral modular housing **160**, which includes a backplane for interconnecting the modules **161**. As illustrated in FIG. 6, the modules **161** are arranged laterally in the lateral modular housing **160**. Alternatively, the modules **161** may be arranged vertically in a lateral modular housing.

[0251] FIG. 7 illustrates a vertical modular housing **164** configured to receive a plurality of modules **165** of the surgical hub **106**. The modules **165** are slidably inserted into docking stations, or drawers, **167** of vertical modular housing **164**, which includes a backplane for interconnecting the modules **165**. Although the drawers **167** of the vertical modular housing **164** are arranged vertically, in certain instances, a vertical modular housing **164** may include drawers that are arranged laterally. Furthermore, the modules **165** may interact with one another through the docking ports of the vertical modular housing **164**. In the example of FIG. 7, a display **177** is provided for displaying data relevant to the operation of the modules **165**. In addition, the vertical modular housing **164** includes a master module **178** housing a plurality of sub-modules that are slidably received in the master module **178**.

[0252] In various aspects, the imaging module **138** comprises an integrated video processor and a modular light source and is adapted for use with various imaging devices. In one aspect, the imaging device is comprised of a modular housing that can be assembled with a light source module and a camera module. The housing can be a disposable housing. In at least one example, the disposable housing is removably coupled to a reusable controller, a light source module, and a camera module. The light source module and/or the camera module can be selectively chosen depending on the type of surgical procedure. In one aspect, the camera module comprises a CCD sensor. In another aspect, the camera module comprises a CMOS sensor. In another aspect, the camera module is configured for scanned beam imaging. Likewise, the light source module can be configured to deliver a white light or a different light, depending on the surgical procedure.

[0253] During a surgical procedure, removing a surgical device from the surgical field and replacing it with another surgical device that includes a different camera or a different light source can be inefficient. Temporarily losing sight of the surgical field may lead to undesirable consequences. The module imaging device of the present disclosure is config-

ured to permit the replacement of a light source module or a camera module midstream during a surgical procedure, without having to remove the imaging device from the surgical field.

**[0254]** In one aspect, the imaging device comprises a tubular housing that includes a plurality of channels. A first channel is configured to slidably receive the camera module, which can be configured for a snap-fit engagement with the first channel. A second channel is configured to slidably receive the light source module, which can be configured for a snap-fit engagement with the second channel. In another example, the camera module and/or the light source module can be rotated into a final position within their respective channels. A threaded engagement can be employed in lieu of the snap-fit engagement.

**[0255]** In various examples, multiple imaging devices are placed at different positions in the surgical field to provide multiple views. The imaging module **138** can be configured to switch between the imaging devices to provide an optimal view. In various aspects, the imaging module **138** can be configured to integrate the images from the different imaging device.

**[0256]** Various image processors and imaging devices suitable for use with the present disclosure are described in U.S. Pat. No. 7,995,045, titled COMBINED SBI AND CONVENTIONAL IMAGE PROCESSOR, which issued on Aug. 9, 2011, which is herein incorporated by reference in its entirety. In addition, U.S. Pat. No. 7,982,776, titled SBI MOTION ARTIFACT REMOVAL APPARATUS AND METHOD, which issued on Jul. 19, 2011, which is herein incorporated by reference in its entirety, describes various systems for removing motion artifacts from image data. Such systems can be integrated with the imaging module **138**. Furthermore, U.S. Patent Application Publication No. 2011/0306840, titled CONTROLLABLE MAGNETIC SOURCE TO FIXTURE INTRACORPOREAL APPARATUS, which published on Dec. 15, 2011, and U.S. Patent Application Publication No. 2014/0243597, titled SYSTEM FOR PERFORMING A MINIMALLY INVASIVE SURGICAL PROCEDURE, which published on Aug. 28, 2014, each of which is herein incorporated by reference in its entirety.

**[0257]** FIG. 8 illustrates a surgical data network **201** comprising a modular communication hub **203** configured to connect modular devices located in one or more operating theaters of a healthcare facility, or any room in a healthcare facility specially equipped for surgical operations, to a cloud-based system (e.g., the cloud **204** that may include a remote server **213** coupled to a storage device **205**). In one aspect, the modular communication hub **203** comprises a network hub **207** and/or a network switch **209** in communication with a network router. The modular communication hub **203** also can be coupled to a local computer system **210** to provide local computer processing and data manipulation. The surgical data network **201** may be configured as passive, intelligent, or switching. A passive surgical data network serves as a conduit for the data, enabling it to go from one device (or segment) to another and to the cloud computing resources. An intelligent surgical data network includes additional features to enable the traffic passing through the surgical data network to be monitored and to configure each port in the network hub **207** or network switch **209**. An intelligent surgical data network may be referred to as a

manageable hub or switch. A switching hub reads the destination address of each packet and then forwards the packet to the correct port.

**[0258]** Modular devices **1a-1n** located in the operating theater may be coupled to the modular communication hub **203**. The network hub **207** and/or the network switch **209** may be coupled to a network router **211** to connect the devices **1a-1n** to the cloud **204** or the local computer system **210**. Data associated with the devices **1a-1n** may be transferred to cloud-based computers via the router for remote data processing and manipulation. Data associated with the devices **1a-1n** may also be transferred to the local computer system **210** for local data processing and manipulation. Modular devices **2a-2m** located in the same operating theater also may be coupled to a network switch **209**. The network switch **209** may be coupled to the network hub **207** and/or the network router **211** to connect to the devices **2a-2m** to the cloud **204**. Data associated with the devices **2a-2m** may be transferred to the cloud **204** via the network router **211** for data processing and manipulation. Data associated with the devices **2a-2m** may also be transferred to the local computer system **210** for local data processing and manipulation.

**[0259]** It will be appreciated that the surgical data network **201** may be expanded by interconnecting multiple network hubs **207** and/or multiple network switches **209** with multiple network routers **211**. The modular communication hub **203** may be contained in a modular control tower configured to receive multiple devices **1a-1n/2a-2m**. The local computer system **210** also may be contained in a modular control tower. The modular communication hub **203** is connected to a display **212** to display images obtained by some of the devices **1a-1n/2a-2m**, for example during surgical procedures. In various aspects, the devices **1a-1n/2a-2m** may include, for example, various modules such as an imaging module **138** coupled to an endoscope, a generator module **140** coupled to an energy-based surgical device, a smoke evacuation module **126**, a suction/irrigation module **128**, a communication module **130**, a processor module **132**, a storage array **134**, a surgical device coupled to a display, and/or a non-contact sensor module, among other modular devices that may be connected to the modular communication hub **203** of the surgical data network **201**.

**[0260]** In one aspect, the surgical data network **201** may comprise a combination of network hub(s), network switch(es), and network router(s) connecting the devices **1a-1n/2a-2m** to the cloud. Any one of or all of the devices **1a-1n/2a-2m** coupled to the network hub or network switch may collect data in real time and transfer the data to cloud computers for data processing and manipulation. It will be appreciated that cloud computing relies on sharing computing resources rather than having local servers or personal devices to handle software applications. The word “cloud” may be used as a metaphor for “the Internet,” although the term is not limited as such. Accordingly, the term “cloud computing” may be used herein to refer to “a type of Internet-based computing,” where different services—such as servers, storage, and applications—are delivered to the modular communication hub **203** and/or computer system **210** located in the surgical theater (e.g., a fixed, mobile, temporary, or field operating room or space) and to devices connected to the modular communication hub **203** and/or computer system **210** through the Internet. The cloud infrastructure may be maintained by a cloud service provider. In

this context, the cloud service provider may be the entity that coordinates the usage and control of the devices  $1a-1n/2a-2m$  located in one or more operating theaters. The cloud computing services can perform a large number of calculations based on the data gathered by smart surgical instruments, robots, and other computerized devices located in the operating theater. The hub hardware enables multiple devices or connections to be connected to a computer that communicates with the cloud computing resources and storage.

[0261] Applying cloud computer data processing techniques on the data collected by the devices  $1a-1n/2a-2m$ , the surgical data network provides improved surgical outcomes, reduced costs, and improved patient satisfaction. At least some of the devices  $1a-1n/2a-2m$  may be employed to view tissue states to assess leaks or perfusion of sealed tissue after a tissue sealing and cutting procedure. At least some of the devices  $1a-1n/2a-2m$  may be employed to identify pathology, such as the effects of diseases, using the cloud-based computing to examine data including images of samples of body tissue for diagnostic purposes. This includes localization and margin confirmation of tissue and phenotypes. At least some of the devices  $1a-1n/2a-2m$  may be employed to identify anatomical structures of the body using a variety of sensors integrated with imaging devices and techniques such as overlaying images captured by multiple imaging devices. The data gathered by the devices  $1a-1n/2a-2m$ , including image data, may be transferred to the cloud 204 or the local computer system 210 or both for data processing and manipulation including image processing and manipulation. The data may be analyzed to improve surgical procedure outcomes by determining if further treatment, such as the application of endoscopic intervention, emerging technologies, a targeted radiation, targeted intervention, and precise robotics to tissue-specific sites and conditions, may be pursued. Such data analysis may further employ outcome analytics processing, and using standardized approaches may provide beneficial feedback to either confirm surgical treatments and the behavior of the surgeon or suggest modifications to surgical treatments and the behavior of the surgeon.

[0262] In one implementation, the operating theater devices  $1a-1n$  may be connected to the modular communication hub 203 over a wired channel or a wireless channel depending on the configuration of the devices  $1a-1n$  to a network hub. The network hub 207 may be implemented, in one aspect, as a local network broadcast device that works on the physical layer of the Open System Interconnection (OSI) model. The network hub provides connectivity to the devices  $1a-1n$  located in the same operating theater network. The network hub 207 collects data in the form of packets and sends them to the router in half duplex mode. The network hub 207 does not store any media access control/Internet Protocol (MAC/IP) to transfer the device data. Only one of the devices  $1a-1n$  can send data at a time through the network hub 207. The network hub 207 has no routing tables or intelligence regarding where to send information and broadcasts all network data across each connection and to a remote server 213 (FIG. 9) over the cloud 204. The network hub 207 can detect basic network errors such as collisions, but having all information broadcast to multiple ports can be a security risk and cause bottlenecks.

[0263] In another implementation, the operating theater devices  $2a-2m$  may be connected to a network switch 209

over a wired channel or a wireless channel. The network switch 209 works in the data link layer of the OSI model. The network switch 209 is a multicast device for connecting the devices  $2a-2m$  located in the same operating theater to the network. The network switch 209 sends data in the form of frames to the network router 211 and works in full duplex mode. Multiple devices  $2a-2m$  can send data at the same time through the network switch 209. The network switch 209 stores and uses MAC addresses of the devices  $2a-2m$  to transfer data.

[0264] The network hub 207 and/or the network switch 209 are coupled to the network router 211 for connection to the cloud 204. The network router 211 works in the network layer of the OSI model. The network router 211 creates a route for transmitting data packets received from the network hub 207 and/or network switch 211 to cloud-based computer resources for further processing and manipulation of the data collected by any one of or all the devices  $1a-1n/2a-2m$ . The network router 211 may be employed to connect two or more different networks located in different locations, such as, for example, different operating theaters of the same healthcare facility or different networks located in different operating theaters of different healthcare facilities. The network router 211 sends data in the form of packets to the cloud 204 and works in full duplex mode. Multiple devices can send data at the same time. The network router 211 uses IP addresses to transfer data.

[0265] In one example, the network hub 207 may be implemented as a USB hub, which allows multiple USB devices to be connected to a host computer. The USB hub may expand a single USB port into several tiers so that there are more ports available to connect devices to the host system computer. The network hub 207 may include wired or wireless capabilities to receive information over a wired channel or a wireless channel. In one aspect, a wireless USB short-range, high-bandwidth wireless radio communication protocol may be employed for communication between the devices  $1a-1n$  and devices  $2a-2m$  located in the operating theater.

[0266] In other examples, the operating theater devices  $1a-1n/2a-2m$  may communicate to the modular communication hub 203 via Bluetooth wireless technology standard for exchanging data over short distances (using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz) from fixed and mobile devices and building personal area networks (PANs). In other aspects, the operating theater devices  $1a-1n/2a-2m$  may communicate to the modular communication hub 203 via a number of wireless or wired communication standards or protocols, including but not limited to W-Fi (IEEE 802.11 family), WiMAX (IEEE 802.16 family), IEEE 802.20, long-term evolution (LTE), and Ev-DO, HSPA+, HSDPA+, HSUPA+, EDGE, GSM, GPRS, CDMA, TDMA, DECT, and Ethernet derivatives thereof, as well as any other wireless and wired protocols that are designated as 3G, 4G, 5G, and beyond. The computing module may include a plurality of communication modules. For instance, a first communication module may be dedicated to shorter-range wireless communications such as Wi-Fi and Bluetooth, and a second communication module may be dedicated to longer-range wireless communications such as GPS, EDGE, GPRS, CDMA, WiMAX, LTE, Ev-DO, and others.

[0267] The modular communication hub 203 may serve as a central connection for one or all of the operating theater

devices *1a-1n/2a-2m* and handles a data type known as frames. Frames carry the data generated by the devices *1a-1n/2a-2m*. When a frame is received by the modular communication hub **203**, it is amplified and transmitted to the network router **211**, which transfers the data to the cloud computing resources by using a number of wireless or wired communication standards or protocols, as described herein.

[0268] The modular communication hub **203** can be used as a standalone device or be connected to compatible network hubs and network switches to form a larger network. The modular communication hub **203** is generally easy to install, configure, and maintain, making it a good option for networking the operating theater devices *1a-1n/2a-2m*.

[0269] FIG. 9 illustrates a computer-implemented interactive surgical system **200**. The computer-implemented interactive surgical system **200** is similar in many respects to the computer-implemented interactive surgical system **100**. For example, the computer-implemented interactive surgical system **200** includes one or more surgical systems **202**, which are similar in many respects to the surgical systems **102**. Each surgical system **202** includes at least one surgical hub **206** in communication with a cloud **204** that may include a remote server **213**. In one aspect, the computer-implemented interactive surgical system **200** comprises a modular control tower **236** connected to multiple operating theater devices such as, for example, intelligent surgical instruments, robots, and other computerized devices located in the operating theater. As shown in FIG. 10, the modular control tower **236** comprises a modular communication hub **203** coupled to a computer system **210**. As illustrated in the example of FIG. 9, the modular control tower **236** is coupled to an imaging module **238** that is coupled to an endoscope **239**, a generator module **240** that is coupled to an energy device **241**, a smoke evacuator module **226**, a suction/irrigation module **228**, a communication module **230**, a processor module **232**, a storage array **234**, a smart device/instrument **235** optionally coupled to a display **237**, and a non-contact sensor module **242**. The operating theater devices are coupled to cloud computing resources and data storage via the modular control tower **236**. A robot hub **222** also may be connected to the modular control tower **236** and to the cloud computing resources. The devices/instruments **235**, visualization systems **208**, among others, may be coupled to the modular control tower **236** via wired or wireless communication standards or protocols, as described herein. The modular control tower **236** may be coupled to a hub display **215** (e.g., monitor, screen) to display and overlay images received from the imaging module, device/instrument display, and/or other visualization systems **208**. The hub display also may display data received from devices connected to the modular control tower in conjunction with images and overlaid images.

