CLAIMS

What is claimed is:

1. A cryogenic storage system, comprising:

at least one freezer port configured to receive a first sample box extracted from a respective freezer;

a working chamber configured to maintain a cryogenic environment;

an input/output (I/O) port configured to enable external access to samples;

a box transport robot configured to transport the first sample box between the at least one freezer port, the working chamber, and the I/O port; ~~and~~

a picker robot configured to transport, within the working chamber, a sample tube between the first sample box and a second sample box;

a transport chamber coupled to the at least one freezer port during access by the box transport robot, the transport chamber housing the box transport robot; and

an intermediate chamber coupled between the transport chamber and the working chamber, the intermediate chamber housing at least a portion of the picker robot, the box transport robot being configured to transport the first sample box through the intermediate chamber to the working chamber.

2. The system of claim 1, further comprising an ejector configured to transport the first sample box through at least a portion of the at least one freezer port to a position accessible to the box transport robot.

3. The system of claim 2, wherein the ejector includes a pair of arms configured to move and guide opposite sides to control positioning of the first sample box.

4. The system of claim 2, wherein the ejector includes a floor configured to support the first sample box, at least a portion of the floor being depressible via a force applied by the box transport robot.

5. The system of claim 2, wherein the ejector is configured to transport a plurality of different sample box formats.

~~6. The system of claim 1, further comprising a transport chamber, the transport chamber being coupled to the at least one freezer port during access by the box transport robot, the transport chamber housing the box transport robot.~~

~~7.~~6. The system of claim 1~~6~~, wherein the transport chamber is further configured to maintain an environment above a glass transition temperature of samples of the first sample box.

~~8.~~7. The system of claim 1~~6~~, wherein the transport chamber is connected to the working chamber via an aperture.

~~9. The system of claim 6, wherein the transport chamber is connected to the working chamber via an intermediate chamber, the intermediate chamber housing at least a portion of the picker robot.~~

~~10.~~8. The system of claim 7~~8~~, wherein the box transport robot is configured to extend into the working chamber via the aperture during transport of the first sample box.

~~11.~~9. The system of claim 7~~8~~, wherein the picker robot is configured to extend into the working chamber via the aperture during transport of the sample tube.

~~12.~~10. The system of claim 1, wherein the box transport robot further includes a box gripper assembly configured to grip the first sample box.

~~13.~~11. The system of claim 10~~12~~, wherein the box gripper assembly includes a pair of arms configured to clamp opposing corners of the first sample box, each of the pair of arms including a set of contact points adapted to accommodate a plurality of sample box formats, the pair of arms being further configured to adjust the first sample box to a target rotational and positional orientation.

~~14.~~12. The system of claim 11~~13~~, wherein at least one of the sets of contact points define a W shape, a first portion of the W shape accommodates a first sample box format, and a second portion of the W shape accommodates a second sample box format.

~~15.~~13. The system of claim 10~~12~~, wherein the box transport robot includes a rail assembly on which the box gripper assembly moves.

~~16.~~14. The system of claim 1, wherein the picker robot includes a first arm including a tube gripper assembly and a second arm including a push-up pin.

~~17.~~15. The system of claim 14~~16~~, wherein the second arm extends under a platform supporting sample boxes in the working chamber, the second arm being configured to drive the push-up pin into the first sample box to raise a portion of the sample tube from the first sample box.

~~18.~~16. The system of claim 14~~16~~, wherein the tube gripper assembly includes a plurality of teeth, the tube gripper assembly configured to rotate horizontally the plurality of teeth around and toward a center axis to grip the sample tube.

~~19.~~17. The system of claim 16~~18~~, wherein the teeth are thermally isolated from components of the picker robot external to the working chamber via a thermal insulator.

~~20.~~18. The system of claim 14~~16~~, wherein the first arm is configured to move the sample tube to a position enabling an identification (ID) tag of the sample tube to be read by an ID reader.

~~21.~~19. The system of claim 18~~20~~, wherein the position is external to the working chamber.

~~22.~~20. The system of claim 18~~20~~, wherein the first arm is further configured to 1) pass the sample tube along a cleaner to remove frost from the sample tube and 2) rotate the sample tube to align the ID tag with the ID reader.

