Claims

1. An endoscopy apparatus comprising:

a primary endoscope probe comprising an elongate flexible body having a length, a central axis, a proximal end, a distal end, and plurality of channels therewithin extending away from the proximal end and toward the distal end of the primary endoscope probe, the plurality of channels including:

at least one tool channel configured for receiving an endoscopy tool, each tool channel having a proximal opening and a distal opening; and

a secondary endoscope probe channel configured for carrying a secondary endoscope probe, the secondary endoscope probe channel having a central axis, a proximal opening, and a distal opening,

wherein the distal opening of the secondary endoscope probe channel is proximally offset away from the distal end of the primary endoscope probe.

2. The endoscopy apparatus of claim 1, wherein the distal opening of the secondary probe channel is proximally offset away from the distal end of the primary endoscope probe by up to 15% of the length of the primary endoscope probe.

3. The endoscopy apparatus of claim 2, wherein the distal opening of the secondary probe channel is proximally offset away from the distal end of the primary endoscope probe by up to 10% of the length of the primary endoscope probe.

4. The endoscopy apparatus of claim 1, further comprising:

an actuation assembly disposed within a tool channel of the at least one tool channel, the actuation assembly including an end effector and a set of actuation elements configured for controlling the end effector, the actuation assembly translatable along the primary endoscope probe central axis such that the end effector is disposable within a target environment beyond the distal end of the primary endoscope probe; and

a secondary endoscope probe carried within the secondary endoscope probe channel, the secondary endoscope probe having a distal end displaceable beyond the distal opening of the secondary endoscope probe channel,

wherein the secondary endoscope probe comprises an imaging endoscope configured for capturing images of the end effector within the target environment beyond the distal end of the primary endoscope probe, and

wherein the imaging endoscope includes at least one of:

at least one controllable region configured for enabling controllable displacement of the imaging endoscope toward or away from the primary endoscope probe central axis; and

an image capture module having a field of view disposed toward the central axis of the primary endoscope probe.

5. The endoscopy apparatus of claim 4, wherein the imaging endoscope is configured for capturing anterograde and retrograde views of end effector operation within the target environment.

6. The endoscopy apparatus of claim 4, wherein the at least one controllable region is configured for enabling heave displacement of the imaging endoscope relative to the primary endoscope probe central axis.

7. The endoscopy apparatus of claim 6, wherein the at least one controllable region is further configured for enabling sway displacement of the imaging endoscope relative to the primary endoscope probe central axis.

8. The endoscopy apparatus of claim 4, wherein the imaging endoscope includes a plurality of distinct controllable regions.

9. The endoscopy apparatus of claim 8, wherein the imaging endoscope comprises an S-bend endoscope.

10. The endoscopy apparatus of claim 4, wherein the imaging endoscope is configured for controllable rotation about a central axis thereof.

11. The endoscopy apparatus of claim 4, further comprising a ramp structure positioned proximate to the distal end of the primary endoscope probe and configured for receiving the imaging endoscope and guiding a central axis of the imaging endoscope toward or away from the central axis of the primary endoscope probe to thereby facilitate heave displacement of the imaging endoscope relative to the central axis of the primary endoscope probe.

12. The endoscopy apparatus of claim 11, wherein the ramp structure is controllably displaceable in a direction parallel to the central axis of the primary endoscope probe.

13. The endoscopy apparatus of claim 4, wherein the image capture module field of view is disposed toward the central axis of the primary endoscope probe by way of one of:

a beveled face carrying a lens element and positioned at a non-normal angle relative to the central axis of the secondary endoscope probe; and

a rotatable housing carrying the lens element, the rotatable housing controllably displaceable about an axis of rotation transverse to the central axis of the primary endoscope probe.

14. The endoscopy apparatus of claim 13, wherein the distal end of the primary endoscope probe is configured for mating engagement with the rotatable housing, and wherein the rotatable housing is displaceable beyond the distal end of the primary endoscope probe.

15. An endoscopy apparatus comprising:

a primary endoscope probe comprising an elongate flexible body having a central axis, a proximal end, a distal end, and plurality of channels therewithin extending away from the proximal end and toward the distal end of the primary endoscope probe, the plurality of channels including:

~~at least one tool channel, each tool channel having a proximal opening and a distal opening; and~~

~~a secondary endoscope probe channel configured for carrying a secondary endoscope probe, the secondary endoscope probe channel having a central axis, a proximal opening, and a distal opening; and~~

~~a ramp structure positioned proximate to the distal end of the primary endoscope probe and configured for receiving the secondary endoscope probe and guiding the central axis of the central axis of the secondary endoscope probe toward or away from the central axis of the primary endoscope probe to thereby facilitate heave displacement of the secondary endoscope probe relative to the central axis of the primary endoscope probe.~~