[0270] FIG. 10 illustrates a surgical hub **206** comprising a plurality of modules coupled to the modular control tower **236**. The modular control tower **236** comprises a modular communication hub **203**, e.g., a network connectivity device, and a computer system **210** to provide local processing, visualization, and imaging, for example. As shown in FIG. 10, the modular communication hub **203** may be connected in a tiered configuration to expand the number of modules (e.g., devices) that may be connected to the modular communication hub **203** and transfer data associated with the modules to the computer system **210**, cloud computing

resources, or both. As shown in FIG. 10, each of the network hubs/switches in the modular communication hub **203** includes three downstream ports and one upstream port. The upstream network hub/switch is connected to a processor to provide a communication connection to the cloud computing resources and a local display **217**. Communication to the cloud **204** may be made either through a wired or a wireless communication channel.

[0271] The surgical hub **206** employs a non-contact sensor module **242** to measure the dimensions of the operating theater and generate a map of the surgical theater using either ultrasonic or laser-type non-contact measurement devices. An ultrasound-based non-contact sensor module scans the operating theater by transmitting a burst of ultrasound and receiving the echo when it bounces off the perimeter walls of an operating theater as described under the heading “Surgical Hub Spatial Awareness Within an Operating Room” in U.S. Provisional Patent Application Ser. No. 62/611,341, titled INTERACTIVE SURGICAL PLATFORM, filed Dec. 28, 2017, which is herein incorporated by reference in its entirety, in which the sensor module is configured to determine the size of the operating theater and to adjust Bluetooth-pairing distance limits. A laser-based non-contact sensor module scans the operating theater by transmitting laser light pulses, receiving laser light pulses that bounce off the perimeter walls of the operating theater, and comparing the phase of the transmitted pulse to the received pulse to determine the size of the operating theater and to adjust Bluetooth pairing distance limits, for example.

[0272] The computer system **210** comprises a processor **244** and a network interface **245**. The processor **244** is coupled to a communication module **247**, storage **248**, memory **249**, non-volatile memory **250**, and input/output interface **251** via a system bus. The system bus can be any of several types of bus structure(s) including the memory bus or memory controller, a peripheral bus or external bus, and/or a local bus using any variety of available bus architectures including, but not limited to, 9-bit bus, Industrial Standard Architecture (ISA), Micro-Charmel Architecture (MSA), Extended ISA (EISA), Intelligent Drive Electronics (IDE), VESA Local Bus (VLB), Peripheral Component Interconnect (PCI), USB, Advanced Graphics Port (AGP), Personal Computer Memory Card International Association bus (PCMCIA), Small Computer Systems Interface (SCSI), or any other proprietary bus.

[0273] The processor **244** may be any single-core or multicore processor such as those known under the trade name ARM Cortex by Texas Instruments. In one aspect, the processor may be an LM4F230H5QR ARM Cortex-M4F Processor Core, available from Texas Instruments, for example, comprising an on-chip memory of 256 KB single-cycle flash memory, or other non-volatile memory, up to 40 MHz, a prefetch buffer to improve performance above 40 MHz, a 32 KB single-cycle serial random access memory (SRAM), an internal read-only memory (ROM) loaded with StellarisWare® software, a 2 KB electrically erasable programmable read-only memory (EEPROM), and/or one or more pulse width modulation (PWM) modules, one or more quadrature encoder inputs (QEI) analogs, one or more 12-bit analog-to-digital converters (ADCs) with 12 analog input channels, details of which are available for the product datasheet.

[0274] In one aspect, the processor **244** may comprise a safety controller comprising two controller-based families

such as TMS570 and RM4x, known under the trade name Hercules ARM Cortex R4, also by Texas Instruments. The safety controller may be configured specifically for IEC 61508 and ISO 26262 safety critical applications, among others, to provide advanced integrated safety features while delivering scalable performance, connectivity, and memory options.

**[0275]** The system memory includes volatile memory and non-volatile memory. The basic input/output system (BIOS), containing the basic routines to transfer information between elements within the computer system, such as during start-up, is stored in non-volatile memory. For example, the non-volatile memory can include ROM, programmable ROM (PROM), electrically programmable ROM (EPROM), EEPROM, or flash memory. Volatile memory includes random-access memory (RAM), which acts as external cache memory. Moreover, RAM is available in many forms such as SRAM, dynamic RAM (DRAM), synchronous DRAM (SDRAM), double data rate SDRAM (DDR SDRAM), enhanced SDRAM (ESDRAM), Synchlink DRAM (SL-DRAM), and direct Rambus RAM (DRRAM).

**[0276]** The computer system **210** also includes removable/non-removable, volatile/non-volatile computer storage media, such as for example disk storage. The disk storage includes, but is not limited to, devices like a magnetic disk drive, floppy disk drive, tape drive, Jaz drive, Zip drive, LS-60 drive, flash memory card, or memory stick. In addition, the disk storage can include storage media separately or in combination with other storage media including, but not limited to, an optical disc drive such as a compact disc ROM device (CD-ROM), compact disc recordable drive (CD-R Drive), compact disc rewritable drive (CD-RW Drive), or a digital versatile disc ROM drive (DVD-ROM). To facilitate the connection of the disk storage devices to the system bus, a removable or non-removable interface may be employed.

**[0277]** It is to be appreciated that the computer system **210** includes software that acts as an intermediary between users and the basic computer resources described in a suitable operating environment. Such software includes an operating system. The operating system, which can be stored on the disk storage, acts to control and allocate resources of the computer system. System applications take advantage of the management of resources by the operating system through program modules and program data stored either in the system memory or on the disk storage. It is to be appreciated that various components described herein can be implemented with various operating systems or combinations of operating systems.

**[0278]** A user enters commands or information into the computer system **210** through input device(s) coupled to the I/O interface **251**. The input devices include, but are not limited to, a pointing device such as a mouse, trackball, stylus, touch pad, keyboard, microphone, joystick, game pad, satellite dish, scanner, TV tuner card, digital camera, digital video camera, web camera, and the like. These and other input devices connect to the processor through the system bus via interface port(s). The interface port(s) include, for example, a serial port, a parallel port, a game port, and a USB. The output device(s) use some of the same types of ports as input device(s). Thus, for example, a USB port may be used to provide input to the computer system and to output information from the computer system to an output device. An output adapter is provided to illustrate that there are some output devices like monitors, displays, speak-

ers, and printers, among other output devices that require special adapters. The output adapters include, by way of illustration and not limitation, video and sound cards that provide a means of connection between the output device and the system bus. It should be noted that other devices and/or systems of devices, such as remote computer(s), provide both input and output capabilities.

**[0279]** The computer system **210** can operate in a networked environment using logical connections to one or more remote computers, such as cloud computer(s), or local computers. The remote cloud computer(s) can be a personal computer, server, router, network PC, workstation, micro-processor-based appliance, peer device, or other common network node, and the like, and typically includes many or all of the elements described relative to the computer system. For purposes of brevity, only a memory storage device is illustrated with the remote computer(s). The remote computer(s) is logically connected to the computer system through a network interface and then physically connected via a communication connection. The network interface encompasses communication networks such as local area networks (LANs) and wide area networks (WANs). LAN technologies include Fiber Distributed Data Interface (FDDI), Copper Distributed Data Interface (CDDI), Ethernet/IEEE 802.3, Token Ring/IEEE 802.5 and the like. WAN technologies include, but are not limited to, point-to-point links, circuit-switching networks like Integrated Services Digital Networks (ISDN) and variations thereon, packet-switching networks, and Digital Subscriber Lines (DSL).

**[0280]** In various aspects, the computer system **210** of FIG. **10**, the imaging module **238** and/or visualization system **208**, and/or the processor module **232** of FIGS. **9-10**, may comprise an image processor, image-processing engine, media processor, or any specialized digital signal processor (DSP) used for the processing of digital images. The image processor may employ parallel computing with single instruction, multiple data (SIMD) or multiple instruction, multiple data (MIMD) technologies to increase speed and efficiency. The digital image-processing engine can perform a range of tasks. The image processor may be a system on a chip with multicore processor architecture.

**[0281]** The communication connection(s) refers to the hardware/software employed to connect the network interface to the bus. While the communication connection is shown for illustrative clarity inside the computer system, it can also be external to the computer system **210**. The hardware/software necessary for connection to the network interface includes, for illustrative purposes only, internal and external technologies such as modems, including regular telephone-grade modems, cable modems, and DSL modems, ISDN adapters, and Ethernet cards.

**[0282]** In various aspects, the devices/instruments **235** described with reference to FIGS. **9-10**, may be implemented as surgical instruments **200018** (FIG. **17**), **200062** (FIG. **20**), **200072a,b** (FIG. **21**) **200088** and **200078a,b** (FIG. **23**), surgical device **200078a,b** (FIG. **22**), and visualization system **200086** (FIG. **23**). Accordingly, as surgical instruments **200018** (FIG. **17**), **200062** (FIG. **20**), **200072a,b** (FIG. **21**) **200088** and **200078a,b** (FIG. **23**), surgical device **200078a,b** (FIG. **22**), and visualization system **200086** (FIG. **23**) are configured to interface with the modular control tower **236** and the surgical hub **206**. Once connected to the surgical hub **206** as surgical instruments **200018** (FIG. **17**),

**200062** (FIG. 20), **200072<sub>a,b</sub>** (FIG. 21) **200088** and **200078<sub>a,b</sub>** (FIG. 23), surgical device **200078<sub>a,b</sub>** (FIG. 22), and visualization system **200086** (FIG. 23) are configured to interface with the cloud **204**, the server **213**, other hub connected instruments, the hub display **215**, or the visualization system **209**, or combinations thereof. Further, once connected to hub **206**, as surgical instruments **200018** (FIG. 17), **200062** (FIG. 20), **200072<sub>a,b</sub>** (FIG. 21) **200088** and **200078<sub>a,b</sub>** (FIG. 23), surgical device **200078<sub>a,b</sub>** (FIG. 22), and visualization system **200086** (FIG. 23) may utilize the processing circuits available in the hub local computer system **210**.

**[0283]** FIG. 11 illustrates a functional block diagram of one aspect of a USB network hub **300** device, in accordance with at least one aspect of the present disclosure. In the illustrated aspect, the USB network hub device **300** employs a TUSB2036 integrated circuit hub by Texas Instruments. The USB network hub **300** is a CMOS device that provides an upstream USB transceiver port **302** and up to three downstream USB transceiver ports **304**, **306**, **308** in compliance with the USB 2.0 specification. The upstream USB transceiver port **302** is a differential root data port comprising a differential data minus (DM0) input paired with a differential data plus (DP0) input. The three downstream USB transceiver ports **304**, **306**, **308** are differential data ports where each port includes differential data plus (DP1-DP3) outputs paired with differential data minus (DM1-DM3) outputs.

**[0284]** The USB network hub **300** device is implemented with a digital state machine instead of a microcontroller, and no firmware programming is required. Fully compliant USB transceivers are integrated into the circuit for the upstream USB transceiver port **302** and all downstream USB transceiver ports **304**, **306**, **308**. The downstream USB transceiver ports **304**, **306**, **308** support both full-speed and low-speed devices by automatically setting the slew rate according to the speed of the device attached to the ports. The USB network hub **300** device may be configured either in bus-powered or self-powered mode and includes a hub power logic **312** to manage power.

**[0285]** The USB network hub **300** device includes a serial interface engine **310** (SIE). The SIE **310** is the front end of the USB network hub **300** hardware and handles most of the protocol described in chapter 8 of the USB specification. The SIE **310** typically comprehends signaling up to the transaction level. The functions that it handles could include: packet recognition, transaction sequencing, SOP, EOP, RESET, and RESUME signal detection/generation, clock/data separation, non-return-to-zero invert (NRZI) data encoding/decoding and bit-stuffing, CRC generation and checking (token and data), packet ID (PID) generation and checking/decoding, and/or serial-parallel/parallel-serial conversion. The **310** receives a clock input **314** and is coupled to a suspend/resume logic and frame timer **316** circuit and a hub repeater circuit **318** to control communication between the upstream USB transceiver port **302** and the downstream USB transceiver ports **304**, **306**, **308** through port logic circuits **320**, **322**, **324**. The SIE **310** is coupled to a command decoder **326** via interface logic **328** to control commands from a serial EEPROM via a serial EEPROM interface **330**.

**[0286]** In various aspects, the USB network hub **300** can connect **127** functions configured in up to six logical layers (tiers) to a single computer. Further, the USB network hub **300** can connect to all peripherals using a standardized

four-wire cable that provides both communication and power distribution. The power configurations are bus-powered and self-powered modes. The USB network hub **300** may be configured to support four modes of power management: a bus-powered hub, with either individual-port power management or ganged-port power management, and the self-powered hub, with either individual-port power management or ganged-port power management. In one aspect, using a USB cable, the USB network hub **300**, the upstream USB transceiver port **302** is plugged into a USB host controller, and the downstream USB transceiver ports **304**, **306**, **308** are exposed for connecting USB compatible devices, and so forth.

**[0287]** Additional details regarding the structure and function of the surgical hub and/or surgical hub networks can be found in U.S. Provisional Patent Application No. 62/659,900, titled METHOD OF HUB COMMUNICATION, filed Apr. 19, 2018, which is hereby incorporated by reference herein in its entirety.

#### Cloud System Hardware and Functional Modules

**[0288]** FIG. 12 is a block diagram of the computer-implemented interactive surgical system, in accordance with at least one aspect of the present disclosure. In one aspect, the computer-implemented interactive surgical system is configured to monitor and analyze data related to the operation of various surgical systems that include surgical hubs, surgical instruments, robotic devices and operating theaters or healthcare facilities. The computer-implemented interactive surgical system comprises a cloud-based analytics system. Although the cloud-based analytics system is described as a surgical system, it is not necessarily limited as such and could be a cloud-based medical system generally. As illustrated in FIG. 12, the cloud-based analytics system comprises a plurality of surgical instruments **7012** (may be the same or similar to instruments **112**), a plurality of surgical hubs **7006** (may be the same or similar to hubs **106**), and a surgical data network **7001** (may be the same or similar to network **201**) to couple the surgical hubs **7006** to the cloud **7004** (may be the same or similar to cloud **204**). Each of the plurality of surgical hubs **7006** is communicatively coupled to one or more surgical instruments **7012**. The hubs **7006** are also communicatively coupled to the cloud **7004** of the computer-implemented interactive surgical system via the network **7001**. The cloud **7004** is a remote centralized source of hardware and software for storing, manipulating, and communicating data generated based on the operation of various surgical systems. As shown in FIG. 12, access to the cloud **7004** is achieved via the network **7001**, which may be the Internet or some other suitable computer network. Surgical hubs **7006** that are coupled to the cloud **7004** can be considered the client side of the cloud computing system (i.e., cloud-based analytics system). Surgical instruments **7012** are paired with the surgical hubs **7006** for control and implementation of various surgical procedures or operations as described herein.

