A docking mechanism for the docking of a space vehicle 11 to a space station 12 comprising a flexible tunnel frame structure which is deployable from the space station. The tunnel structure comprises a plurality of series connected frame sections 21, one end section of which is attached to the space station and the other end attached to a docking module 15 of a configuration adapted for docking in the payload bay of the space vehicle 11. The docking module is provided with turntables 41, 42 adapted for latching engagement with latches 17 installed in the vehicle payload bay and with hatch means 44 connectable to a hatch of the crew cabin of the space vehicle. Each frame section 21 comprises a pair of spaced ring members 31a, 31b interconnected by actuator-attenuator devices 33 which are individually controllable by automatic control means to impart relative movement of one ring member to the other in six degrees of freedom. The control means includes computer logic responsive to sensor signals of range and attitude information, capture latch condition, structural loads, and actuator stroke for generating commands to the on-board flight control system and the individual actuator-attenuator devices 33 which are individually controllable by automatic control means to impart relative movement of one ring member to the other in six degrees of freedom. A tubular fluid-impervious liner, preferably fabric 51, is disposed through the frame sections 21 of a size sufficient to accommodate the passage of personnel and cargo.
4,860,975

SMAR T TUNNEL - DOCKING MECHANISM

ORIGIN OF THE INVENTION

The invention described herein was made by employees of the U.S. Government and may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

RELATED APPLICATIONS


FIELD OF THE INVENTION

This invention relates to docking mechanisms for spacecraft, and more particularly to a mechanism for docking and undocking a space vehicle to a space station or another space vehicle which provides a tunnel connection between the spacecraft in the form of a flexible tunnel structure with motion capability in six degrees of freedom for effecting initial coupling of the spacecraft and adjustment of their relative orientation thereafter.

BACKGROUND ART

The rendezvous and docking/undocking of a space vehicle with a space station or another space vehicle requires the successful operation of many complex systems. These include systems for controlling the relative maneuvering and alignment of the spacecraft, spacecraft coupling and decoupling mechanisms, and shock attenuating and absorbing systems for reducing impact loads and for sustaining tension loads in holding the spacecraft together after initial engagement. An important consideration is the need for ensuring that the docking mechanism can be easily disengaged in the event of failure of the relative maneuvering and alignment systems, the docking couplings, or the relative motion control systems. Another important consideration is the ability to maintain a sealed connection between the docking mechanisms while the space vehicle is in motion.

SUMMARY OF THE INVENTION

The invention is a docking mechanism for the docking of spacecraft such as a space vehicle to a space station or another space vehicle. The mechanism comprises a flexible tunnel structure in the form of a plurality of series-connected frame sections, each comprising a pair of docking ring members connected in a substantially coaxial relationship. One end section of the series is connected to the space station in sealing engagement therewith and about an egress hatch provided on the station. The other end section of the series connected frame sections is attached to a docking module equipped with trunnions adapted for connection and latching engagement with a plurality of latch mechanisms installed in the payload bay of the space vehicle. An actuator control means, which includes a plurality of actuator-attenuator devices connecting the docking ring members of each said frame section, is provided for imparting a relative motion between the ring members of each frame section in six degrees of freedom of movement. The control means is adapted to respond to sensor signals indicative of relative range and attitude of the space vehicle and space station. Structural loads imposed on the tunnel structure, the latched or unlatched condition of the latching mechanisms, and the measurement of actuator strokes whereby the tunnel structure may be controlled in movement to effect latching engagement with the space vehicle and docking of the docking module in the payload bay of the vehicle. It may also be controlled to adjust the attitude orientation of the space vehicle relative to the space station after docking which allows the station to fly in its desired attitude. Hatch means provided on the docking module are adapted for interconnection with the crew cabin of the space vehicle. In the preferred embodiment of the invention, a flexible tubular member, connected at its ends to the space station and the docking module, lines the interior of the series-connected frame sections to provide a tunnel connection between the space vehicle and space station which is suitable for the passage of personnel and cargo. The docking system can be used in the reverse manner to separate said vehicles.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view showing the docking mechanism of the invention attached to a space station being approached by a space shuttle orbiter in preparation for docking;

FIG. 2 is a view similar to FIG. 1 but showing the end module of a flexible tunnel structure of the invention in docked position within the payload bay of the space shuttle orbiter;

FIG. 3 is a view similar to FIG. 2 but showing the space shuttle orbiter in a pitched orientation relative to the space station;

FIG. 4 is a view similar to FIG. 3 which shows the space shuttle orbiter retracted by the mechanism of the invention in a compact rigidized connection therewith;
4,860,975

FIG. 5 is a fragmentary view, partly in section, showing details of the tunnel structure of the embodiment of the invention shown in FIG. 3 as it appears when the end module of the tunnel structure is berthed in the payload bay of the space shuttle orbiter;

FIG. 6 is an enlarged view of a section of the tunnel structure of the invention wherein the flexible outer wall of the tunnel structure is removed to show structural details;

FIG. 7 is a schematic flow chart illustrating the logic control system for controlling the movement of the tunnel sections of the invention; and

FIG. 8 is a perspective view of a modified form of the invention showing a space shuttle orbiter coupled thereby to a space station without the use of a flexible tunnel.