~~16. The endoscopy apparatus of claim 15, wherein the ramp structure is controllably displaceable in a direction parallel to the central axis of the primary endoscope probe.~~

~~17. An imaging endoscope comprising:~~

~~a flexible body having a length, a central axis along its length, a proximal end, and a distal end; and~~

~~an image capture module disposed at the distal end of the flexible body and having a field of view that is controllably positionable toward and away from the central axis of the flexible body by way of a rotatable housing having an axis of rotation transverse to the central axis of the flexible body.~~

1~~8~~. An endoscopy apparatus comprising:

a primary endoscope probe comprising an elongate flexible body having an exterior shape, a central axis, a proximal end, a distal end, and at least one tool channel therein extending away from the proximal end toward the distal end of the body, each tool channel having a proximal opening and a distal opening, wherein a distal portion of the primary endoscope probe is segmented into:

a tool channel member comprising a distal extension of a first cross sectional portion of the body, the tool channel member having a distal end carrying the distal opening of each tool channel of the at least one tool channel; and

a secondary probe member comprising a distal extension of a second cross sectional portion of the body, the secondary probe member having a distal end carrying an image capture module, the secondary probe member configured for selectable (a) position locking adjacent to the tool channel member, and (b) positioning of the image capture module away from the tool channel member by way of heave displacement of the image capture module away from the central axis of the body,

wherein the distal end of the tool channel member and the distal end of the secondary probe member terminate at the distal end of the body when the secondary probe member is position locked adjacent to the tool channel member.

2~~19~~. The endoscopy apparatus of claim 18, wherein the secondary probe member includes a proximal controllable region configured for enabling heave displacement of the image capture module away from the central axis of the body.

3~~20~~. The endoscopy apparatus of claim 19, wherein the secondary probe member includes a distal controllable region configured for selectively orienting a field of view of the image capture module toward the central axis of the body.

4~~21~~. The endoscopy apparatus of claim 18, wherein the tool channel member and the secondary probe member each have an outer surface that uniformly maintain the exterior shape of the body from the proximal end of the body to the distal end of the body when the secondary probe member is position locked adjacent to the tool channel member.

~~22. The endoscopy apparatus of claim 4, wherein positioning of the primary endoscope probe and positioning of the secondary endoscope probe is controllable by an interface coupled to the proximal end of the primary endoscope probe, and wherein positioning of the robot arm is controllable by a master controller disposed remote from the primary~~

endoscope probe and the interface coupled to the proximal end of the primary endoscope probe.

23. The endoscopy apparatus of claim 22, wherein positioning of the secondary endoscope probe is further selectably controllable by the master controller.

24. A selectively shape lockable endoscopy apparatus comprising:

a primary endoscope probe comprising:

an elongate flexible body having a length, a central axis, a proximal end, a distal end, and at least one tool channel therein extending away from the proximal end toward the distal end of the body, each tool channel having a proximal opening and a distal opening;

a plurality of tensionable cables carried internal to the flexible body and configured for selectively shape locking at least one shape lockable section of the flexible body in response to applied tension during navigation of the flexible body toward and into a target environment,

wherein the plurality of cables is coupled to at least one of (a) a plurality of actuated joints disposed at each predetermined shape lockable section, and (b) the elongate flexible body at predetermined longitudinal distances along the flexible body length to effectuate shape locking in response to applied tension;

an actuation assembly disposed within a tool channel of the at least one tool channel, the actuation assembly including a robot arm carrying an end effector and a set of actuation elements configured for controlling the robot arm and end effector;

an interface coupled to the proximal end of the flexible body and configured for controlling navigation of the flexible body; and

a master controller disposed remote from the flexible body and the interface coupled to the interface coupled to the proximal end of the flexible body, and configured for controlling the operation of the robot arm and the end effector.

~~25. The endoscopy apparatus of claim 24, wherein the plurality of tensionable cables is coupled to each of (a) a plurality of actuated joints disposed at each predetermined shape lockable section, and (b) the elongate flexible body at predetermined longitudinal distances along the flexible body length.~~

~~26. A robot arm assembly including an end effector, the robot arm assembly configured for selectively positioning the end effector in accordance with at least one degree of freedom (DOF), the robot arm assembly having a central axis and comprising a plurality of joint primitives, each joint primitive disposed at a predetermined position along a length of the robot arm assembly, each joint primitive configured for selectively enabling motion corresponding to a particular DOF, each joint primitive actuatable by way of a set of tendons, the plurality of joint primitives including at least two of:~~