**[0289]** In addition, surgical instruments **7012** may comprise transceivers for data transmission to and from their corresponding surgical hubs **7006** (which may also comprise transceivers). Combinations of surgical instruments **7012** and corresponding hubs **7006** may indicate particular locations, such as operating theaters in healthcare facilities (e.g., hospitals), for providing medical operations. For example, the memory of a surgical hub **7006** may store location data.



As shown in FIG. 12, the cloud 7004 comprises central servers 7013 (which may be same or similar to remote server 113 in FIG. 1 and/or remote server 213 in FIG. 9), hub application servers 7002, data analytics modules 7034, and an input/output (“I/O”) interface 7007. The central servers 7013 of the cloud 7004 collectively administer the cloud computing system, which includes monitoring requests by client surgical hubs 7006 and managing the processing capacity of the cloud 7004 for executing the requests. Each of the central servers 7013 comprises one or more processors 7008 coupled to suitable memory devices 7010 which can include volatile memory such as random-access memory (RAM) and non-volatile memory such as magnetic storage devices. The memory devices 7010 may comprise machine executable instructions that when executed cause the processors 7008 to execute the data analytics modules 7034 for the cloud-based data analysis, operations, recommendations and other operations described below. Moreover, the processors 7008 can execute the data analytics modules 7034 independently or in conjunction with hub applications independently executed by the hubs 7006. The central servers 7013 also comprise aggregated medical data databases 2212, which can reside in the memory 2210.

[0290] Based on connections to various surgical hubs 7006 via the network 7001, the cloud 7004 can aggregate data from specific data generated by various surgical instruments 7012 and their corresponding hubs 7006. Such aggregated data may be stored within the aggregated medical databases 7011 of the cloud 7004. In particular, the cloud 7004 may advantageously perform data analysis and operations on the aggregated data to yield insights and/or perform functions that individual hubs 7006 could not achieve on their own. To this end, as shown in FIG. 12, the cloud 7004 and the surgical hubs 7006 are communicatively coupled to transmit and receive information. The I/O interface 7007 is connected to the plurality of surgical hubs 7006 via the network 7001. In this way, the I/O interface 7007 can be configured to transfer information between the surgical hubs 7006 and the aggregated medical data databases 7011. Accordingly, the I/O interface 7007 may facilitate read/write operations of the cloud-based analytics system. Such read/write operations may be executed in response to requests from hubs 7006. These requests could be transmitted to the hubs 7006 through the hub applications. The I/O interface 7007 may include one or more high speed data ports, which may include universal serial bus (USB) ports, IEEE 1394 ports, as well as W-Fi and Bluetooth I/O interfaces for connecting the cloud 7004 to hubs 7006. The hub application servers 7002 of the cloud 7004 are configured to host and supply shared capabilities to software applications (e.g. hub applications) executed by surgical hubs 7006. For example, the hub application servers 7002 may manage requests made by the hub applications through the hubs 7006, control access to the aggregated medical data databases 7011, and perform load balancing. The data analytics modules 7034 are described in further detail with reference to FIG. 13.

[0291] The particular cloud computing system configuration described in the present disclosure is specifically designed to address various issues arising in the context of medical operations and procedures performed using medical devices, such as the surgical instruments 7012, 112. In particular, the surgical instruments 7012 may be digital surgical devices configured to interact with the cloud 7004

for implementing techniques to improve the performance of surgical operations. Various surgical instruments 7012 and/or surgical hubs 7006 may comprise touch controlled user interfaces such that clinicians may control aspects of interaction between the surgical instruments 7012 and the cloud 7004. Other suitable user interfaces for control such as auditory controlled user interfaces can also be used.

[0292] FIG. 13 is a block diagram which illustrates the functional architecture of the computer-implemented interactive surgical system, in accordance with at least one aspect of the present disclosure. The cloud-based analytics system includes a plurality of data analytics modules 7034 that may be executed by the processors 7008 of the cloud 7004 for providing data analytic solutions to problems specifically arising in the medical field. As shown in FIG. 13, the functions of the cloud-based data analytics modules 7034 may be assisted via hub applications 7014 hosted by the hub application servers 7002 that may be accessed on surgical hubs 7006. The cloud processors 7008 and hub applications 7014 may operate in conjunction to execute the data analytics modules 7034. Application program interfaces (APIs) 7016 define the set of protocols and routines corresponding to the hub applications 7014. Additionally, the APIs 7016 manage the storing and retrieval of data into and from the aggregated medical data databases 7011 for the operations of the applications 7014. The caches 7018 also store data (e.g., temporarily) and are coupled to the APIs 7016 for more efficient retrieval of data used by the applications 7014. The data analytics modules 7034 in FIG. 13 include modules for resource optimization 7020, data collection and aggregation 7022, authorization and security 7024, control program updating 7026, patient outcome analysis 7028, recommendations 7030, and data sorting and prioritization 7032. Other suitable data analytics modules could also be implemented by the cloud 7004, according to some aspects. In one aspect, the data analytics modules are used for specific recommendations based on analyzing trends, outcomes, and other data.

[0293] For example, the data collection and aggregation module 7022 could be used to generate self-describing data (e.g., metadata) including identification of notable features or configuration (e.g., trends), management of redundant data sets, and storage of the data in paired data sets which can be grouped by surgery but not necessarily keyed to actual surgical dates and surgeons. In particular, pair data sets generated from operations of surgical instruments 7012 can comprise applying a binary classification, e.g., a bleeding or a non-bleeding event. More generally, the binary classification may be characterized as either a desirable event (e.g., a successful surgical procedure) or an undesirable event (e.g., a misfired or misused surgical instrument 7012). The aggregated self-describing data may correspond to individual data received from various groups or sub-groups of surgical hubs 7006. Accordingly, the data collection and aggregation module 7022 can generate aggregated metadata or other organized data based on raw data received from the surgical hubs 7006. To this end, the processors 7008 can be operationally coupled to the hub applications 7014 and aggregated medical data databases 7011 for executing the data analytics modules 7034. The data collection and aggregation module 7022 may store the aggregated organized data into the aggregated medical data databases 2212.

[0294] The resource optimization module 7020 can be configured to analyze this aggregated data to determine an

optimal usage of resources for a particular or group of healthcare facilities. For example, the resource optimization module 7020 may determine an optimal order point of surgical stapling instruments 7012 for a group of healthcare facilities based on corresponding predicted demand of such instruments 7012. The resource optimization module 7020 might also assess the resource usage or other operational configurations of various healthcare facilities to determine whether resource usage could be improved. Similarly, the recommendations module 7030 can be configured to analyze aggregated organized data from the data collection and aggregation module 7022 to provide recommendations. For example, the recommendations module 7030 could recommend to healthcare facilities (e.g., medical service providers such as hospitals) that a particular surgical instrument 7012 should be upgraded to an improved version based on a higher than expected error rate, for example. Additionally, the recommendations module 7030 and/or resource optimization module 7020 could recommend better supply chain parameters such as product reorder points and provide suggestions of different surgical instrument 7012, uses thereof, or procedure steps to improve surgical outcomes. The healthcare facilities can receive such recommendations via corresponding surgical hubs 7006. More specific recommendations regarding parameters or configurations of various surgical instruments 7012 can also be provided. Hubs 7006 and/or surgical instruments 7012 each could also have display screens that display data or recommendations provided by the cloud 7004.

[0295] The patient outcome analysis module 7028 can analyze surgical outcomes associated with currently used operational parameters of surgical instruments 7012. The patient outcome analysis module 7028 may also analyze and assess other potential operational parameters. In this connection, the recommendations module 7030 could recommend using these other potential operational parameters based on yielding better surgical outcomes, such as better sealing or less bleeding. For example, the recommendations module 7030 could transmit recommendations to a surgical hub 7006 regarding when to use a particular cartridge for a corresponding stapling surgical instrument 7012. Thus, the cloud-based analytics system, while controlling for common variables, may be configured to analyze the large collection of raw data and to provide centralized recommendations over multiple healthcare facilities (advantageously determined based on aggregated data). For example, the cloud-based analytics system could analyze, evaluate, and/or aggregate data based on type of medical practice, type of patient, number of patients, geographic similarity between medical providers, which medical providers/facilities use similar types of instruments, etc., in a way that no single healthcare facility alone would be able to analyze independently.

[0296] The control program updating module 7026 could be configured to implement various surgical instrument 7012 recommendations when corresponding control programs are updated. For example, the patient outcome analysis module 7028 could identify correlations linking specific control parameters with successful (or unsuccessful) results. Such correlations may be addressed when updated control programs are transmitted to surgical instruments 7012 via the control program updating module 7026. Updates to instruments 7012 that are transmitted via a corresponding hub 7006 may incorporate aggregated performance data that

was gathered and analyzed by the data collection and aggregation module 7022 of the cloud 7004. Additionally, the patient outcome analysis module 7028 and recommendations module 7030 could identify improved methods of using instruments 7012 based on aggregated performance data.

[0297] The cloud-based analytics system may include security features implemented by the cloud 7004. These security features may be managed by the authorization and security module 7024. Each surgical hub 7006 can have associated unique credentials such as username, password, and other suitable security credentials. These credentials could be stored in the memory 7010 and be associated with a permitted cloud access level. For example, based on providing accurate credentials, a surgical hub 7006 may be granted access to communicate with the cloud to a predetermined extent (e.g., may only engage in transmitting or receiving certain defined types of information). To this end, the aggregated medical data databases 7011 of the cloud 7004 may comprise a database of authorized credentials for verifying the accuracy of provided credentials. Different credentials may be associated with varying levels of permission for interaction with the cloud 7004, such as a predetermined access level for receiving the data analytics generated by the cloud 7004.

[0298] Furthermore, for security purposes, the cloud could maintain a database of hubs 7006, instruments 7012, and other devices that may comprise a “black list” of prohibited devices. In particular, a surgical hub 7006 listed on the black list may not be permitted to interact with the cloud, while surgical instruments 7012 listed on the black list may not have functional access to a corresponding hub 7006 and/or may be prevented from fully functioning when paired to its corresponding hub 7006. Additionally or alternatively, the cloud 7004 may flag instruments 7012 based on incompatibility or other specified criteria. In this manner, counterfeit medical devices and improper reuse of such devices throughout the cloud-based analytics system can be identified and addressed.

[0299] The surgical instruments 7012 may use wireless transceivers to transmit wireless signals that may represent, for example, authorization credentials for access to corresponding hubs 7006 and the cloud 7004. Wired transceivers may also be used to transmit signals. Such authorization credentials can be stored in the respective memory devices of the surgical instruments 7012. The authorization and security module 7024 can determine whether the authorization credentials are accurate or counterfeit. The authorization and security module 7024 may also dynamically generate authorization credentials for enhanced security. The credentials could also be encrypted, such as by using hash based encryption. Upon transmitting proper authorization, the surgical instruments 7012 may transmit a signal to the corresponding hubs 7006 and ultimately the cloud 7004 to indicate that the instruments 7012 are ready to obtain and transmit medical data. In response, the cloud 7004 may transition into a state enabled for receiving medical data for storage into the aggregated medical data databases 7011. This data transmission readiness could be indicated by a light indicator on the instruments 7012, for example. The cloud 7004 can also transmit signals to surgical instruments 7012 for updating their associated control programs. The cloud 7004 can transmit signals that are directed to a particular class of surgical instruments 7012 (e.g., electro-

surgical instruments) so that software updates to control programs are only transmitted to the appropriate surgical instruments **7012**. Moreover, the cloud **7004** could be used to implement system wide solutions to address local or global problems based on selective data transmission and authorization credentials. For example, if a group of surgical instruments **7012** are identified as having a common manufacturing defect, the cloud **7004** may change the authorization credentials corresponding to this group to implement an operational lockout of the group.

**[0300]** The cloud-based analytics system may allow for monitoring multiple healthcare facilities (e.g., medical facilities like hospitals) to determine improved practices and recommend changes (via the recommendations module **2030**, for example) accordingly. Thus, the processors **7008** of the cloud **7004** can analyze data associated with an individual healthcare facility to identify the facility and aggregate the data with other data associated with other healthcare facilities in a group. Groups could be defined based on similar operating practices or geographical location, for example. In this way, the cloud **7004** may provide healthcare facility group wide analysis and recommendations. The cloud-based analytics system could also be used for enhanced situational awareness. For example, the processors **7008** may predictively model the effects of recommendations on the cost and effectiveness for a particular facility (relative to overall operations and/or various medical procedures). The cost and effectiveness associated with that particular facility can also be compared to a corresponding local region of other facilities or any other comparable facilities.

**[0301]** The data sorting and prioritization module **7032** may prioritize and sort data based on criticality (e.g., the severity of a medical event associated with the data, unexpectedness, suspiciousness). This sorting and prioritization may be used in conjunction with the functions of the other data analytics modules **7034** described above to improve the cloud-based analytics and operations described herein. For example, the data sorting and prioritization module **7032** can assign a priority to the data analysis performed by the data collection and aggregation module **7022** and patient outcome analysis modules **7028**. Different prioritization levels can result in particular responses from the cloud **7004** (corresponding to a level of urgency) such as escalation for an expedited response, special processing, exclusion from the aggregated medical data databases **7011**, or other suitable responses. Moreover, if necessary, the cloud **7004** can transmit a request (e.g. a push message) through the hub application servers for additional data from corresponding surgical instruments **7012**. The push message can result in a notification displayed on the corresponding hubs **7006** for requesting supporting or additional data. This push message may be required in situations in which the cloud detects a significant irregularity or outlier and the cloud cannot determine the cause of the irregularity. The central servers **7013** may be programmed to trigger this push message in certain significant circumstances, such as when data is determined to be different from an expected value beyond a predetermined threshold or when it appears security has been comprised, for example.

**[0302]** In various aspects, the surgical instrument(s) **7012** described above with reference to FIGS. **12** and **13**, may be implemented as surgical instruments **200018** (FIG. **17**), **200062** (FIG. **20**), **200072a,b** (FIG. **21**) **200088** and

**200078a,b** (FIG. **23**), surgical device **200078a,b** (FIG. **22**), and visualization system **200086** (FIG. **23**). Accordingly, the surgical instruments **200018** (FIG. **17**), **200062** (FIG. **20**), **200072a,b** (FIG. **21**) **200088** and **200078a,b** (FIG. **23**), surgical device **200078a,b** (FIG. **22**), and visualization system **200086** (FIG. **23**) are configured to interface with the surgical hub **7006** and the network **2001**, which is configured to interface with cloud **7004**. Accordingly, the processing power provided by the central servers **7013** and the data analytics module **7034** are configured to process information (e.g., data and control) from the surgical instruments **200018** (FIG. **17**), **200062** (FIG. **20**), **200072a,b** (FIG. **21**) **200088** and **200078a,b** (FIG. **23**), surgical device **200078a,b** (FIG. **22**), and visualization system **200086** (FIG. **23**).

**[0303]** Additional details regarding the cloud analysis system can be found in U.S. Provisional Patent Application No. 62/659,900, titled METHOD OF HUB COMMUNICATION, filed Apr. 19, 2018, which is hereby incorporated by reference herein in its entirety.

