

CLAIMS:

1. In combination, a storage unit storable within a three-dimensional storage system and a storage/retrieval vehicle navigable through said three-dimensional storage system to storage locations therein at which said storage unit is
5 selectively storable and retrievable, wherein said storage/retrieval vehicle comprises a frame conveyable through said three-dimensional storage system, a platform atop said frame for receipt of said storage unit on said platform, and a loading/unloading mechanism operable to load and unload said storage unit to and from said platform at four different sides thereof, wherein said storage unit and said storage/retrieval vehicle
10 are configured to enable unloading of the storage unit from said platform in any one of four different directions at four different respective sides of the vehicle regardless of an original orientation in which said storage unit was previously loaded onto the platform and without reorienting said storage unit from said original orientation.

2. The combination of claim 1 wherein the loading/unloading
15 mechanism is switchable between four different working states each operable to load and unload said storage unit at a respective one of the four different sides of the platform, and the storage unit and said storage/retrieval vehicle are configured to enable static support of the storage unit on said platform in a static orientation thereon while said loading/unloading mechanism transitions between the different working
20 states.

3. The combination of any preceding claim wherein the loading/unloading mechanism comprises an extendable/retractable device selectively deployable at each of said four different sides of the platform to define a respective one of the four different working states.

25 4. The combination of any preceding claim wherein:
said loading/unloading mechanism of the vehicle comprises a rotatable turret installed in said platform to reside beneath the storage unit when loaded onto said platform, and an extendable arm selectively extendable from said rotatable turret into a deployed position reaching outwardly beyond a perimeter of said platform, said turret
30 being rotatable into a plurality of different working positions in which the arm is

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extendable outwardly from the turret in said different directions at said different respective sides of the vehicle, and said extendable arm comprises a catch member carried thereon for engagement with an underside of the storage unit; and

5 said storage unit comprises a catch channel residing in an underside of the storage unit and in which the catch member of the loading/unloading mechanism is selectively engageable, wherein said catch channel lies on a circular path along which the catch member can traverse the catch channel during rotation of the turret while the storage unit is seated on said platform.

10 5. The combination of claim 4 wherein said catch channel spans at least 270-degrees of said circular path.

6. The combination of claim 5 wherein said catch channel spans a full 360-degrees of said circular path.

15 7. The combination of any one of claims 4 to 6 wherein said extendable arm comprises a movable shuttle that is displaceable back and forth along said extendable arm and on which the catch member resides.

8. The combination of any one of claims 4 to 7 wherein said platform comprises outer deck surfaces disposed around the turret, and the turret resides in recessed elevation relative to said outer deck surfaces.

20 9. The combination of any one of claims 4 to 8 wherein the storage unit comprises at least one redundant catch feature recessed in the underside thereof at a distance situated outwardly from the circular path of the catch channel.

10. The combination of claim 9 wherein said at least one redundant catch feature comprises a plurality of redundant catch recesses each residing between the catch channel and a respective side of the storage unit.

25 11. The combination of any one of claims 1 to 3 wherein the loading/unloading mechanism comprises an extendable arm that is selectively extendable into a deployed position reaching outwardly beyond a perimeter of the platform, and that comprises a movable shuttle that is engageable with the storage unit and displaceable back and forth along said extendable arm.

30 12. The combination of claim any one of claims 1 to 3 and 11 wherein

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the storage unit comprises a primary catch feature engageable by the loading/unloading mechanism in a deployed state thereof during a loading operation intended to pull said storage unit onto the platform of the vehicle, and at least one secondary catch feature positioned relative to the primary catch feature to be engaged by the loading/unloading mechanism in more retracted state thereof later in the loading operation should the loading/unloading mechanism fail to engage the primary catch feature.

13. The combination of claim 12 comprising a plurality of secondary catch features, each residing adjacent a respective outer perimeter side of the storage unit.

14. The combination of claim 12 or 13 wherein the primary and secondary catch features are located at an underside of the storage unit.

15. The combination of any one of claims 12 to 14 wherein each secondary catch feature is recessed into the storage unit.

16. The combination of any one of claims 12 to 15 wherein the primary catch feature is recessed into the storage unit.

17. The combination of any one of claims 12 to 16 wherein the primary catch feature comprises a curved feature lying on a circular path.