Referring more particularly to the drawings, there is shown in FIG. 1 a space shuttle orbiter 11 in the process of making a docking approach to a space station 12. A docking mechanism 14, representing a preferred embodiment of the invention is shown mounted on the space station 12. The space shuttle orbiter 11, only a portion of which is shown, has opened its payload bay doors 13 for receiving the end module 15 of the docking mechanism 14 and allows its connection with a plurality of latching devices 17 mounted on the walls and keel 19 of the payload bay.

The docking mechanism 14 is comprised of a plurality of tunnel frame sections 21, see FIG. 2, connected in series with the end module 15 to form an accordion-like flexible frame structure which may be elongated or shortened and controlled in six degrees of freedom for purposes to be hereinafter explained. As best shown in FIG. 6, each of the sections 21 is comprised of a pair of rings 31a, 31b of a diameter sufficient to accommodate the passage therethrough of personnel and cargo. The rings 31a, 31b are connected in a normally coaxial relation and spaced apart by a plurality of attenuator-actuator devices 33, which are at least six in number. For purposes of redundancy additional attenuator-actuator devices 33 may be provided in pairs. Each attenuator-actuator device 33 is connected by a pivot or swivel connection 35 at its ends to the rings 31a, 31b and the attachment points for the six attenuator-actuator devices 33 are arranged in three pairs, the attachment points in each pair being closely adjacent and the pairs being equianullaneously spaced about the ring 31a. The attachment points to the ring 31b are similarly arranged but at locations which are intermediate to the attachment locations on the ring 31a with respect to their angular relation to the central axes of the rings.

The attenuator-actuator devices 33 are each comprised of telescoping members 33a, 33b and are preferably of the conventional ball screw type which includes an actuating drive motor adapted to respond to electrical command signals for effecting a relative telescopic movement of the members 33a, 33b in a linear expansion or contraction thereof. Since each of the attenuator-actuators 33 is individually controllable, it is therefore possible to move the ring 31b with respect to the ring 31a in a direction towards or away from another, tilted or rotated with respect to one another, thereby impart a six degrees of freedom of motion capability to a ring 31b.

In the embodiment of the invention described herein as shown in FIG. 1, one of the tunnel frame sections 21 is connected in sealing engagement about a hatch open-
latching devices
capture latch sensors (not shown) are provided for indicating the capture and latch of each trunnion by the proximity switches or limit switches which may be mounted on each of the trunnions 41, 42 or on the end module structure adjacent the trunnions.

The electrical signals, from the plurality of sensors noted above, are delivered to computer control logic circuitry 61 in the computer aboard the space station for generating command signals to each of the actuator-attenuation devices 33 and the on-board flight control system of the space station. The logic circuitry first checks to determine if there is a load sensor signal indicating contact between the space vehicle and the space station in which there is no contact, range and attitude information are used by a logic unit 74 for generating command signals to the on-board flight control system in order to correctly position and align the space station docking hardware, represented by the berthing module 25, 41, 42, with respect to the docking hardware on the space vehicle, as represented by the trunnion latches 17 and the keel socket receptacle for the trunnion 42.

If there has been contact indicated by the load sensors, the computer logic circuitry next checks for capture latch signals indicating if the trunnions are latched in place and a capture has been effected. If no capture is indicated, a path for movement of the tunnel structure is calculated by a logic unit 75 in order to effect a capture latch position and command signals generated thereby are delivered to the on-board flight control system of the space station and the actuator-attenuators 33. However, if the capture latch sensors indicate there has been a capture, a path for movement of the tunnel frame structure by individual control of the actuator-attenuators 33 is calculated by logic unit 76 which will lessen the relative velocity of the space vehicle and space station and move the spacecraft into a preselected final position.

It is to be understood that the tunnel structure may be rigidized by computer control in any selected position, and in any degree of extension or compaction. A modified form of the tunnel structure is shown in FIG. 8 wherein another fabric liner has eliminated. In lieu thereof, however, a rigid cylindrical stub tunnel 81 is fixed to the lower end of the egress module 12a of the space station and the frame sections 21 as shown in FIG. 6 are sleeved thereabout. Once a capture of the space shuttle orbiter is effected with the docking module 35 docking in the payload bay of the space shuttle orbiter, the space station and space shuttle orbiter must be retracted towards one another to where the end of the stub tunnel 81 contacts the docking module 15 and is sealedly engaged therewith about the opening to the docking module, which is of a panel construction. A complete fluid-tight tunnel connection is therefore established.