#### Situational Awareness

**[0304]** Although an “intelligent” device including control algorithms that respond to sensed data can be an improvement over a “dumb” device that operates without accounting for sensed data, some sensed data can be incomplete or inconclusive when considered in isolation, i.e., without the context of the type of surgical procedure being performed or the type of tissue that is being operated on. Without knowing the procedural context (e.g., knowing the type of tissue being operated on or the type of procedure being performed), the control algorithm may control the modular device incorrectly or suboptimally given the particular context-free sensed data. For example, the optimal manner for a control algorithm to control a surgical instrument in response to a particular sensed parameter can vary according to the particular tissue type being operated on. This is due to the fact that different tissue types have different properties (e.g., resistance to tearing) and thus respond differently to actions taken by surgical instruments. Therefore, it may be desirable for a surgical instrument to take different actions even when the same measurement for a particular parameter is sensed. As one specific example, the optimal manner in which to control a surgical stapling and cutting instrument in response to the instrument sensing an unexpectedly high force to close its end effector will vary depending upon whether the tissue type is susceptible or resistant to tearing. For tissues that are susceptible to tearing, such as lung tissue, the instrument’s control algorithm would optimally ramp down the motor in response to an unexpectedly high force to close to avoid tearing the tissue. For tissues that are resistant to tearing, such as stomach tissue, the instrument’s control algorithm would optimally ramp up the motor in response to an unexpectedly high force to close to ensure that the end effector is clamped properly on the tissue. Without knowing whether lung or stomach tissue has been clamped, the control algorithm may make a suboptimal decision.

**[0305]** One solution utilizes a surgical hub including a system that is configured to derive information about the surgical procedure being performed based on data received from various data sources and then control the paired modular devices accordingly. In other words, the surgical hub is configured to infer information about the surgical procedure from received data and then control the modular devices paired to the surgical hub based upon the inferred

context of the surgical procedure. FIG. 14 illustrates a diagram of a situationally aware surgical system 5100, in accordance with at least one aspect of the present disclosure. In some exemplifications, the data sources 5126 include, for example, the modular devices 5102 (which can include sensors configured to detect parameters associated with the patient and/or the modular device itself), databases 5122 (e.g., an EMR database containing patient records), and patient monitoring devices 5124 (e.g., a blood pressure (BP) monitor and an electrocardiography (EKG) monitor).

[0306] A surgical hub 5104, which may be similar to the hub 106 in many respects, can be configured to derive the contextual information pertaining to the surgical procedure from the data based upon, for example, the particular combination(s) of received data or the particular order in which the data is received from the data sources 5126. The contextual information inferred from the received data can include, for example, the type of surgical procedure being performed, the particular step of the surgical procedure that the surgeon is performing, the type of tissue being operated on, or the body cavity that is the subject of the procedure. This ability by some aspects of the surgical hub 5104 to derive or infer information related to the surgical procedure from received data can be referred to as “situational awareness.” In one exemplification, the surgical hub 5104 can incorporate a situational awareness system, which is the hardware and/or programming associated with the surgical hub 5104 that derives contextual information pertaining to the surgical procedure from the received data.

[0307] The situational awareness system of the surgical hub 5104 can be configured to derive the contextual information from the data received from the data sources 5126 in a variety of different ways. In one exemplification, the situational awareness system includes a pattern recognition system, or machine learning system (e.g., an artificial neural network), that has been trained on training data to correlate various inputs (e.g., data from databases 5122, patient monitoring devices 5124, and/or modular devices 5102) to corresponding contextual information regarding a surgical procedure. In other words, a machine learning system can be trained to accurately derive contextual information regarding a surgical procedure from the provided inputs. In another exemplification, the situational awareness system can include a lookup table storing pre-characterized contextual information regarding a surgical procedure in association with one or more inputs (or ranges of inputs) corresponding to the contextual information. In response to a query with one or more inputs, the lookup table can return the corresponding contextual information for the situational awareness system for controlling the modular devices 5102. In one exemplification, the contextual information received by the situational awareness system of the surgical hub 5104 is associated with a particular control adjustment or set of control adjustments for one or more modular devices 5102. In another exemplification, the situational awareness system includes a further machine learning system, lookup table, or other such system, which generates or retrieves one or more control adjustments for one or more modular devices 5102 when provided the contextual information as input.

[0308] A surgical hub 5104 incorporating a situational awareness system provides a number of benefits for the surgical system 5100. One benefit includes improving the interpretation of sensed and collected data, which would in turn improve the processing accuracy and/or the usage of the

data during the course of a surgical procedure. To return to a previous example, a situationally aware surgical hub 5104 could determine what type of tissue was being operated on; therefore, when an unexpectedly high force to close the surgical instrument's end effector is detected, the situationally aware surgical hub 5104 could correctly ramp up or ramp down the motor of the surgical instrument for the type of tissue.

[0309] As another example, the type of tissue being operated can affect the adjustments that are made to the compression rate and load thresholds of a surgical stapling and cutting instrument for a particular tissue gap measurement. A situationally aware surgical hub 5104 could infer whether a surgical procedure being performed is a thoracic or an abdominal procedure, allowing the surgical hub 5104 to determine whether the tissue clamped by an end effector of the surgical stapling and cutting instrument is lung (for a thoracic procedure) or stomach (for an abdominal procedure) tissue. The surgical hub 5104 could then adjust the compression rate and load thresholds of the surgical stapling and cutting instrument appropriately for the type of tissue.

[0310] As yet another example, the type of body cavity being operated in during an insufflation procedure can affect the function of a smoke evacuator. A situationally aware surgical hub 5104 could determine whether the surgical site is under pressure (by determining that the surgical procedure is utilizing insufflation) and determine the procedure type. As a procedure type is generally performed in a specific body cavity, the surgical hub 5104 could then control the motor rate of the smoke evacuator appropriately for the body cavity being operated in. Thus, a situationally aware surgical hub 5104 could provide a consistent amount of smoke evacuation for both thoracic and abdominal procedures.

[0311] As yet another example, the type of procedure being performed can affect the optimal energy level for an ultrasonic surgical instrument or radio frequency (RF) electrosurgical instrument to operate at. Arthroscopic procedures, for example, require higher energy levels because the end effector of the ultrasonic surgical instrument or RF electrosurgical instrument is immersed in fluid. A situationally aware surgical hub 5104 could determine whether the surgical procedure is an arthroscopic procedure. The surgical hub 5104 could then adjust the RF power level or the ultrasonic amplitude of the generator (i.e., “energy level”) to compensate for the fluid filled environment. Relatedly, the type of tissue being operated on can affect the optimal energy level for an ultrasonic surgical instrument or RF electrosurgical instrument to operate at. A situationally aware surgical hub 5104 could determine what type of surgical procedure is being performed and then customize the energy level for the ultrasonic surgical instrument or RF electrosurgical instrument, respectively, according to the expected tissue profile for the surgical procedure. Furthermore, a situationally aware surgical hub 5104 can be configured to adjust the energy level for the ultrasonic surgical instrument or RF electrosurgical instrument throughout the course of a surgical procedure, rather than just on a procedure-by-procedure basis. A situationally aware surgical hub 5104 could determine what step of the surgical procedure is being performed or will subsequently be performed and then update the control algorithms for the generator and/or ultrasonic surgical instrument or RF electrosurgical instrument to set the energy level at a value appropriate for the expected tissue type according to the surgical procedure step.

[0312] As yet another example, data can be drawn from additional data sources 5126 to improve the conclusions that the surgical hub 5104 draws from one data source 5126. A situationally aware surgical hub 5104 could augment data that it receives from the modular devices 5102 with contextual information that it has built up regarding the surgical procedure from other data sources 5126. For example, a situationally aware surgical hub 5104 can be configured to determine whether hemostasis has occurred (i.e., whether bleeding at a surgical site has stopped) according to video or image data received from a medical imaging device. However, in some cases the video or image data can be inconclusive. Therefore, in one exemplification, the surgical hub 5104 can be further configured to compare a physiologic measurement (e.g., blood pressure sensed by a BP monitor communicably connected to the surgical hub 5104) with the visual or image data of hemostasis (e.g., from a medical imaging device 124 (FIG. 2) communicably coupled to the surgical hub 5104) to make a determination on the integrity of the staple line or tissue weld. In other words, the situational awareness system of the surgical hub 5104 can consider the physiological measurement data to provide additional context in analyzing the visualization data. The additional context can be useful when the visualization data may be inconclusive or incomplete on its own.

[0313] Another benefit includes proactively and automatically controlling the paired modular devices 5102 according to the particular step of the surgical procedure that is being performed to reduce the number of times that medical personnel are required to interact with or control the surgical system 5100 during the course of a surgical procedure. For example, a situationally aware surgical hub 5104 could proactively activate the generator to which an RF electro-surgical instrument is connected if it determines that a subsequent step of the procedure requires the use of the instrument. Proactively activating the energy source allows the instrument to be ready for use as soon as the preceding step of the procedure is completed.

[0314] As another example, a situationally aware surgical hub 5104 could determine whether the current or subsequent step of the surgical procedure requires a different view or degree of magnification on the display according to the feature(s) at the surgical site that the surgeon is expected to need to view. The surgical hub 5104 could then proactively change the displayed view (supplied by, e.g., a medical imaging device for the visualization system 108) accordingly so that the display automatically adjusts throughout the surgical procedure.

[0315] As yet another example, a situationally aware surgical hub 5104 could determine which step of the surgical procedure is being performed or will subsequently be performed and whether particular data or comparisons between data will be required for that step of the surgical procedure. The surgical hub 5104 can be configured to automatically call up data screens based upon the step of the surgical procedure being performed, without waiting for the surgeon to ask for the particular information.

[0316] Another benefit includes checking for errors during the setup of the surgical procedure or during the course of the surgical procedure. For example, a situationally aware surgical hub 5104 could determine whether the operating theater is setup properly or optimally for the surgical procedure to be performed. The surgical hub 5104 can be configured to determine the type of surgical procedure being

performed, retrieve the corresponding checklists, product location, or setup needs (e.g., from a memory), and then compare the current operating theater layout to the standard layout for the type of surgical procedure that the surgical hub 5104 determines is being performed. In one exemplification, the surgical hub 5104 can be configured to compare the list of items for the procedure scanned by a suitable scanner, for example, and/or a list of devices paired with the surgical hub 5104 to a recommended or anticipated manifest of items and/or devices for the given surgical procedure. If there are any discontinuities between the lists, the surgical hub 5104 can be configured to provide an alert indicating that a particular modular device 5102, patient monitoring device 5124, and/or other surgical item is missing. In one exemplification, the surgical hub 5104 can be configured to determine the relative distance or position of the modular devices 5102 and patient monitoring devices 5124 via proximity sensors, for example. The surgical hub 5104 can compare the relative positions of the devices to a recommended or anticipated layout for the particular surgical procedure. If there are any discontinuities between the layouts, the surgical hub 5104 can be configured to provide an alert indicating that the current layout for the surgical procedure deviates from the recommended layout.

[0317] As another example, a situationally aware surgical hub 5104 could determine whether the surgeon (or other medical personnel) was making an error or otherwise deviating from the expected course of action during the course of a surgical procedure. For example, the surgical hub 5104 can be configured to determine the type of surgical procedure being performed, retrieve the corresponding list of steps or order of equipment usage (e.g., from a memory), and then compare the steps being performed or the equipment being used during the course of the surgical procedure to the expected steps or equipment for the type of surgical procedure that the surgical hub 5104 determined is being performed. In one exemplification, the surgical hub 5104 can be configured to provide an alert indicating that an unexpected action is being performed or an unexpected device is being utilized at the particular step in the surgical procedure.

[0318] Overall, the situational awareness system for the surgical hub 5104 improves surgical procedure outcomes by adjusting the surgical instruments (and other modular devices 5102) for the particular context of each surgical procedure (such as adjusting to different tissue types) and validating actions during a surgical procedure. The situational awareness system also improves surgeons' efficiency in performing surgical procedures by automatically suggesting next steps, providing data, and adjusting displays and other modular devices 5102 in the surgical theater according to the specific context of the procedure.

[0319] In one aspect, as described hereinbelow with reference to FIGS. 17-23, the modular device 5102 is implemented as a surgical instruments 200018 (FIG. 17), 200062 (FIG. 20), 200072<sub>a,b</sub> (FIG. 21) 200088 and 200078<sub>a,b</sub> (FIG. 23), surgical device 200078<sub>a,b</sub> (FIG. 22), and visualization system 200086 (FIG. 23). Accordingly, the modular device 5102 implemented as a surgical instruments 200018 (FIG. 17), 200062 (FIG. 20), 200072<sub>a,b</sub> (FIG. 21) 200088 and 200078<sub>a,b</sub> (FIG. 23), surgical device 200078<sub>a,b</sub> (FIG. 22), and visualization system 200086 (FIG. 23) are configured to operate as a data source 5126 and to interact with the database 5122 and patient monitoring devices 5124.

The modular device **5102** implemented as a surgical instruments **200018** (FIG. 17), **200062** (FIG. 20), **200072a,b** (FIG. 21) **200088** and **200078a,b** (FIG. 23), surgical device **200078a,b** (FIG. 22), and visualization system **200086** (FIG. 23) are further configured to interact with the surgical hub **5104** to provide information (e.g., data and control) to the surgical hub **5104** and receive information (e.g., data and control) from the surgical hub **5104**.

[0320] Referring now to FIG. 15, a timeline **5200** depicting situational awareness of a hub, such as the surgical hub **106** or **206** (FIGS. 1-11), for example, is depicted. The timeline **5200** is an illustrative surgical procedure and the contextual information that the surgical hub **106, 206** can derive from the data received from the data sources at each step in the surgical procedure. The timeline **5200** depicts the typical steps that would be taken by the nurses, surgeons, and other medical personnel during the course of a lung segmentectomy procedure, beginning with setting up the operating theater and ending with transferring the patient to a post-operative recovery room.

[0321] The situationally aware surgical hub **106, 206** receives data from the data sources throughout the course of the surgical procedure, including data generated each time medical personnel utilize a modular device that is paired with the surgical hub **106, 206**. The surgical hub **106, 206** can receive this data from the paired modular devices and other data sources and continually derive inferences (i.e., contextual information) about the ongoing procedure as new data is received, such as which step of the procedure is being performed at any given time. The situational awareness system of the surgical hub **106, 206** is able to, for example, record data pertaining to the procedure for generating reports, verify the steps being taken by the medical personnel, provide data or prompts (e.g., via a display screen) that may be pertinent for the particular procedural step, adjust modular devices based on the context (e.g., activate monitors, adjust the field of view (FOV) of the medical imaging device, or change the energy level of an ultrasonic surgical instrument or RF electro-surgical instrument), and take any other such action described above.

[0322] As the first step **5202** in this illustrative procedure, the hospital staff members retrieve the patient's EMR from the hospital's EMR database. Based on select patient data in the EMR, the surgical hub **106, 206** determines that the procedure to be performed is a thoracic procedure.