~~23.~~21. The system of claim 18~~20~~, wherein the position enables the ID tag to be read by the ID reader via a reflection of the ID tag from a mirror.

~~24.~~22. The system of claim 1, wherein the working chamber includes a platform configured to support the first and second sample boxes.

~~25.~~23. The system of claim 22~~24~~, further comprising a clamp assembly configured to secure the first sample box via a force applied to a corner of the first sample box, the clamp including a set of contact points adapted to accommodate a plurality of sample box formats.

~~26.~~24. The system of claim 23~~25~~, wherein the set of contact points define a W shape, a first portion of the W shape accommodates a first sample box format, and a second portion of the W shape accommodates a second sample box format.

~~27.~~25. The system of claim 22~~24~~, wherein the platform includes an aperture exposing a portion of a bottom surface of the first sample box, the aperture enabling access to a bottom of the sample tube by the tube picker robot.

~~28.~~26. The system of claim 22~~24~~, wherein the working chamber is further configured to contain a liquid coolant below the platform.

~~29.~~27. The system of claim 26~~28~~, further comprising a heat sink coupled to the platform and configured to be partially immersed in the liquid coolant.

~~30.~~28. The system of claim 26~~28~~, wherein the tube picker robot includes an arm supporting a push-up pin, the arm configured to be at least partially immersed in the liquid coolant.

~~31.~~29. The system of claim 1, further including a light curtain configured to detect a format of a third sample box at the I/O port.

~~32.~~30. The system of claim 29~~31~~, wherein the light curtain projects a single collimated light source.

~~33.~~31. The system of claim 1, wherein the at least one freezer port includes a plurality of freezer ports, each of the plurality of freezer ports being configured to receive sample boxes extracted from a respective freezer.

~~34.~~32. The system of claim 1, further comprising a rail assembly configured to move the at least one freezer port between a plurality of freezers.

~~35.~~33. The system of claim 32~~34~~, wherein the rail assembly is further configured to move the working chamber, the box transport robot, and the tube picker robot in unison with the at least one freezer port.

~~36.~~34. The system of claim 1, wherein the at least one freezer port is configured to connect with an extractor assembly, the extractor assembly being configured to raise a storage rack from a freezer and eject the first sample box from the rack.

~~37.~~35. A method of transporting a sample, comprising:

extracting a first sample box from a respective freezer via a freezer port;

transporting the first sample box, via a box transport robot, from the freezer port to a transport chamber coupled to the freezer port during access by the box transport robot, the transport chamber housing the box transport robot;

transporting the first sample box, via the box transport robot, from the transport chamber to an intermediate chamber coupled between the transport chamber and a working chamber, the intermediate chamber housing at least a portion of a picker robot;

transporting the first sample box, via ~~a~~ the box transport robot, from the ~~freezer port~~ intermediate chamber to a working chamber configured to maintain a cryogenic environment; and

transporting, via ~~a~~ the picker robot within the working chamber, a sample tube between the first sample box and a second sample box.

~~38.~~36. The method of claim 35~~37~~, further comprising transporting the first sample box, via the box transport robot, from the working chamber to an I/O port configured to enable external access to samples.

~~39.~~37. The method of claim 35~~37~~, wherein the working chamber includes a platform configured to support a plurality of sample boxes including the first sample box and the second sample box.

~~40.~~38. The method of claim 37~~39~~, wherein the working chamber is further configured to contain a liquid coolant below the platform.

~~41.~~39. The method of claim 38~~40~~, further comprising a heat sink coupled to the platform and configured to be partially immersed in the liquid coolant.

~~42.~~40. The method of claim 38~~40~~, wherein the tube picker robot includes an arm supporting a push-up pin, the arm configured to be at least partially immersed in the liquid coolant.

~~43.~~41. The method of claim 35~~37~~, further comprising:

picking the sample tube in the working chamber using the picker robot;

removing frost from the sample tube while the sample tube is at least partially within the cryogenic environment of the working chamber; and

reading the indicia from the sample tube.