## Chapter 6

# Escape and Rescue Vehicles

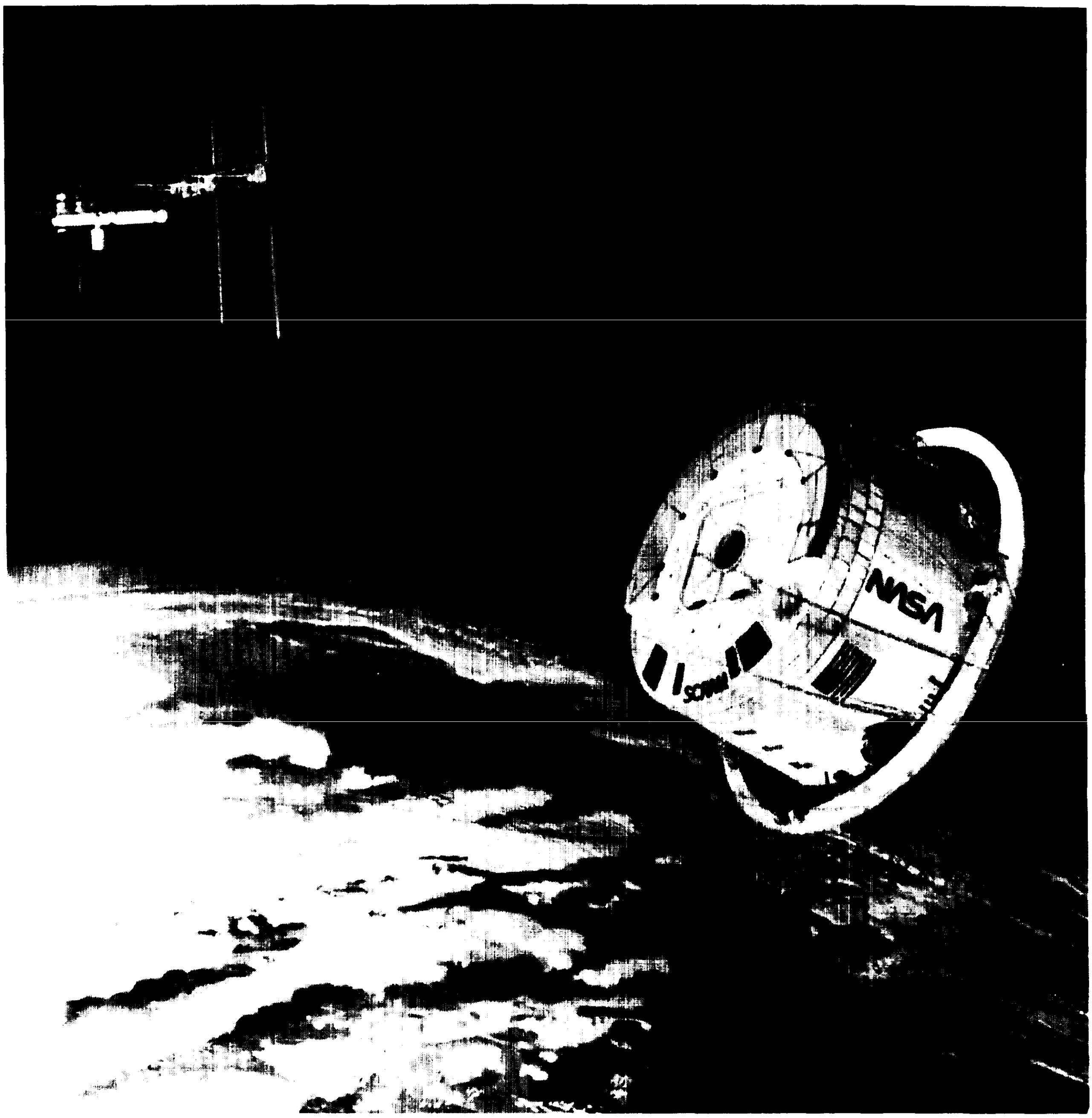


Photo credit National Aeronautics and Space Administration

Artist's conception of a capsule-type escape vehicle after it has just left the international Space Station.