[0323] Second step **5204**, the staff members scan the incoming medical supplies for the procedure. The surgical hub **106, 206** cross-references the scanned supplies with a list of supplies that are utilized in various types of procedures and confirms that the mix of supplies corresponds to a thoracic procedure. Further, the surgical hub **106, 206** is also able to determine that the procedure is not a wedge procedure (because the incoming supplies either lack certain supplies that are necessary for a thoracic wedge procedure or do not otherwise correspond to a thoracic wedge procedure).

[0324] Third step **5206**, the medical personnel scan the patient band via a scanner that is communicably connected to the surgical hub **106, 206**. The surgical hub **106, 206** can then confirm the patient's identity based on the scanned data.

[0325] Fourth step **5208**, the medical staff turns on the auxiliary equipment. The auxiliary equipment being utilized can vary according to the type of surgical procedure and the techniques to be used by the surgeon, but in this illustrative case they include a smoke evacuator, insufflator, and medical

imaging device. When activated, the auxiliary equipment that are modular devices can automatically pair with the surgical hub **106, 206** that is located within a particular vicinity of the modular devices as part of their initialization process. The surgical hub **106, 206** can then derive contextual information about the surgical procedure by detecting the types of modular devices that pair with it during this pre-operative or initialization phase. In this particular example, the surgical hub **106, 206** determines that the surgical procedure is a VATS procedure based on this particular combination of paired modular devices. Based on the combination of the data from the patient's EMR, the list of medical supplies to be used in the procedure, and the type of modular devices that connect to the hub, the surgical hub **106, 206** can generally infer the specific procedure that the surgical team will be performing. Once the surgical hub **106, 206** knows what specific procedure is being performed, the surgical hub **106, 206** can then retrieve the steps of that procedure from a memory or from the cloud and then cross-reference the data it subsequently receives from the connected data sources (e.g., modular devices and patient monitoring devices) to infer what step of the surgical procedure the surgical team is performing.

[0326] Fifth step **5210**, the staff members attach the EKG electrodes and other patient monitoring devices to the patient. The EKG electrodes and other patient monitoring devices are able to pair with the surgical hub **106, 206**. As the surgical hub **106, 206** begins receiving data from the patient monitoring devices, the surgical hub **106, 206** thus confirms that the patient is in the operating theater.

[0327] Sixth step **5212**, the medical personnel induce anesthesia in the patient. The surgical hub **106, 206** can infer that the patient is under anesthesia based on data from the modular devices and/or patient monitoring devices, including EKG data, blood pressure data, ventilator data, or combinations thereof, for example. Upon completion of the sixth step **5212**, the pre-operative portion of the lung segmentectomy procedure is completed and the operative portion begins.

[0328] Seventh step **5214**, the patient's lung that is being operated on is collapsed (while ventilation is switched to the contralateral lung). The surgical hub **106, 206** can infer from the ventilator data that the patient's lung has been collapsed, for example. The surgical hub **106, 206** can infer that the operative portion of the procedure has commenced as it can compare the detection of the patient's lung collapsing to the expected steps of the procedure (which can be accessed or retrieved previously) and thereby determine that collapsing the lung is the first operative step in this particular procedure.

[0329] Eighth step **5216**, the medical imaging device (e.g., a scope) is inserted and video from the medical imaging device is initiated. The surgical hub **106, 206** receives the medical imaging device data (i.e., video or image data) through its connection to the medical imaging device. Upon receipt of the medical imaging device data, the surgical hub **106, 206** can determine that the laparoscopic portion of the surgical procedure has commenced. Further, the surgical hub **106, 206** can determine that the particular procedure being performed is a segmentectomy, as opposed to a lobectomy (note that a wedge procedure has already been discounted by the surgical hub **106, 206** based on data received at the second step **5204** of the procedure). The data from the medical imaging device **124** (FIG. 2) can be utilized to

determine contextual information regarding the type of procedure being performed in a number of different ways, including by determining the angle at which the medical imaging device is oriented with respect to the visualization of the patient's anatomy, monitoring the number or medical imaging devices being utilized (i.e., that are activated and paired with the surgical hub **106, 206**), and monitoring the types of visualization devices utilized. For example, one technique for performing a VATS lobectomy places the camera in the lower anterior corner of the patient's chest cavity above the diaphragm, whereas one technique for performing a VATS segmentectomy places the camera in an anterior intercostal position relative to the segmental fissure. Using pattern recognition or machine learning techniques, for example, the situational awareness system can be trained to recognize the positioning of the medical imaging device according to the visualization of the patient's anatomy. As another example, one technique for performing a VATS lobectomy utilizes a single medical imaging device, whereas another technique for performing a VATS segmentectomy utilizes multiple cameras. As yet another example, one technique for performing a VATS segmentectomy utilizes an infrared light source (which can be communicably coupled to the surgical hub as part of the visualization system) to visualize the segmental fissure, which is not utilized in a VATS lobectomy. By tracking any or all of this data from the medical imaging device, the surgical hub **106, 206** can thereby determine the specific type of surgical procedure being performed and/or the technique being used for a particular type of surgical procedure.

[0330] Ninth step **5218**, the surgical team begins the dissection step of the procedure. The surgical hub **106, 206** can infer that the surgeon is in the process of dissecting to mobilize the patient's lung because it receives data from the RF or ultrasonic generator indicating that an energy instrument is being fired. The surgical hub **106, 206** can cross-reference the received data with the retrieved steps of the surgical procedure to determine that an energy instrument being fired at this point in the process (i.e., after the completion of the previously discussed steps of the procedure) corresponds to the dissection step. In certain instances, the energy instrument can be an energy tool mounted to a robotic arm of a robotic surgical system.

[0331] Tenth step **5220**, the surgical team proceeds to the ligation step of the procedure. The surgical hub **106, 206** can infer that the surgeon is ligating arteries and veins because it receives data from the surgical stapling and cutting instrument indicating that the instrument is being fired. Similarly to the prior step, the surgical hub **106, 206** can derive this inference by cross-referencing the receipt of data from the surgical stapling and cutting instrument with the retrieved steps in the process. In certain instances, the surgical instrument can be a surgical tool mounted to a robotic arm of a robotic surgical system.

[0332] Eleventh step **5222**, the segmentectomy portion of the procedure is performed. The surgical hub **106, 206** can infer that the surgeon is transecting the parenchyma based on data from the surgical stapling and cutting instrument, including data from its cartridge. The cartridge data can correspond to the size or type of staple being fired by the instrument, for example. As different types of staples are utilized for different types of tissues, the cartridge data can thus indicate the type of tissue being stapled and/or transected. In this case, the type of staple being fired is utilized

for parenchyma (or other similar tissue types), which allows the surgical hub **106, 206** to infer that the segmentectomy portion of the procedure is being performed.

[0333] Twelfth step **5224**, the node dissection step is then performed. The surgical hub **106, 206** can infer that the surgical team is dissecting the node and performing a leak test based on data received from the generator indicating that an RF or ultrasonic instrument is being fired. For this particular procedure, an RF or ultrasonic instrument being utilized after parenchyma was transected corresponds to the node dissection step, which allows the surgical hub **106, 206** to make this inference. It should be noted that surgeons regularly switch back and forth between surgical stapling/cutting instruments and surgical energy (i.e., RF or ultrasonic) instruments depending upon the particular step in the procedure because different instruments are better adapted for particular tasks. Therefore, the particular sequence in which the stapling/cutting instruments and surgical energy instruments are used can indicate what step of the procedure the surgeon is performing. Moreover, in certain instances, robotic tools can be utilized for one or more steps in a surgical procedure and/or handheld surgical instruments can be utilized for one or more steps in the surgical procedure. The surgeon(s) can alternate between robotic tools and handheld surgical instruments and/or can use the devices concurrently, for example. Upon completion of the twelfth step **5224**, the incisions are closed up and the post-operative portion of the procedure begins.

[0334] Thirteenth step **5226**, the patient's anesthesia is reversed. The surgical hub **106, 206** can infer that the patient is emerging from the anesthesia based on the ventilator data (i.e., the patient's breathing rate begins increasing), for example.

[0335] Lastly, the fourteenth step **5228** is that the medical personnel remove the various patient monitoring devices from the patient. The surgical hub **106, 206** can thus infer that the patient is being transferred to a recovery room when the hub loses EKG, BP, and other data from the patient monitoring devices. As can be seen from the description of this illustrative procedure, the surgical hub **106, 206** can determine or infer when each step of a given surgical procedure is taking place according to data received from the various data sources that are communicably coupled to the surgical hub **106, 206**.

[0336] In various aspects, the surgical instruments **200018** (FIG. 17), **200062** (FIG. 20), **200072a,b** (FIG. 21) **200088** and **200078a,b** (FIG. 23), surgical device **200078a,b** (FIG. 22), and visualization system **200086** (FIG. 23) are configured to operate in a situational awareness in a hub environment, such as the surgical hub **106** or **206** (FIGS. 1-11), for example, as depicted by the timeline **5200**. Situational awareness is further described in U.S. Provisional Patent Application Ser. No. 62/659,900, titled METHOD OF HUB COMMUNICATION, filed Apr. 19, 2018, which is herein incorporated by reference in its entirety. In certain instances, operation of a robotic surgical system, including the various robotic surgical systems disclosed herein, for example, can be controlled by the hub **106, 206** based on its situational awareness and/or feedback from the components thereof and/or based on information from the cloud **104**.

## Wireless Hub Interaction

### Device-to-Device Intercommunication

**[0337]** In various aspects, various techniques for pairing devices and rules defining device interactions are described herein. Accordingly, wireless interactive pairing for surgical hub devices is described herein.

**[0338]** In one aspect, wireless pairing of a surgical device with another device within the sterile surgical field is based on the usage and situational awareness of the devices. In one aspect, the situational awareness could include awareness of which user has control of which devices based on location devices on the user. In one aspect, the pairing between the devices could be based on simultaneous activation of the two devices for a predetermined amount of time when no tissue or patient is sensed by the active device. In another aspect, one device could be within the sterile field while the other device could be outside of the sterile field.

### Pairing of Personally Owned Wireless Devices

**[0339]** Various techniques for pairing personally owned wireless devices are described herein. In one aspect, an encrypted key can be used to authenticate a smart phone, wearable, or other personally owned device is supplied to a given user. Defining of the functions a personal device will request of the Hub to do given certain input elements. In one aspect, porting the personally owned device into the system provides a link from the device to the surgical hub to run an internal function. For example, a device can be connected to a hub and the music from a library or playlist on the device to be ported into (i.e., streamed through) the hub's speakers. As another example, a phone or another such device can be connected to a hub and options for the device can be linked through the hub to allow the porting of calls through the hub monitors and speakers. In one application, an auto reply voice or text message can be sent to incoming calls or texts that states that the user is unavailable when the user's device is connected to the hub, unless, e.g., the call or text is from a select subset of numbers (e.g., from other physicians that may call to consult on cases). In another application, a contact list from a linked phone can be stored so that incoming calls to the surgeon's phone during surgery can be answered or ignored according to whether the incoming call is from a number on the contact list.

**[0340]** In one aspect, a surgical hub can be configured to display functional imported data (e.g., data imported from a mobile device) on a secondary display due to the hub's awareness of the type of data and/or how common the use of the data is. In one aspect, the information can be displayed on a secondary display when the data is uploaded/imported to the surgical hub. In another aspect, an interactive menu can become actionable on the primary or in-use display when the data is uploaded/imported to the surgical hub when interaction is available. For example, when a call is received by a mobile device connected to a surgical hub, caller ID information from the mobile device's contact list can pop up on selected monitors visible by surgeon and nurses. As another example, the caller ID information could be displayed on secondary monitor that for displaying ancillary information, such as device settings, or a configurable computer tablet positioned in the sterile field that the surgeon could touch to answer if needed in order to avoid cluttering the main surgical screen with pop-ups. As another

example, depending on the particular sensed user, the number of times that user utilizes the secondary device, and other parameters, the hub can be configured to flag the most commonly used and/or most appropriate option or menu according to the particular the interaction. In some aspects, the hub can be configured to display the option or menu on the user interface without interfering with the task at hand.

**[0341]** FIG. 16 depicts an example of a pairing of a personally owned wireless device 200002 with a surgical hub 200006. The wireless device 200002 and the surgical hub 200006 may communicate with each other over a wireless link 200004. As disclosed above, the surgical hub 200006 may display imported data received from the wireless device 200002 on one or more displays visible to the members of the surgical team. In one aspect, the surgical hub 200006 may cause the imported data to be displayed on a primary or in-use display monitor 200008. In another aspect, the surgical hub 200006 may cause the imported data to be displayed on a secondary display monitor 200010.

### Smart Cartridge Communication with Hub without Going Through the Attached Device

**[0342]** Various techniques for smart cartridge communication with the hub, without utilizing the instrument in which the cartridge is attached as a communication medium, are described herein.

**[0343]** In various aspects, a cartridge can be configured such that there is a wired connection between the device and the cartridge and that physical contact is needed between the instrument and the cartridge is required to transfer power to the cartridge. In one such aspect, the cartridge can include a circuit for identification that includes a portion that requires both the sled of the instrument and at least one staple to make contact thereagainst for there to be continuity. If either of the sled or a staple is not contacting the circuit, the power transfer to the cartridge will not occur and the device will be locked out. In these aspects, the described circuit can be utilized to provide a secondary or backup method of locking out an instrument from being utilized with a spent cartridge.

**[0344]** In various aspects, the cartridge can be configured to communicate with the hub, without requiring any power from the surgical instrument (e.g., a surgical stapler).

**[0345]** In one such aspect, inserting the cartridge into device is configured to supply a momentary amount of power to the cartridge, which is then configured to communicate directly with hub without going through the device. In some aspects, the cartridge includes no battery or power source onboard. In some aspects, the small amount of power can be tapped off upon connection and during transmission, after which the power drain by the cartridge ceases. For example, FIG. 17 is a diagram of a cartridge 200012 configured to wirelessly communicate with a surgical hub 200006, in accordance with at least one aspect of the present disclosure. In one aspect, the communication may be accomplished by a wireless communication circuit 200028 imbedded in the cartridge 200012. In this example, power is wirelessly transferred from the device to the cartridge through inductive coupling. In one aspect, a first wire transmission antenna coil 200014 is printed into the wall 200016 of a channel of the instrument 200018. A second receiver coil 200020 may be printed on a mating surface of the cartridge 200012. Power may be transmitted from the transmission antenna coil 200014 to the receiver coil 200020 when the two coils are proximate to and overlap each other.



In some aspects, power **200024** may be supplied to the instrument **200018** and conducted to the transmission coil **200014** via any suitable conductor, such as by a flexible circuit conductor **200026**.

[0346] FIG. 17A depicts the overlap **200022** of the transmission coil **200014** and the receiver coil **200020**. The transmission coil **200014** may receive power **200024** sourced to the instrument **200018**. The amount of overlap **200022** and degree of proximity between the transmission coil **200014** and the receiver coil **200020** may determine the amount of power received by the receiver coil **200020**. Power in the receiver coil **200020** may be used to power the communication circuit **200028**.