18. The combination of claim 17 wherein the curved feature spans at least 270-degrees of said circular path.

19. The combination of claim 18 wherein said curved feature spans a full 360-degrees of said circular path.

20. A storage/retrieval vehicle for use in a three-dimensional storage system delimiting storage locations at which respective storage units are selectively storable and retrievable, wherein said storage/retrieval vehicle comprises a frame conveyable through said three-dimensional storage system, a platform atop said frame for receipt of said storage unit on said platform, and a loading/unloading mechanism operable to load and unload said storage unit to and from said platform; wherein the loading/unloading mechanism comprises an extendable arm that is selectively extendable into a deployed position reaching outwardly beyond a perimeter of the platform, and that comprises a movable shuttle that is engageable with the storage unit

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and displaceable back and forth along said extendable arm.

21. The vehicle of claim 20 in combination with at least one of said storage units, wherein a distance by which the extendable arm reaches outward from the platform in the deployed position is less than half of a width of the storage unit, and
5 the storage unit comprises a primary catch feature that is engageable by the movable shuttle and is situated intermediately between a center of the bin and an outer side thereof.

22. The combination of claim 21 wherein the storage unit comprises a secondary catch feature disposed outwardly from said primary catch feature toward the
10 outer side thereof.

23. The combination of any one of claims 12 to 19 and 22 wherein the storage/retrieval vehicle comprises a set of load status sensors distributed at different locations over a landing area of the platform and each operable to detect presence of the storage unit in overlying relation to said sensor when said storage unit is seated on
15 said landing area, wherein the loading/unloading mechanism is configured to retract a predetermined distance that is sufficient to pull the storage unit fully into the landing area of the platform if the primary catch feature was engaged, and wherein the combination further comprises a processor configured to query the set of load status sensors after retraction of the loading/unloading mechanism by said predetermined
20 distance, and based on said query, identify either a successful loading of the storage unit onto the landing area based on a positive detection signal from all of said load sensors, or a failed or incomplete loading of the storage unit onto the landing area based on a lack of positive detection signal from one or more of said load sensors.

24. The combination of claim 23 wherein said predetermined distance
25 is sufficient to pull the storage unit partially onto the platform if the secondary catch feature was engaged, and receipt of the positive detection signal from a partial subset of said load sensors after retraction of the loading/unloading mechanism by said predetermined distance identifies failed engagement of the primary catch feature, successful engagement of the secondary catch feature, and partial loading of the
30 storage unit onto the platform.

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25. The combination of claim 24 wherein, the processor is configured to, after detection of said failed engagement of the primary catch feature and said partial loading of the storage unit, partially re-deploy the loading/unloading mechanism and thereby push the partially loaded storage unit off the platform.

5 26. The combination of claim 25 wherein the processor is configured to, after partial re-deployment of the unloading mechanism and pushing of the partially loaded storage unit off the platform, re-attempt loading of the storage unit onto the platform via engagement of the primary catch feature by the loading/unloading mechanism.

10 27. A storage unit for use in a three dimensional storage system navigable by a fleet of storage/retrieval vehicles each having a selectively extendable arm thereon by which the storage unit is engageable to unload said storage unit from the vehicle into a storage location in said three-dimensional storage system and/or load said storage unit onto vehicle from said storage location, said storage unit comprising
15 a primary catch feature engageable by the extendable arms of the storage/retrieval vehicles, wherein said primary catch features is a curved feature lying on a circular path.

28. The storage unit of claim 27 wherein the primary catch feature is a recessed channel.

20 29. The storage unit of claim 27 or 28 wherein the primary catch feature spans at least 270-degrees of said circular path.

30. The storage unit of claim 29 wherein said primary catch feature spans a full 360-degrees of said circular path.

25 31. The storage unit of any one of claims 27 to 30 comprising a secondary catch feature residing at a location situated outwardly from the circular path of said primary catch feature.

32. The storage unit of claim 31 comprising a plurality of secondary catch features, each residing outwardly of the circular path of the primary catch feature.

30 33. The storage unit of any one of claims 27 to 32 wherein each catch feature resides at an underside of the storage unit.

34. A method of handling a storage unit using a robotic storage/retrieval vehicle in a storage system having storage locations disposed on multiple sides of travel paths through said storage system, said robotic storage/retrieval vehicle having a loading/unloading mechanism that is adjustable between four different working states each operable to load and unload said storage unit at a respective one of four different sides of the vehicle, said method comprising, with said storage unit carried on said robotic storage/retrieval vehicle, and while maintaining said storage unit in a static orientation and position on said robotic storage/retrieval vehicle, adjusting the loading/unloading mechanism between two of the four different working states, thereby changing which side of the vehicle said storage unit is offloadable therefrom without re-positioning or re-orienting said storage unit on said vehicle.