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# Escape and Rescue Vehicles

## INTRODUCTION

Several contingencies could arise that would require the emergency escape or rescue of personnel in space. These include medical emergencies of Space Station crewmembers, major equipment failures, or damage from orbital debris. Rescue might also be necessary if the Shuttle failed to meet its scheduled launch date by so long that the Station was in danger of running out of critical supplies.

The U.S. space community is investigating the need for a means of crew rescue or escape[1] from the Space Station, independent of the Space Shuttle. **As noted in chapter 3, the existing Space Shuttle system is neither robust enough nor reliable enough to support continuously, at low risk, the needs of Space Station crew during deployment and operations. The** Space Station may need a ''lifeboat,' a capsule kept at the Space Station for emergency escape to Earth, or a rescue vehicle kept ready on a launch pad on Earth.

## SPACE STATION CREW SAFETY

The National Aeronautics and Space Administration (NASA) has studied several Space Station safety and emergency management options, including building ''safe havens," with limited on-board medical support, and resupply/rescue by the Shuttle (see figure 6-l). Because a rescue by the Shuttle could take several weeks, NASA has also investigated options for an assured crew return capability (ACRC).[2]

The Space Station itself will be designed to provide Station crew with safe havens during emergencies. Methods for assuring maximum possible safety include: providing the means to seal off modules or systems experiencing failures, frees, or breaches; providing all modules with at least two exits; and placing emergency supplies in each section to sustain any trapped or isolated crew. The safe haven approach could also be extended to include an ability to leave a crippled Space Station and seek temporary refuge in an independent orbiting facility until rescue could be initiated from Earth.

NASA is assessing two categories of ACRC options: 1) escape vehicles based at the Space Station that could respond within hours, and 2) ground-based rescue vehicles that would be independent of the Shuttle and potentially more responsive than the Shuttle to an emergency. These ACRC options include:

- anew ground- or space-based emergency return vehicle;
- aground-based Shuttle ready to be launched on demand;
- an orbiter, modified as necessary, for extended on-orbit stay time to be docked at the Space Station;
- unpiloted Shuttle launch with automated or remote control capability for rendezvous operations;
- ELVs to resupply Station crew for an indefinite period, possibly in conjunction with an orbital manuevering vehicle (OMV);
- modifications to the Station safe havens, which may enhance the other five options.