[0347] In such aspects, the close proximity and alignment of the transmission coil **200014** and the receiver coil **200020** may be achieved with lug features **200030** formed into the body of the cartridge **200012**. The lug features **200030** may be configured to align the cartridge **200012** within the channel of the instrument **200018** when the cartridge **200012** is inserted into the instrument **200018**. The lug features **200030** may be configured to align the cartridge within the channel of the instrument **200018** by mating with corresponding slot features **200032** fabricated in the channel.

[0348] In some aspects, the cartridge and/or instrument further include resonating circuits to increase the efficiency of the power transfer therebetween. For example, FIG. 18 is a block diagram of a resonant inductive wireless power system **200034** in accordance with at least one aspect of the present disclosure. The resonant inductive wireless power system **200034** can include, for example, a transmitter oscillator **200040** that receives power from a power source **200042**. The transmitter oscillator **200040** may supply AC current to a transmission coil **200044**. The resonant inductive wireless power system **200034** can also include, for example, a rectifier **200046** that may receive power from the a transmission coil **200044** via a receiver coil **200048**.

[0349] The receiver coil **200048** may be coupled to the transmission coil **200044** through the magnetic (B) field generated by the transmission coil **200044**. In some aspects, The rectifier **200046** may convert the AC power received from the transmitter oscillator **200040** to DC power to source to a load **200050**. In one example, a load **200050** may include the communication circuit **200028**. The resonant inductive wireless power system **200034** may further include, for example, one or more resonance coils **200036a,b** made of copper wire for example, that resonate with their internal capacitance (indicated as capacitors **200038a,b** in phantom) at a resonant frequency (for example at 10 MHz). In some aspects, the resonance coils **200036a,b** may have matched impedances to optimize the power transmission from the transmitter oscillator **200040** to the rectifier **200046**.

[0350] In another aspect, the cartridge **200012** may include a battery that may power the communication circuit **200028** when the cartridge **200012** is inserted into the instrument **200018**. In this aspect, the communication circuit **200028** may be powered regardless of the power status of the instrument **200018**.

[0351] In another aspect, a sterile scanning pad can be configured to scan an instrument **200018** and/or a cartridge **200012**. In operation, the scanning pad can be present on a back table within the operating room (OR) and a health care professional may scan the instrument **200018** or cartridge **200012** by placing the instrument **200018** or cartridge

**200012** on the scanning pad. Data from the instrument **200018** or cartridge **200012** may be provided to the hub when the instrument **200018** or cartridge **200012** is opened and placed on the scanning pad. In some aspects, the instrument **200018** or cartridge **200012** may be scanned, for example via radiofrequency (RF), to activate the instrument **200018** or cartridge **200012** and track it by the hub. In some further aspects, there may be a wired connection from the pad to the hub to supply power for scanning.

#### Detection of Environment and Setting a Geo-Fenced Area

[0352] Various techniques for detecting an environment and establishing a geo-fence are described herein.

[0353] FIG. 19A is a diagram of a surgical hub detecting an area or room perimeter, for example the perimeter of an operating room (OR) in accordance with at least one aspect of the present disclosure. In one aspect, a perimeter **200052** of a space detectable by a surgical hub **200006** can be defined by one or more freestanding beacons **200054a-d** with directional antennas. In one aspect, the beacons **200054a-d** can be placed at desired positions within a room in which the hub **200006** is or will be located. In one aspect, the perimeter **200052** delimited by the beacons **200054a-d** may form a boundary of a device detection space by the surgical hub **200006**. The beacons **200054a-d** can be used, for example, to define a zone that has a regular three-dimensional shape or an irregular three-dimensional shape. In some applications, as few as three beacons (generically, **200054**) can be used to define a simple device detection perimeter, such as the interior of a square or rectangular room. In other aspects, more than three beacons **200054a-d** may be used to delimit a detection zone having an irregular shape, such as that depicted in FIG. 19.

[0354] In some aspects, the beacons **200054a-d** may be active or passive. Active beacons **200054a-d** may actively transmit information for receipt by the hub **200006** without requiring the hub **200006** to transmit any information to them. Passive beacons **200054a-d** may be activated only on receipt of one or more transmissions from the hub **200006**. Passive beacons **200054a-d** may then respond to an initiating query by the hub **200006** and transmit, in response to receiving the initiating query from the hub **200006**, a response signal. The signals transmitted by the beacons **200054a-d** may be of any suitable form including, without limitation, a wireless signal, an acoustic signal, or a light signal. The signals transmitted by the beacons **200054a-d** may include any suitable information, such as identification information, locational information, or any other information that the hub **200006** may use to determine the location of the beacons **200054a-d** and thus permit the hub **200006** to determine the perimeter **200052**.

[0355] As disclosed above, the perimeter **200052** may define a detection zone in which the hub **200006** may scan for one or more surgical instruments or other devices. Devices within the detection zone may be recognized by the hub **200006** as being potentially associated with a surgical procedure. It may be understood that in this aspect, devices located outside of the detection zone may not be recognized by the hub **200006** as being potentially associated with a surgical procedure. Alternatively, the beacons can be utilized to define an excluded zone in which devices may not be recognized by the hub **200006**. In some aspects, the transmission angle of signals from the beacons **200054a-d** can be

adjustable. Starting at about 90 degrees, multiple beacons **200054a-d** could be placed on the floor or on walls around OR to define the perimeter **200052**. In some aspects, the perimeter **200052** may form a surgical instrument detection zone. In some aspects, the detection angle of the beacons can be visually shown with light beam when setting up the beacon assembly.

[0356] FIG. 19B depicts some aspects of a geo-fence system that may further include a “jamming” beacon **200056**. In some aspects, a spatial region may be protected from receiving a transmission from the hub or devices within the spatial region may be shielded from receiving transmissions from the hub **200006**. For example, the “jamming” beacon **200056** may be placed at, near, or within a perimeter that interferes with the hub or a device signal to prevent devices within the excluded region defined by the jamming beacon(s) **200056** from connecting to the surgical hub. In various applications, a “jamming” beacon can be utilized to define a shielded zone, a sterile table, an instrument cabinet **200058** in the OR, or a storage zone between OR rooms, for example.

[0357] It may be recognized that the use of a “jamming” beacon **200056** may operate differently than the use of beacons **200054a-d** to define an exclusion zone. For example, a “jamming” beacon **200056** may be associated with a movable instrument cabinet **200058**. The “jamming” function of the “jamming” beacon **200056** may prevent the hub **200006** from establishing communications with medical instruments stored in the instrument cabinet **200058** regardless of the location of the instrument cabinet **200058**.

[0358] In some applications, positioning the beacons **200054a-d** along the borders of a room such as an operating room, may establish a controlled means of determining the real-world size and orientation of the OR with respect to the hub **200006**. In still other applications, positioning the beacons **200054a-d** at the boundaries of the sterile field can designate disposable instruments that are opened and ready for use as compared to capital instruments or instruments that are available, but not yet opened.

#### On-the-Fly Pairing Between Multiple Controllers and Controlled Devices

[0359] In one aspect, the hub and/or hub-connectable devices can be configured to wirelessly and interactively pair with each other. Accordingly, multiple controllers and controlled devices can be configured to wirelessly, on-the-fly input pairing, without the need for any direct user control. For example, FIG. 20 is a diagram of user and device pairing **200060** between a hub **200006**, a user-worn identifier **200066**, and a surgical instrument **200062**, in accordance with at least one aspect of the present disclosure. In the depicted aspect, an identifier **200066** can be worn or attached to the hand(s) of each user. The identifier **200066** may interact with a receiver **200064** that is attached to or integral with a surgical device **200062**. In one aspect, the receiver **200064** may be integrated within a handle of the surgical device **200062**. The identifier **200066** and the receiver **200064** can be configured to communication via near-field communication (NFC) or another such communication protocol.

[0360] In operation, whenever a user picks up a device **200062**, the receiver **200064** of the device automatically pairs the device **200062** with the identifier **200066**. In response to the pairing between the receiver **200064** and the

identifier **200066**, the hub **200006** recognizes the device **200062** permitting the hub **200006** to control and/or receive status data from the device **200062**. In some aspects, the hub **200006** may communicate with the device **200062** directly. In other aspects, the hub **200006** may communicate with the device **200062** via a communication link from the hub **200006** through the identifier **200066** to the device receiver **200064**. The NFC linkage allows communication of the surgical device **200062** with the identifier **200066**, which in turn communicates with the hub **200006**. In some aspects, the identifier **200066** may act as a communications relay **200068** between the hub **200006** and the surgical device **200062**, permitting identification and/or sensor information from the surgical device **200062** to be transmitted to the hub **200006**, and control data to be transmitted from the hub **200006** to control the surgical device **200062**.

[0361] In some other aspects, the identifier **200066** may transmit information to either one or both of the hub **200006** and the surgical device **200062**. In some aspects, the information from the identifier **200066** may include an identification of the user. In some other aspects, the information from the identifier **200066** may include which hand is using the surgical device **200062**. In some additional aspects, the hub **200006** may also provide either one or both of the identifier **200066** and the surgical device **200062** with the appropriate identification information of each device to allow them to communicate with either directly or through the hub **200006** to coordinate activation of a control with activation of a device function.

#### Methods of Interchanging of Control Paired Instruments Between Two Controllers

[0362] In various aspects, control of instruments paired with surgical hubs can be interchangeably switched between different surgical hubs.

[0363] Initiation of the control change between the paired instruments and the surgical hubs can be controlled and/or indicated to users/other devices in different manners. In one aspect, a predefined sequence could be used to indicate by the user the release of a controlled device to the control device (e.g., the surgical hub) and/or associated devices (e.g., other devices connected to the surgical hub).

[0364] Designation of a new relationship between the control device and the controlled device can be controlled and/or indicated to users/other devices in different manners. In one aspect, once released or when not paired to a control system within the local network of the OR, a series of steps could be used to link two system for the purposes of controlling one system with the other system. In an alternative aspect, the in-sterile field control and interaction device can be utilized to display all the paired links within the OR and to redistribute them in a different order.

[0365] Identification and notification of a control change of a device, without used of a control device, can be effected in different manners. In one aspect, the illumination of a built-in display screen of a handheld device could be configured to change from a first color (e.g., blue or green) to a second color (e.g., red) and/or from a first state (e.g., solid color) to a second state (e.g., flashing) to indicate and notify the user in changes to the control state of the device. For example, the first color and/or first state can indicate control of the device (e.g., the device is paired with a surgical hub) and the second color and/or second state can indicate that there is no control device connected to the instrument.

Further, the illumination could be around the perimeter of the built-in display of the device. Still further, the illumination could also be through light transmission plastic surrounding a control module. In an alternative aspect, the device could be outlined on the primary display and the color and/or state of the outline around the device (or a component of the device, such as a shaft of an instrument) can indicate its control state (i.e., pairing of the device with a control device or a lack thereof).

[0366] In one aspect, control can be shared from more than one control device to a single controlled device. For example, the system could be used to either enable two wireless control devices to both control the same device simultaneously or to control multiple devices from a single control device.

#### Device Position and Orientation Detection

[0367] Various techniques for detecting the position and orientation of devices are described herein.

[0368] In one aspect, measurements with respect to a ground coordinate system or with respect to one another can be displayed. In such aspects, a display system can be configured to display user-selectable measurements of the position of the device with respect to the patient, the hub, or a device (e.g., a trocar). FIG. 21 depicts an aspect of a surgical suite 200070 in which surgical instruments (for example, surgical instruments 200072a,b) are used as part of a surgical procedure.

[0369] In one aspect, the display system could be configured to show the current location of the surgical instruments 200072a,b with respect to a local coordinate system. In another aspect, the display system could be configured to calculate whether there is or will be interaction between the surgical instruments 200072a,b. In one aspect, the display could switch from displaying the local coordinate measures to the interaction calculation as the surgical instruments 200072a,b come closer in proximity to one another or to the tissue. The interaction calculation could be used to avoid inadvertent collisions between the surgical instruments 200072a,b or to allow the user(s) to coordinate the motions of two surgical instruments 200072a,b specifically to control the interaction between them.

[0370] In one aspect, the display system is configured to display the true position of the surgical instruments 200072a,b with respect to an outside established frame of reference. For example, triangulation beacons that interface with the hub can be positioned around the OR to establish location and orientation of any devices within the OR (see, for example, FIGS. 19A,B). Further, a beacon could be attached to each of the surgical instruments 200072a,b to establish the location of each of the surgical instruments 200072a,b with respect to each other, other devices, and/or other beacons. In one aspect, a trocar could be tagged with a beacon, which would allow the hub 200006 to identify which of the surgical instruments 200072a,b is currently inserted into the trocar. The display system may display an identifier of a surgical instrument (for example surgical instruments 200072a,b) in insure that the surgical instrument and the trocar in which it is inserted is retained on the display.

[0371] By determining the relative positions and/or orientation of the surgical instruments 200072a,b with respect to each other or with respect to other instruments, the hub 200006 may provide angle, insertion depth, and relative

orientation of the surgical instruments 200072a,b and/or an end effector of each of the surgical instruments 200072a,b for a member of the surgical team. In some aspects, the position and/or orientation of the surgical instruments 200072a,b may be determined with respect to the patient, surgical site, or incision site for critical instrument positioning.

[0372] As disclosed above, the surgical instruments 200072a,b and/or other devices may include one or more beacons to assist in determining their relative position and/or orientation with respect to each other. Such beacons could be based on RF, magnetics, or another energy waveform capable of penetrating tissue as well as air for sending and receiving triangulation signals. In some aspects, the hub 200006 may receive the triangulation signals emitted by the beacons. In some aspects, the triangulation signals may include identifier information permitting the hub 200006 to determine which beacon is associated with which triangulation signal. In some aspects, an elongated surgical instrument (such as surgical instruments 200072a,b) may have multiple beacons attached to a handle and a shaft so that the orientation of the instrument shaft with respect to the instrument handle may be determined by the hub 200006.

[0373] As disclosed above, the location and/or orientation of a surgical instrument may be determined relative to a location and/or orientation of another surgical instrument or other surgical device. In another aspect, the location and/or orientation of the surgical instruments 200072a,b may be determined with respect to one or more local references. In some aspects, the one or more local references may include one or more wireless or RF beacons disposed within the surgical suite. In another aspect, a local reference may include a magnetic field generator 200074 on a stand within the OR or mounted on a wall or ceiling. The magnetic field generator 200074 can be configured to create a predefined magnetic field within the room, as depicted in FIG. 21. Further, each surgical instrument or medical device may include one or more built-in or attached sensors to detect the magnetic field (or RF field for the use with one or more RF beacons) and determine the device orientation with respect to the magnetic field (or RF field).