- ~~a vertebra joint primitive configured for displacing a first segment of the robot arm assembly toward or away from the central axis of the robot arm assembly relative to a second segment of the robot arm assembly, the vertebra joint primitive comprising:~~
  - ~~a proximal body portion corresponding to the first segment of the robot arm assembly, the proximal body portion having a cross sectional area and a central axis; and~~
  - ~~a distal body portion corresponding to the second segment of the robot arm assembly, the distal body portion carried by the proximal body portion by way of pivotable mating engagement relative to the proximal body portion, the distal body portion having a cross sectional area and a central axis alignable with the central axis of the proximal body portion, the distal body portion comprising a first tendon coupling portion couplable to a first tendon, and a second tendon coupling portion couplable to a second tendon,~~
  - ~~wherein the central axis of the distal body portion is selectively alignable with the central axis of the proximal body portion and the central axis of the robot arm assembly by way of application of forces to the first and second tendons;~~

a rotational joint primitive configured for rotating a third segment of the robot arm assembly in a clockwise or counterclockwise relative to the central axis of the robot arm assembly, the rotational joint primitive comprising:

a drum member having an outer periphery, a cross sectional area, and an axis of rotation perpendicular to the cross sectional area; and

a third tendon wrapped around the outer periphery of the drum member and configured to rotate the drum member in response to a pulling force differentially applied to a first end of the third tendon relative to a second end of the third tendon; and

a revolute joint primitive configured for pivoting a fourth segment of the robot arm assembly relative to a fifth segment of the robot arm assembly, the revolute joint primitive comprising a body revolvable in a first direction relative to the central axis of the robot arm assembly by way of a first pulling force applied to a fourth tendon secured to the body and revolvable in a second direction opposite to the first direction by way of a second pulling force applied to a fifth tendon secured to the body.

27. The robot arm assembly of claim 26, wherein the robot arm assembly is movable in a plurality of DOF corresponding to at least one of shoulder medial rotation, elbow flexion / extension, forearm supination / pronation, wrist flexion / extension, and finger opposition / reopposition.

28. The robot arm assembly of claim 26, wherein the robot arm assembly is configured for motion in eight DOF.

29. An endoscopy apparatus comprising:

a quick release assembly comprising a plurality of selectively engageable / releaseable elements which when engaged are configured for:

(a) receiving (i) a first set of flexible tendon-sheath elements corresponding to an actuation controller configured for linearly driving tendons within the first set of tendon-sheath elements, and (ii) a second set of flexible tendon-sheath elements

corresponding to an actuation assembly insertable into an endoscope probe and including the second set of tendon-sheath elements and a robot arm carrying an end effector controllable by way of linear motion of tendons within the second set of tendon-sheath elements; and

(b) converting linear motion of tendons within the first set of tendon-sheath elements into rotational motion, and converting the rotational motion into linear motion of tendons within the second set of tendon-sheath elements to facilitate control of the robot arm and the end effector in response to linear motion of tendons within the first set of tendon-sheath elements.

30. The endoscopy apparatus of claim 29, wherein the quick release assembly carries a portion of a surgical drape that facilitates environmental isolation between (a) the actuation controller and the first set of tendon-sheath elements, and (b) the actuation assembly and the endoscope probe.

31. The endoscopy apparatus of claim 29, wherein the plurality of selectively engageable / releaseable elements comprises:

an actuator-side interface configured to receive the first set of flexible tendon-sheath elements; and

an endoscope-side interface configured to receive the second set of tendon-sheath elements,

wherein the actuator-side interface and the endoscope-side interface are configured for detachable mechanical coupling with each other.

32. The endoscopy apparatus of claim 31, wherein the plurality of selectively engageable / releaseable elements further comprises an intermediate interface configured for detachable mating engagement with each of the actuator-side interface and the endoscope-side interface, and wherein the conversion of linear motion of tendons within the first set of tendon-sheath elements into rotational motion and the conversion of the rotational motion into linear motion of tendons within the second set of tendon-sheath elements occurs by way of the intermediate interface.

~~33. The endoscopy apparatus of claim 32, wherein the intermediate interface is configured for snap-fit engagement with each of the actuator-side interface and the endoscope-side interface.~~

~~34. The endoscopy apparatus assembly of claim 32, wherein the intermediate interface carries a portion of a surgical drape that facilitates environmental isolation between (a) the actuation controller and the first set of tendon sheath elements, and (b) the actuation assembly and the endoscope probe.~~

~~35. The endoscopy apparatus of claim 29, wherein the quick release assembly carries a set of sensors configured to detect tendon forces and/or tendon elongation.~~