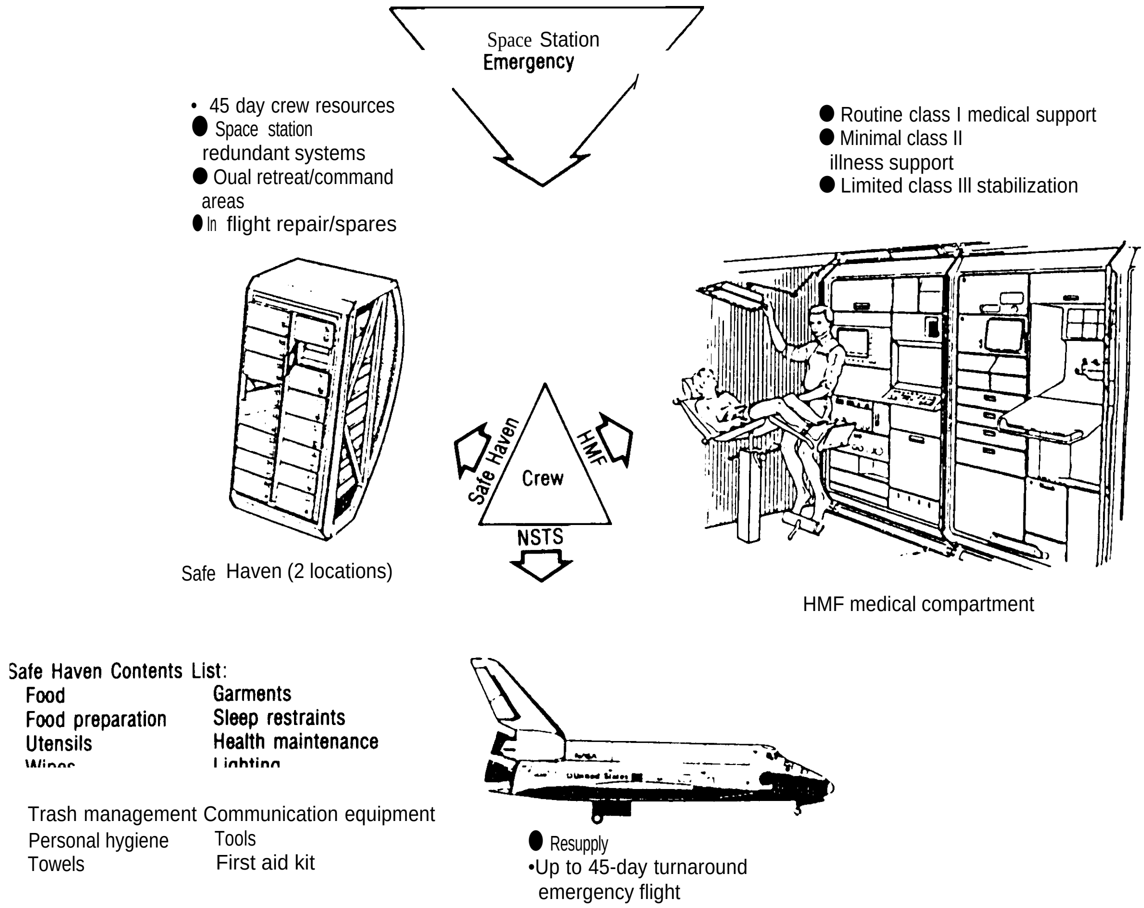
NASA has characterized the need for an escape or rescue capability by defining three possible scenarios (''design reference missions' that would require some or all Station crew to return to Earth before a Shuttle could be dispatched to rescue them.[3] NASA has estimated some of the probabilities that these or other emergencies might occur. However, it has not characterized the probabilities of other scenarios in which a rescue capability would **not** help-for example, loss of an orbiter carrying crewmembers for the Station during ascent on a

[1] AS used in this report, crew escape implies return from the Space Station in a capsule or vehicle docked at the Station, while rescue implies sending up an Earth-based vehicle (piloted or unpiloted) to retrieve crew members.

[2] Also known as &w Emergency Rescue Vehicle (CERV) options. NASA completed Phase A work on the CERV concept in December, 1988. NASA expected to issue an RFP in April 1989 for further studies of CERV for the Space Station, which would focus on more specific concepts. After this study, a follow-on contract was supposed to be awarded for Phase B work. These plans have been placed on hold, however, until after the NASA FY90 budget request is acted upon,

[3] See ''ACRC-CERV Phase A Report, ' NASA Johnson Space Center, JSC-23321, Dec. 23, 1988, sec. 1.4.1, Space Station Crew Safety Alternatives Study, p. 4-7.