[0374] Each device (such as surgical instruments 200072a,b) can transmit the location and/or orientation information to the hub 200006 via a wired or a wireless communication system to allow the hub 200006 to track the position and orientation of the device. In one aspect, each of the surgical instruments 200072a,b could include several sensors that would be able to detect their respective distances and orientations with respect to the predefined magnetic field. Multiple sensors may be useful for surgical instruments that include an elongated shaft connected to a hand held unit. For example, magnetic sensors may be disposed with the hand held unit, half-way along a length of the elongated shaft, and at a distal end effector attached to the elongated shaft. The instrument could then report its location and orientation of the elongated shaft and end effector to a central procedural system (executed, e.g., by the hub 200006). The procedural system could then calculate and track the use and disposition of all of the instruments within the OR and display or highlight to the user on a visual display when interactions or special conditions exist.

[0375] In another aspect, each of the surgical instruments 200072a,b may define a coordinate system local to the instrument. In some aspects, the local coordinate systems

may be determined with respect to one or more local references, such as a magnetic field generator **200074**. In another example, the local coordinate systems may be established with respect to a local ground such as a trocar port on the patient. The use of a local ground, in proximity to the surgical instruments **200072a,b**, can establish a local coordinate system having increased spatial resolution compared to a coordinate system based on a distant beacon (such as the magnetic field generator **200074**). Such a finer resolution coordinate system may provide detailed information regarding the location and orientation of a surgical instrument passing through the trocar. Further, trocar positions themselves can be used to aid in understanding of port placement and other operations to inform other systems, both intraoperatively as well as postoperatively, for training purposes.

[**0376**] In one aspect, a first frame of reference is established with respect to a device (e.g., a scope) positioned inside the patient and a second frame of reference is established outside the patient with respect to a predefined position. Further, the system can include a means for linking one frame of reference to the other to be able to establish instrument position to jaw position relative to the tissue. Accordingly, the position and orientation of devices can be determined according to two separate, interrelated coordinate systems.

[**0377**] In one aspect, a coupling sensor could be used to link an internal visualization image within a surgical site to the exterior visualization image of the surgical field in order to coordinate an end effector position of a surgical instrument with respect to patient tissues in the surgical field and an outside position and orientation of a handle of the surgical instrument. For example, the primary internal visualization system could be used to determine positions, distances, and velocities between aspects of the instruments and tissues of interest within the body. In one aspect, a primary internal visualization system may use a specialized frame capture imaging device. Such a device may capture the image of the internal surgical site by using a beam of light that is bounced off an internal structure of the surgical site and any devices disposed therein. Accordingly, the refraction of the beam of light by the tissue can be used to determine the distance between the internal tissue structure(s) and the device(s), rather than the reflectivity of the tissues.

[**0378**] In one aspect, lidar may be used as the measurement method for this type of system. Lidar measurements may use a pulsed laser to create a pattern and then the reflected pulses are measured. In some aspects, such a technique may be referred to as laser scanning. In various aspects, a CMOS array multi laser light source used for advanced visualization may be employed for this technique. For example, FIG. 22 depicts such a system **200076** for using lidar to determine the positions of surgical devices **200078a,b** relative to a user-selected measurement site **200080**, in accordance with at least one aspect of the present disclosure. As depicted in FIG. 22, the primary internal visualization system may permit a user of the surgical devices **200078a,b** to assess a distance **200082** between end effectors of the surgical devices **200078a,b**. In some aspects, a surgical hub may display the positions of the end effectors within the surgical site. In some additional aspects, the surgical hub may provide a warning, such as a visual indicator in a display, to warn the user of the surgical devices

**200078a,b** if the surgical devices **200078a,b** are approaching or at a minimum collision distance between them.

[**0379**] In another aspect, RF could be used to determine the locations of end-effectors within the abdomen cavity or within any internal surgical field. FIG. 23 depicts such a system. Radio Frequency time-of-flight would be one measure of determining distance to smart devices. For example, a primary transmitter and receiver could be used on a scope or visualization system **200086**. In one aspect, the primary transmitter may include a first antenna **200084a** and the receiver may include a second antenna **200084b**. In another aspect, the first antenna **200084a** may be used as both a transmitting element and as a receiving element. Similarly, the second antenna **200084b** may be used as both a transmitting element and as a receiving element. By incorporating the primary transmitter and receiver into an end of the visualization system **200086**, the receiver may measure a distance from the visualization system **200086** to a first target device with respect to the visualization focus, thereby allowing the user to measure from a frame of reference based on what the user can see.

[**0380**] In one aspect, an antenna array **200083** associated with the scope or visualization system **200086** may be composed of the first antenna **200084a** and the second antenna **200084b**. In one aspect, one antenna (such as first antenna **200084a**) of the antenna array **200083** can be configured to transmit a signal at one frequency while a second antenna (such as first antenna **200084a**) of the antenna array **200083** can be configured to receive a signal transmitted back from a first target surgical instrument **200088**. As one example, the frequency of the signal transmitted by the antenna array **200083** may be about 13.56 MHz. In another example, the strength of the signal received by the first target surgical instrument **200088** may be about at about -36 dbm RSSI. In some aspects, a return signal to the antenna array **200083** may be transmitted by the first target surgical instrument **200088** at a frequency that differs from the frequency of the signal transmitted by the antenna array **200083**. Such a communication protocol is considered full duplex communication **200090**. Separate transmission and reception frequencies may be used to prevent interference of the transmission signal by the reception signal (and vice versa). In addition, separate transmission and reception frequencies may permit the measurement of the round trip time of the signal to and from a first target surgical instrument **200088**. In some aspects, the round trip time of the signal to and from a first target surgical instrument **200088** may be used to calculate a distance of the first target surgical instrument **200088** from the antenna array **200083**.

[**0381**] In another aspect, the distance of the first target surgical instrument **200088** from the antenna array **200083** to the first target surgical instrument **200088** may be calculated based on the power loss of a signal transmitted by the antenna array **200083** or by a response signal transmitted by the first target surgical instrument **200088**. Geometric factors, such as the spread of the transmitted signal over distance, as well as the absorption loss due to the medium between the antenna array **200083** and the first target surgical instrument **200088** may permit such a distance measurement. In general, the distance between the antenna array **200083** and the first target surgical instrument **200088** is proportional to the ratio of the strength of the signal received by the first target surgical instrument **200088** to the strength of the originally transmitted signal by the antenna array

**200083**. Alternatively, the distance between the antenna array **200083** and the first target surgical instrument **200088** may be calculated from the ratio of the signal strength of the response signal received by the antenna array **200083** to the strength of the signal transmitted by the first target surgical instrument **200088**. In some examples of this technique, the signal transmitted by the first target surgical instrument **200088** may include information regarding the signal strength of transmitted signal.

**[0382]** Accordingly, smart systems could determine relative position by receiving and then returning a signal. The receiving array could include a field-programmable gate array (FPGA) and a microcontroller configured to handle the speed of measurements necessary from multiple instruments in real-time. In one aspect, the receiver antenna array **200083** could consist of two different antennas, for example first antenna **200084a** and second antenna **200084b**. The system could compare the differences of the signal received on the two antennas (first antenna **200084a** and second antenna **200084b**) and triangulate the sources position in 3D space, as depicted in FIG. 23. FIG. 23 is a diagram of a system for determining the relative position of devices via a dual-antenna array **200083**, in accordance with at least one aspect of the present disclosure. In the system depicted in FIG. 23, the dual-antenna array **200083** is disposed on a scope **200086** and receives either actively transmitted signals or passive signals from devices to determine the relative positions of the devices. In one aspect, the passive signal technique may include the full duplex communication system **200090** depicted with respect to first target surgical instrument **200088**. In another aspect, the active signal communication **200092** may involve a second target surgical instrument **200094**. The position of the devices can be determined from the detected signal strength, as shown in FIG. 24.

**[0383]** FIG. 24 depicts a graph **200110** of an example of the spatial resolution for determining the position of multiple target surgical instruments based on the detected signal strength. The abscissa represents a ratio of signal strength, in dBm, of a wireless communication between, for example, a target surgical instrument and a transceiver mounted on a reference device. The ordinate is the distance (for example in cm) that can be resolved based on the signal strength ratio. It can be observed in the graph **200110** that a difference between a maximum **200112** distance and a minimum distance **200114** may increase with increasing signal strength ratio.

**[0384]** Returning to FIG. 23, in another aspect, the end effectors of the instruments (for example second target surgical instrument **200094**) could include one or more transmitters **200096** that are capable of continuously pinging a receiver of antenna array **200083** affixed to the visualization device **200086**. In some non-limiting examples, the transmitter **200096** may transmit a signal at a frequency between about 860 MHz to about 960 MHz. In some examples, the transmitted signal may have a signal strength of about -60 dbm. The one or more transmitters **200096** could transmit a unique ID, as well as the expected intensity of the signal, so the receiver of antenna array **200083** could then calculate distance based on the received strength. In another aspect, the one or more transmitters **200096** may transmit signals to be received by multiple antennas (for example first antenna **200084a** and second antenna **200084b** of the antenna array **200083**). The difference in the reception

time or signal strength of the transmitted signal as determined by the first antenna **200084a** and the second antenna **200084b** may be used to triangulate the position of the one or more transmitters **200096** and thus the position of the end effector of second target surgical instrument **200094**.

**[0385]** In another aspect, an RFID tag could be placed on or in an end effector of each target surgical instrument. The RFID tag could be activated by a signal transmitted by a transmission antenna. In some aspects, the transmission antenna may be part of an antenna array **200083** disposed on a surgical visualization device **200086**. In some aspects, each antenna of the antenna array **200083** (for example first antenna **200084a** and second antenna **200084b**) may act as a separate transmitting antenna. Alternatively, one of the antennae of the antenna array **200083** may be a transmission antenna and another of the antennae of the antenna array **200083** may be a reception antenna. Accordingly, the strength of the transmitted signal received by an RFID tag could be used to determine distance of the RFID tag to the transmitter antenna. In another aspect, the power transmission intensity of the transmitted signal could be varied, allowing the wake-up process of the RFID tag to be used to determine the distance. The wake-up process of the RFID tag may be initiated by the receipt of a radio frequency signal having a power greater than a threshold power. It is recognized that the power of a transmitted signal is attenuated over distance. Thus, an RFID tag disposed at a distance resulting in an attenuated received signal will not enter the wake-up process. However, an RFID tag disposed at a closer distance may receive the transmitted signal at sufficient power to initiate the wake-up process. In either of these examples, the transmitter antenna transmits a power signal for receipt by the passive RFID tag on the end effector. On receipt of a transmitted signal having sufficient power, the RFID tag may wake up and then transmits a return RF signal to be received by the receiver antenna. This return signal could include a unique identifier that the system could use to measure the distance from itself to multiple devices within the operating site.

**[0386]** Returning to FIG. 23, in another aspect, a separate scanning array laser could be used for solely detecting the distances **200098** between itself and structures within the body **200099**. The scanning laser array could be cycled out of sequence from the primary visualization system **200086** to prevent interaction of the light from the distance finder and light from the primary visualization means. Alternatively, an energy means outside of the sensing capability of the primary visualization array could be utilized. If the main visualization device could detect near infrared to near ultraviolet EMR, then a light/EMR source that transmits well into the ultraviolet spectrum could be used for the scanning laser array. Alternatively ultrasonic, microwave, or RF could be used to move completely into another energy spectrum area to prevent interference between the scanning array and the visualization device. For example, ultrasonic diffuse and retroreflective sensors could be used determine distance and size of an object within its range through a gas medium (e.g., Senix or Pepperl+Fuchs ultrasonic sensors). As one example, the distance measurement **200098** between the primary visualization system **200086** and a specific structure within the body **200099** may be used along with measurements to determine the position of a first target surgical instrument **200088** to calculate a distance between the first target surgical instrument **200088** and the specific structure

within the body **200099**. As another example, contact ultrasound sensors could be used to interrogate tissues, fluids, and so on for imaging means. As yet another example, a combination of these two sources could be used to determine the tissue locations and the instrument locations within the insufflation gases of the patient's abdomen.

**[0387]** In another aspect, infrared ID and tracking can be used via projected light and a camera observing the OR. For example, at least two separate reflectors or one reflector with aspect in at least two planes could be used to determine a location and an orientation of a target surgical instrument with respect to a trocar and then with respect to the scope image inside the patient.

#### EXAMPLES

**[0388]** Various aspects of the subject matter described herein are set out in the following numbered examples:

**[0389]** Example 1. A Surgical System Comprising:

**[0390]** a first surgical device comprising a control circuit, the control circuit configured to:

**[0391]** be situationally aware of events occurring within a vicinity of the first surgical device according to data received from a database, a patient monitoring device, or a paired surgical device, or any combination of the database, the patient monitoring device, or the paired surgical device; and

**[0392]** wirelessly pair with a second surgical device according to a usage of the first surgical device and the events of which the first surgical device is situationally aware.

**[0393]** Example 2. The surgical system of Example 1, wherein events of which the first surgical device is situationally aware comprise a first user using the first surgical device and a second user using the second surgical device.

**[0394]** Example 3. The surgical system of Example 2, wherein the events comprising the first user using the first surgical device comprise the first user grasping a handle of the first surgical device.

**[0395]** Example 4. The surgical system of Example 3, wherein the events comprising the first user grasping a handle of the first surgical device comprise the first user grasping the handle of the first surgical device thereby allowing a transceiver in the handle of the first surgical device to communicate with an identifier worn by the first user and allowing, by the identifier, a communication between the first surgical device and a surgical hub.

**[0396]** Example 5. The surgical system of any one or more of Examples 2 through 4, wherein events of which the first surgical device is situationally aware comprise a location of the first surgical device and a location of the second surgical device.

**[0397]** Example 6. The surgical system of Example 5, wherein the control circuit is configured to determine the location of the second surgical device based on a wireless signal transmitted by the second surgical device to the first surgical device.

**[0398]** Example 7. The surgical system of any one or more of Examples 1 through 6, wherein the control circuit is further configured to simultaneously activate the first surgical device and the second surgical device each for a predetermined period of time when no tissue or patient is sensed.

**[0399]** Example 8. The surgical system of any one or more of Examples 1 through 7, wherein the first surgical device is located within a sterile field and the second surgical device

is located outside the sterile field when the first surgical device wirelessly pairs with the second surgical device.

**[0400]** Example 9. The surgical system of any one or more of Examples 1 through 8, wherein the control circuit is further configured to wireless pair with a communication device.

**[0401]** Example 10. The surgical system of any one or more of Examples 1 through 9, wherein events of which the first surgical device is situationally aware comprise a determination of a distance between the first surgical device and a tissue structure within a patient.

**[0402]** Example 11. A method comprising:

**[0403]** being situationally aware, by a control circuit within a first surgical device, of events occurring within a vicinity of a first surgical device according to data received from a database, a patient monitoring device, or a paired surgical device, or any combination of the database, the patient monitoring device, or the paired surgical device; and

**[0404]** wirelessly pairing, by the control circuit, with a second surgical device according to a usage of the first surgical device and the events of which the first surgical device is situationally aware.

**[0405]** Example 12. The method of Example 11, wherein being situationally aware, by a control circuit within a first surgical device, comprise being situationally aware, by a control circuit within a first surgical device, of a first user using the first surgical device and a second user using the second surgical device.

**[0406]** Example 13. The method of Example 12, wherein being situationally aware, by a control circuit within a first surgical device, of a first user using the first surgical device comprises being situationally aware, by a control circuit within a first surgical device, of a first user grasping a handle of the first surgical device.