35. The method of claim 34 wherein switching said loading/unloading mechanism between said first and second working states comprises rotating said loading/unloading mechanism therebetween, and during rotation of the loading/unloading mechanism, accommodating relative movement between the statically maintained storage unit and a catch member of said loading/unloading mechanism using a catch channel of the storage unit that follows a circular path around a rotational axis of said loading/unloading mechanism.

36. The method of claim 35 wherein said catch channel spans at least 270-degrees of said circular path.

37. The combination of claim 36 wherein said catch channel spans a full 360-degrees of said circular path.

38. A method of handling storage units using a robotic storage/retrieval vehicle in a storage system having storage locations in which said storage units are stored, said method comprising:

(a) attempting loading of a storage unit from a storage location onto a platform of said robotic storage/retrieval vehicle using a loading/unloading mechanism of said robotic storage/retrieval vehicle;

(b) performing a load status check using a load status sensing device to detect whether the storage unit has been properly loaded onto said platform of said

robotic storage/retrieval vehicle;

(c) in response to detection by said load status sensing device of a failure to fully load said storage unit onto said platform of said robotic storage/retrieval vehicle, triggering an automatic repositioning of the storage unit in the storage location; and

5 (d) re-attempting loading of the storage unit onto the platform of said robotic storage/retrieval vehicle using said loading/unloading mechanism thereof.

39. The method of claim 38 wherein repositioning of the storage unit in step (c) is performed by the robotic storage/retrieval vehicle.

40. The method of claim 39 wherein repositioning of the storage unit
10 in step (c) is performed by the same loading/unloading mechanism used to attempt and reattempt loading of the storage unit in steps (a) and (d).

41. The method of any one of claims 38 to 40 wherein step (a) comprises failure by the loading/unloading mechanism to engage a primary catch feature of the storage unit, successful engagement by the loading/unloading
15 mechanism of a secondary catch feature, and pulling of the storage unit into a partially loaded position on the platform of the vehicle via said secondary catch feature.

42. The method of claim 41 wherein said repositioning in step (c) comprises pushing the storage unit off the platform and fully into the storage location via said secondary catch feature.

20 43. The method of claim 41 or 42 wherein the re-attempting in step (d) comprises disengaging the loading/unloading mechanism from the secondary catch feature, and re-attempting engagement of the loading/unloading mechanism with the primary catch feature.

44. The method of any one of claims 38 to 43 wherein the load-status
25 sensing device comprises a set of load status sensors on the storage/retrieval vehicle, including one or more front sensors adjacent a front side of the platform from which the loading/unloading mechanism attempts to load the storage unit, and one or more rear sensors adjacent an opposing rear side of the platform, and said failure to fully load said storage unit onto said platform in step (c) is detected by coverage of the one or
30 more front sensors, but not the one or more rear sensors, by the storage unit.

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45. A computer readable medium having recorded thereon statements and instructions executable by a local processor of the robotic storage/retrieval vehicle recited in any one of claims 38 to 44 to perform the method steps thereof.

46. A robotic storage/retrieval vehicle for use in a storage system
5 having storage locations in which storage units are stored, said vehicle comprising:

a landing area sized and shaped to accommodate to an underside of one of said storage units;

a loading/unloading mechanism operable to load and unload a storage unit to and from said landing area of said storage/retrieval vehicle; and

10 a load status sensing device to detect whether the storage unit has been properly loaded onto said landing area of said robotic storage/retrieval vehicle; and

a local processor onboard said storage/retrieval vehicle, said local computer processor being configured to:

(a) actuate the loading/unloading mechanism to attempt loading of the
15 storage unit from a storage location onto the landing area of the vehicle;

(b) perform a load status check using the load status sensing device to detect whether the storage unit has been properly loaded onto said landing area of said robotic storage/retrieval vehicle;

(c) in response to detection by said load status sensing device of a failure
20 to fully load said storage unit onto said platform of said robotic storage/retrieval vehicle, trigger an automatic repositioning of the storage unit in the storage location; and

(d) re-attempt loading of the storage unit onto the platform of said robotic storage/retrieval vehicle using said loading/unloading mechanism thereof.

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