**Figure 6-l-Space Station Emergency Management**




KEY: HMF = health maintenance facility; NSTS = national space transportation system.
SOURCE: National Aeronautics and Space Administration, Johnson Space Center.

crew-rotation mission and its affect on total mission risk.[4]

It may be, for example, that the risks Station crewmembers face are dominated by the risk of ascent on the Shuttle, in which case investment in an alternate crew return capability would reduce the risks of reaching and living on the Space Station only marginally. To decide whether a risk-reducing effort is worth the substantial investment required, Congress must be advised on how much the invest-

[4]NASA does not routinely carry out probabilistic risk analysis of its space systems. Trudy E. Bell and Karl Esch, "The Space Shuttle: A Case of Subjective Engineering," *IEEE Spectrum*, June 1989, pp. 42-46.

ment would reduce the risk.[5] Even if an alternate crew return capability were provided and worked as planned, it would not eliminate all risks to station crewmembers. In deciding whether or not to fund development of a crew escape vehicle, Congress may wish to ask NASA to conduct an analysis comparing the risks faced by crews living on the Space Station to those of reaching the Space Station and returning to Earth.

## CREW EMERGENCY RETURN

If, in the judgment of NASA officials and Congress, a risk assessment demonstrates the need for emergency crew escape, two basic options present themselves:

1. Simple *capsule designs* with an ablative heat shield reminiscent of the "Viking" and "Discoverer" reentry capsules from the early days of spaceflight. Also included in the capsule category, although it has a more extended ''loiter time''[6] than those described above, is an Apollo derivative capsule that would also include an ablative heat shield (figure 6-2). Advantages of capsules include simplicity, relatively low cost, and proven technology. Capsule designs also need little or no piloting, which would be a major advantage. Requiring that a pilot be available at all times on the Space Station would be expensive and a questionable use of resources. In addition, pilots might become too weak to function as pilots after a stay in space of 20 or more days, making capsule designs desirable.
2. Small, aerodynamically stable *gliders* (medium lift/drag lifting bodies)[7] that can land by parachute or at low speed on a runway. A Crew Emergency Rescue Vehicle (CERV) configured for water recovery (figure *6-3)* would provide a wider range of landing sites and greater time margins for reentry and recovery and a softer ride than capsules (important if an injured *crew* member is returning).[8] However, a glider would cost at least 20 to 30 percent more than the simplest chute version of a capsule.[9]

NASA has also considered a Space Taxi and Return (STAR) vehicle, which could serve several missions:

- crew emergency rescue or escape;
- assured crew access (an ''up-CERV,' which could complement the Shuttle);
- small logistics transport; and
- use as an on-orbit maneuver vehicle as shown in figure 6-4.

CERV or STAR spacecraft could be launched by Titan III or Titan IV launchers, an Advanced Launch System, or a booster based on a Shuttle liquid rocket booster. A Shuttle could put two crew rescue vehicles up at one time for docking at the Space Station. Which alternative is chosen depends on which options NASA chooses for the Personnel Launch System.

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[5] What is "acceptable" crew risk is, of course, an emotional issue. Those doing hazardous work on Earth, such as construction and mining, acknowledge risk and expect a certain number of fatalities on a project such as abridge, skyscraper, or tunnel. Some feel that a hard look must be given at spending a few billion dollars to rescue (assuming it is even a survivable emergency) a few people at the Space Station. Any appropriations would have to compete with efforts that maybe seen as saving more lives, such as research on cancer and infant mortality. (Tom Rogers, quoted in "Fleeing [Space Station] Freedom,' by Richard DeMeis, *Aerospace America,* May 1989, pp. 38-41.)

Others believe that no matter what the cost-benefit analyses say, that a rescue craft is a necessity -

> The prospect of all the world seeing the ordeal of a stranded crew or a dying crew member nightly on television is chilling. The national nightmare of a crew in trouble with no timely way home, no matter what the chances of occurrence, is reason enough for many both within and outside of NASA to push for a rescue vehicle as a political necessity.

(Richard DeMeis, Ibid.)

[6] Loiter gives an indication of how rapidly a vehicle plummets towards Earth. Extended loiter allows more flexibility for landing during certain advantageous "windows" and greater crossrange, allowing for landings at more desirable locations.

[7] Some experts distinguish between gliders, which have true wings and provide a relatively high lift-to-drag ratio, and lifting bodies, which have no wings, and a lower lift-to-drag ratio.