**[0407]** Example 14. The method of Example 13, further comprising allowing a transceiver in the handle of the first surgical device to communicate with an identifier worn by the first user and

**[0408]** allowing, by the identifier, a communication between the first surgical device and a surgical hub.

**[0409]** Example 15. The method of any one or more of Examples 12 through 14, wherein being situationally aware, by a control circuit within a first surgical device, of a first user using the first surgical device and a second user using the second surgical device, comprises being situationally aware, by a control circuit within a first surgical device, of a location of the first surgical device and a location of the second surgical device.

**[0410]** Example 16. The method of Example 15, further comprising determining, by the control circuit, the location of the second surgical device based on a wireless signal transmitted by the second surgical device to the first surgical device.

**[0411]** Example 17. The method of any one or more of Examples 11 through 16, further comprising activating, by the control circuit, the first surgical device and the second surgical device each for a predetermined period of time when no tissue or patient is sensed.

**[0412]** Example 18. The method of any one or more of Examples 11 through 17, wherein wirelessly pairing, by the control circuit, with a second surgical device according to a usage of the first surgical device comprises wirelessly pairing, by the control circuit, with a second surgical device

outside of a sterile field when the first surgical device is located within the sterile field.

**[0413]** Example 19. The method of any one or more of Examples 11 through 18, further comprising wirelessly pairing of the control circuit with a communication device.

**[0414]** Example 20. The method of any one or more of Examples 11 through 19, further comprises determining, by the control circuit, a distance between the first surgical device and a tissue structure within a patient.

**[0415]** While several forms have been illustrated and described, it is not the intention of Applicant to restrict or limit the scope of the appended claims to such detail. Numerous modifications, variations, changes, substitutions, combinations, and equivalents to those forms may be implemented and will occur to those skilled in the art without departing from the scope of the present disclosure. Moreover, the structure of each element associated with the described forms can be alternatively described as a means for providing the function performed by the element. Also, where materials are disclosed for certain components, other materials may be used. It is therefore to be understood that the foregoing description and the appended claims are intended to cover all such modifications, combinations, and variations as falling within the scope of the disclosed forms. The appended claims are intended to cover all such modifications, variations, changes, substitutions, modifications, and equivalents.

**[0416]** The foregoing detailed description has set forth various forms of the devices and/or processes via the use of block diagrams, flowcharts, and/or examples. Insofar as such block diagrams, flowcharts, and/or examples contain one or more functions and/or operations, it will be understood by those within the art that each function and/or operation within such block diagrams, flowcharts, and/or examples can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof. Those skilled in the art will recognize that some aspects of the forms disclosed herein, in whole or in part, can be equivalently implemented in integrated circuits, as one or more computer programs running on one or more computers (e.g., as one or more programs running on one or more computer systems), as one or more programs running on one or more processors (e.g., as one or more programs running on one or more microprocessors), as firmware, or as virtually any combination thereof, and that designing the circuitry and/or writing the code for the software and/or firmware would be well within the skill of one of skill in the art in light of this disclosure. In addition, those skilled in the art will appreciate that the mechanisms of the subject matter described herein are capable of being distributed as one or more program products in a variety of forms, and that an illustrative form of the subject matter described herein applies regardless of the particular type of signal bearing medium used to actually carry out the distribution.

**[0417]** Instructions used to program logic to perform various disclosed aspects can be stored within a memory in the system, such as dynamic random access memory (DRAM), cache, flash memory, or other storage. Furthermore, the instructions can be distributed via a network or by way of other computer readable media. Thus a machine-readable medium may include any mechanism for storing or transmitting information in a form readable by a machine (e.g., a computer), but is not limited to, floppy diskettes, optical

disks, compact disc, read-only memory (CD-ROMs), and magneto-optical disks, read-only memory (ROMs), random access memory (RAM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), magnetic or optical cards, flash memory, or a tangible, machine-readable storage used in the transmission of information over the Internet via electrical, optical, acoustical or other forms of propagated signals (e.g., carrier waves, infrared signals, digital signals, etc.). Accordingly, the non-transitory computer-readable medium includes any type of tangible machine-readable medium suitable for storing or transmitting electronic instructions or information in a form readable by a machine (e.g., a computer).

**[0418]** As used in any aspect herein, the term “control circuit” may refer to, for example, hardwired circuitry, programmable circuitry (e.g., a computer processor including one or more individual instruction processing cores, processing unit, processor, microcontroller, microcontroller unit, controller, digital signal processor (DSP), programmable logic device (PLD), programmable logic array (PLA), or field programmable gate array (FPGA)), state machine circuitry, firmware that stores instructions executed by programmable circuitry, and any combination thereof. The control circuit may, collectively or individually, be embodied as circuitry that forms part of a larger system, for example, an integrated circuit (IC), an application-specific integrated circuit (ASIC), a system on-chip (SoC), desktop computers, laptop computers, tablet computers, servers, smart phones, etc. Accordingly, as used herein “control circuit” includes, but is not limited to, electrical circuitry having at least one discrete electrical circuit, electrical circuitry having at least one integrated circuit, electrical circuitry having at least one application specific integrated circuit, electrical circuitry forming a general purpose computing device configured by a computer program (e.g., a general purpose computer configured by a computer program which at least partially carries out processes and/or devices described herein, or a microprocessor configured by a computer program which at least partially carries out processes and/or devices described herein), electrical circuitry forming a memory device (e.g., forms of random access memory), and/or electrical circuitry forming a communications device (e.g., a modem, communications switch, or optical-electrical equipment). Those having skill in the art will recognize that the subject matter described herein may be implemented in an analog or digital fashion or some combination thereof.

**[0419]** As used in any aspect herein, the term “logic” may refer to an app, software, firmware and/or circuitry configured to perform any of the aforementioned operations. Software may be embodied as a software package, code, instructions, instruction sets and/or data recorded on non-transitory computer readable storage medium. Firmware may be embodied as code, instructions or instruction sets and/or data that are hard-coded (e.g., nonvolatile) in memory devices.

**[0420]** As used in any aspect herein, the terms “component,” “system,” “module” and the like can refer to a computer-related entity, either hardware, a combination of hardware and software, software, or software in execution.

**[0421]** As used in any aspect herein, an “algorithm” refers to a self-consistent sequence of steps leading to a desired result, where a “step” refers to a manipulation of physical

quantities and/or logic states which may, though need not necessarily, take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It is common usage to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like. These and similar terms may be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities and/or states.

**[0422]** A network may include a packet switched network. The communication devices may be capable of communicating with each other using a selected packet switched network communications protocol. One example communications protocol may include an Ethernet communications protocol which may be capable permitting communication using a Transmission Control Protocol/Internet Protocol (TCP/IP). The Ethernet protocol may comply or be compatible with the Ethernet standard published by the Institute of Electrical and Electronics Engineers (IEEE) titled "IEEE 802.3 Standard", published in December, 2008 and/or later versions of this standard. Alternatively or additionally, the communication devices may be capable of communicating with each other using an X.25 communications protocol. The X.25 communications protocol may comply or be compatible with a standard promulgated by the International Telecommunication Union-Telecommunication Standardization Sector (ITU-T). Alternatively or additionally, the communication devices may be capable of communicating with each other using a frame relay communications protocol. The frame relay communications protocol may comply or be compatible with a standard promulgated by Consultative Committee for International Telegraph and Telephone (CCITT) and/or the American National Standards Institute (ANSI). Alternatively or additionally, the transceivers may be capable of communicating with each other using an Asynchronous Transfer Mode (ATM) communications protocol. The ATM communications protocol may comply or be compatible with an ATM standard published by the ATM Forum titled "ATM-MPLS Network Interworking 2.0" published August 2001, and/or later versions of this standard. Of course, different and/or after-developed connection-oriented network communication protocols are equally contemplated herein.

**[0423]** Unless specifically stated otherwise as apparent from the foregoing disclosure, it is appreciated that, throughout the foregoing disclosure, discussions using terms such as "processing," "computing," "calculating," "determining," "displaying," or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

**[0424]** One or more components may be referred to herein as "configured to," "configurable to," "operable/operative to," "adapted/adaptable," "able to," "conformable/conformed to," etc. Those skilled in the art will recognize that "configured to" can generally encompass active-state components and/or inactive-state components and/or standby-state components, unless context requires otherwise.

**[0425]** The terms "proximal" and "distal" are used herein with reference to a clinician manipulating the handle portion

of the surgical instrument. The term "proximal" refers to the portion closest to the clinician and the term "distal" refers to the portion located away from the clinician. It will be further appreciated that, for convenience and clarity, spatial terms such as "vertical", "horizontal", "up", and "down" may be used herein with respect to the drawings. However, surgical instruments are used in many orientations and positions, and these terms are not intended to be limiting and/or absolute.

**[0426]** Those skilled in the art will recognize that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to claims containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should typically be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations.

**[0427]** In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean at least the recited number (e.g., the bare recitation of "two recitations," without other modifiers, typically means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that typically a disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms unless context dictates otherwise. For example, the phrase "A or B" will be typically understood to include the possibilities of "A" or "B" or "A and B."



[0428] With respect to the appended claims, those skilled in the art will appreciate that recited operations therein may generally be performed in any order. Also, although various operational flow diagrams are presented in a sequence(s), it should be understood that the various operations may be performed in other orders than those which are illustrated, or may be performed concurrently. Examples of such alternate orderings may include overlapping, interleaved, interrupted, reordered, incremental, preparatory, supplemental, simultaneous, reverse, or other variant orderings, unless context dictates otherwise. Furthermore, terms like “responsive to,” “related to,” or other past-tense adjectives are generally not intended to exclude such variants, unless context dictates otherwise.

[0429] It is worthy to note that any reference to “one aspect,” “an aspect,” “an exemplification,” “one exemplification,” and the like means that a particular feature, structure, or characteristic described in connection with the aspect is included in at least one aspect. Thus, appearances of the phrases “in one aspect,” “in an aspect,” “in an exemplification,” and “in one exemplification” in various places throughout the specification are not necessarily all referring to the same aspect. Furthermore, the particular features, structures or characteristics may be combined in any suitable manner in one or more aspects.

[0430] Any patent application, patent, non-patent publication, or other disclosure material referred to in this specification and/or listed in any Application Data Sheet is incorporated by reference herein, to the extent that the incorporated materials is not inconsistent herewith. As such, and to the extent necessary, the disclosure as explicitly set forth herein supersedes any conflicting material incorporated herein by reference. Any material, or portion thereof, that is said to be incorporated by reference herein, but which conflicts with existing definitions, statements, or other disclosure material set forth herein will only be incorporated to the extent that no conflict arises between that incorporated material and the existing disclosure material.

[0431] In summary, numerous benefits have been described which result from employing the concepts described herein. The foregoing description of the one or more forms has been presented for purposes of illustration and description. It is not intended to be exhaustive or limiting to the precise form disclosed. Modifications or variations are possible in light of the above teachings. The one or more forms were chosen and described in order to illustrate principles and practical application to thereby enable one of ordinary skill in the art to utilize the various forms and with various modifications as are suited to the particular use contemplated. It is intended that the claims submitted herewith define the overall scope.

1. A surgical system comprising:

a first surgical device comprising a control circuit, the control circuit configured to:

be situationally aware of events occurring within a vicinity of the first surgical device according to data received from a database, a patient monitoring device, or a paired surgical device, or any combination of the database, the patient monitoring device, or the paired surgical device; and

wirelessly pair with a second surgical device according to a usage of the first surgical device and the events of which the first surgical device is situationally aware,

wherein the first surgical device is located within a sterile field and the second surgical device is located outside the sterile field when the first surgical device wirelessly pairs with the second surgical device.

2. The surgical system of claim 1, wherein the events of which the first surgical device is situationally aware comprise a first user using the first surgical device and a second user using the second surgical device.

3. The surgical system of claim 2, wherein the events comprising the first user using the first surgical device comprise the first user grasping a handle of the first surgical device.

4. The surgical system of claim 3, wherein the events comprising the first user grasping a handle of the first surgical device comprise the first user grasping the handle of the first surgical device thereby allowing a transceiver in the handle of the first surgical device to communicate with an identifier worn by the first user and allowing, by the identifier, a communication between the first surgical device and a surgical hub.

5. The surgical system of claim 2, wherein the events of which the first surgical device is situationally aware comprise a location of the first surgical device and a location of the second surgical device.

6. The surgical system of claim 5, wherein the control circuit is configured to determine the location of the second surgical device based on a wireless signal transmitted by the second surgical device to the first surgical device.

7. The surgical system of claim 1, wherein the control circuit is further configured to simultaneously activate the first surgical device and the second surgical device each for a predetermined period of time when no tissue or patient is sensed.

8. (canceled)

9. The surgical system of claim 1, wherein the control circuit is further configured to wireless pair with a communication device.

10. The surgical system of claim 1, wherein the events of which the first surgical device is situationally aware comprise a determination of a distance between the first surgical device and a tissue structure within a patient.

11. A method comprising:

being situationally aware, by a control circuit within a first surgical device, of events occurring within a vicinity of the first surgical device according to data received from a database, a patient monitoring device, or a paired surgical device, or any combination of the database, the patient monitoring device, or the paired surgical device; and

wirelessly pairing, by the control circuit, with a second surgical device according to a usage of the first surgical device and the events of which the first surgical device is situationally aware,

wherein wirelessly pairing, by the control circuit, with a second surgical device according to a usage of the first surgical device comprises wirelessly pairing, by the control circuit, with a second surgical device outside of a sterile field when the first surgical device is located within the sterile field.

12. The method of claim 11, wherein being situationally aware, by a control circuit within a first surgical device, comprise being situationally aware, by the control circuit

within the first surgical device, of a first user using the first surgical device and a second user using the second surgical device.

**13.** The method of claim **12**, wherein being situationally aware, by a control circuit within a first surgical device, of a first user using the first surgical device comprises being situationally aware, by the control circuit within the first surgical device, of the first user grasping a handle of the first surgical device.

**14.** The method of claim **13**, further comprising allowing a transceiver in the handle of the first surgical device to communicate with an identifier worn by the first user and allowing, by the identifier, a communication between the first surgical device and a surgical hub.

**15.** The method of claim **12**, wherein being situationally aware, by a control circuit within a first surgical device, of a first user using the first surgical device and a second user using the second surgical device, comprises being situation-

ally aware, by the control circuit within the first surgical device, of a location of the first surgical device and a location of the second surgical device.

**16.** The method of claim **15**, further comprising determining, by the control circuit, the location of the second surgical device based on a wireless signal transmitted by the second surgical device to the first surgical device.

**17.** The method of claim **11**, further comprising activating, by the control circuit, the first surgical device and the second surgical device each for a predetermined period of time when no tissue or patient is sensed.

**18.** (canceled)

**19.** The method of claim **11**, further comprising wirelessly pairing of the control circuit with a communication device.

**20.** The method of claim **11**, further comprises determining, by the control circuit, a distance between the first surgical device and a tissue structure within a patient.

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