It should therefore be appreciated that a unique spacecraft docking mechanism is disclosed herein which makes possible the attenuation of docking impact of relatively large and massive spacecraft without the requirement for relatively heavy and massive support mechanisms. While it would be possible to mount the tunnel structure on the space shuttle orbiter, it is preferred that this structure be mounted as a permanent fixture on the space station so that little cargo space is therefore taken up by the cooperative coupling mechanisms in the form of trunnion latches which are provided on the space shuttle orbiter.

It is also to be understood that the foregoing description of a preferred embodiment of the invention has been presented for purposes of illustration and explanation and is not intended to limit the invention to the precise form disclosed. For example, the number of tunnel frame sections 21 may be increased to expand the range of movement and flexibility of the tunnel structure. In cross section, the tunnel structure and docking rings may be other than circular and the shape of the docking module of the tunnel may be adjusted to accommodate connection with different space vehicles. While the actuator-attenuator devices 33 have been described as ball-screw actuators, it is also feasible to use hydraulic actuators which can be controlled by electrical command signs from the automatic control system. It is to be appreciated therefore, that various material and structural changes, many of which are suggested herein, may be made by those skilled in the art without departing from the spirit of the invention.

We claim:
1. A docking mechanism for the docking and undocking of a space vehicle with a space station or another space vehicle, said docking mechanism comprising:
   a deployable extensible tunnel structure mounted on said space station, said tunnel structure comprising a plurality of interconnected serially arranged frame sections with an end frame section of said series of frame sections being an egress hatch of the space station, each said frame section including a pair of docking ring members interconnected in a normally coaxial spaced apart relation defining an unobstructed central opening through said frame section;
   actuator control means connected to said docking ring members for imparting a relative motion between said docking ring members of each said frame section in six degrees of freedom of movement;
   a docking module attached to the other end section of said series of connected frame sections and provided with an opening communicating with the central opening of the adjacent frame section to which it is attached;
   a plurality of latch mechanisms mounted on the space vehicle;
   a plurality of trunnion members affixed to said docking module and adapted for interconnection with said latch mechanisms whereby said trunnion members are latchable thereto for coupling the space vehicle to the space station;
   a pressurizable tubular member disposed to extend through the central openings defined by said series of interconnected frame sections and of a cross section diameter suitable for the passage of personnel and cargo therethrough, said tubular member being attached at one end about said egress hatch in sealing relationship with the space station; a hatch means provided on said docking module adapted for interconnection in sealing relationship with the space vehicle for establishing communication.
wherein said actuator means comprises: tral openings defined by said series of intercon-

2. A docking mechanism as set forth in claim 1 wherein said pressurizable tubular member is a flexible fluid-impervious fabric connected at its ends in sealing relationship with the space station and the docking module, respectively.

3. A docking mechanism as set forth in claim 1 wherein said actuator means is automatically responsive to the latched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

4. A docking mechanism as set forth in claim 1 wherein said actuator means comprises:

5. A docking mechanism as set forth in claim 1 wherein said docking module trunnions are latched to said space vehicle; and means interconnecting said tubular member with said docking module in sealing relationship therewith about said opening of the docking module when the docking module trunnions are latched to the space vehicle, said tunnel structure being controlla-

6. A docking mechanism for the coupling and dock-

7. A deployable extensible tunnel structure mounted on said space station, said tunnel structure comprising a plurality of interconnected serially arranged frame sections with an end frame section of said series of frame sections being connected about an egress hatch of the space station, each said frame section including a pair of docking ring members interconnected in a normally coaxial spaced apart relationship defining an unobstructed central opening through said frame section of a size sufficient to accommodate the passage of personnel and cargo therethrough;

8. A plurality of latch mechanisms mounted on the space vehicle;

9. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms, and the range and attitude orientation of the space vehicle, respectively.

10. A plurality of linearly adjustable telescopic members and pivotally connected at its ends to the respective ring members of a frame section;

11. A plurality of sensor means for sensing and signalling the relative movement of one ring member to the other.

12. A plurality of sensor means for sensing and signalling the range and attitude orientation of the space vehicle, respectively.

13. A plurality of sensor means for sensing and signalling the relative movement of one ring member to the other.

14. A plurality of sensor means for sensing and signalling the range and attitude orientation of the space vehicle, respectively.

15. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

16. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

17. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

18. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

19. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

20. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

21. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

22. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

23. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

24. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

25. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

26. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

27. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

28. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

29. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

30. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

31. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

32. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

33. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

34. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

35. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

36. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

37. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

38. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

39. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

40. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

41. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

42. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

43. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

44. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

45. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

46. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

47. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

48. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

49. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

50. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

51. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

52. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

53. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

54. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

55. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

56. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

57. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

58. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

59. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

60. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

61. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

62. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

63. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

64. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-

65. A plurality of sensor means for sensing and signalling the latched or unlatched condition of said latching mechanisms and the loads imposed on said tunnel structure on dock-