[8] A glider would experience one to two g's while capsules would experience almost four g's for the Discoverer or Apollo shape, or seven g's for the Viking shape.

[9] Engineers at NASA Langley believe the differential t. be 20 to 30 percent. However, other engineers that OTA consulted believe the differential could be even greater, perhaps 50 percent.

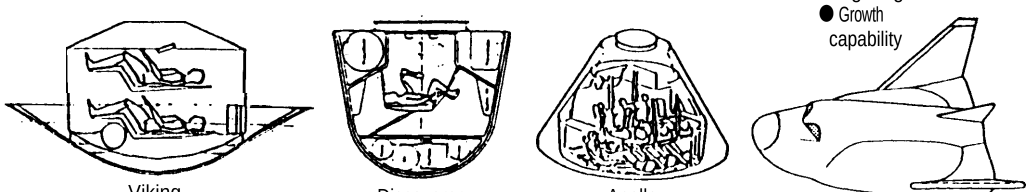
**Figure 6-2--Design Reference Missions (DRMs)**

Viking shape
- •ORM: 1, 2 only
- 'Space ejection seat'
- Minimal loiter
- implest subsystems
- Water landing good boat

Discoverer shape
- IlRM: 1, 2, 3
- Capable space vehicle with limited loiter
- Simpie subsystems
- Water landing good targeting

Apollo shape
- ŽDRM : 1, 2, 3
- Capable space vehicle with extended loiter
- Apollo-based subsystems
- Water landing good targeting

Proven shape
- DRM: 1, 2, 3
- Capable space vehicle with limited loiter
- Simpie subsystems
- Water/land landing good targeting
- Growth capability

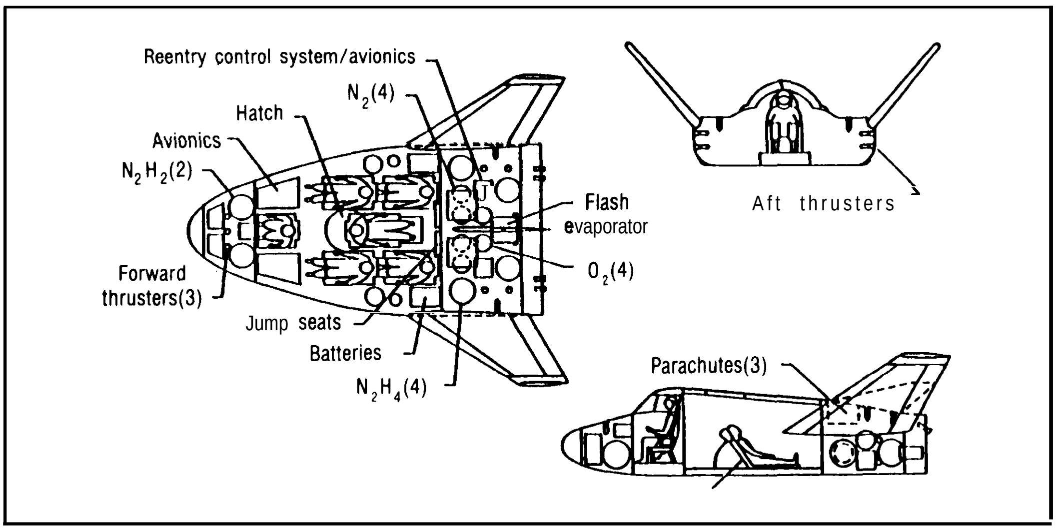



Design Reference Missions(DRMs)

- DRM1 —Some problem makes shuttle not available in timeframe needed. Crew leaves when convenient.
- DRM2—Propagation of failure exceeds safe haven capability. Shuttle turnaround time exceeds need. Crew leaves immediate.
- DRM3—Medical emergency exceeds health maintenance facility capability. Shuttle turnaround time exceeds need. Crew leaves as soon as possible for desired landing zone.

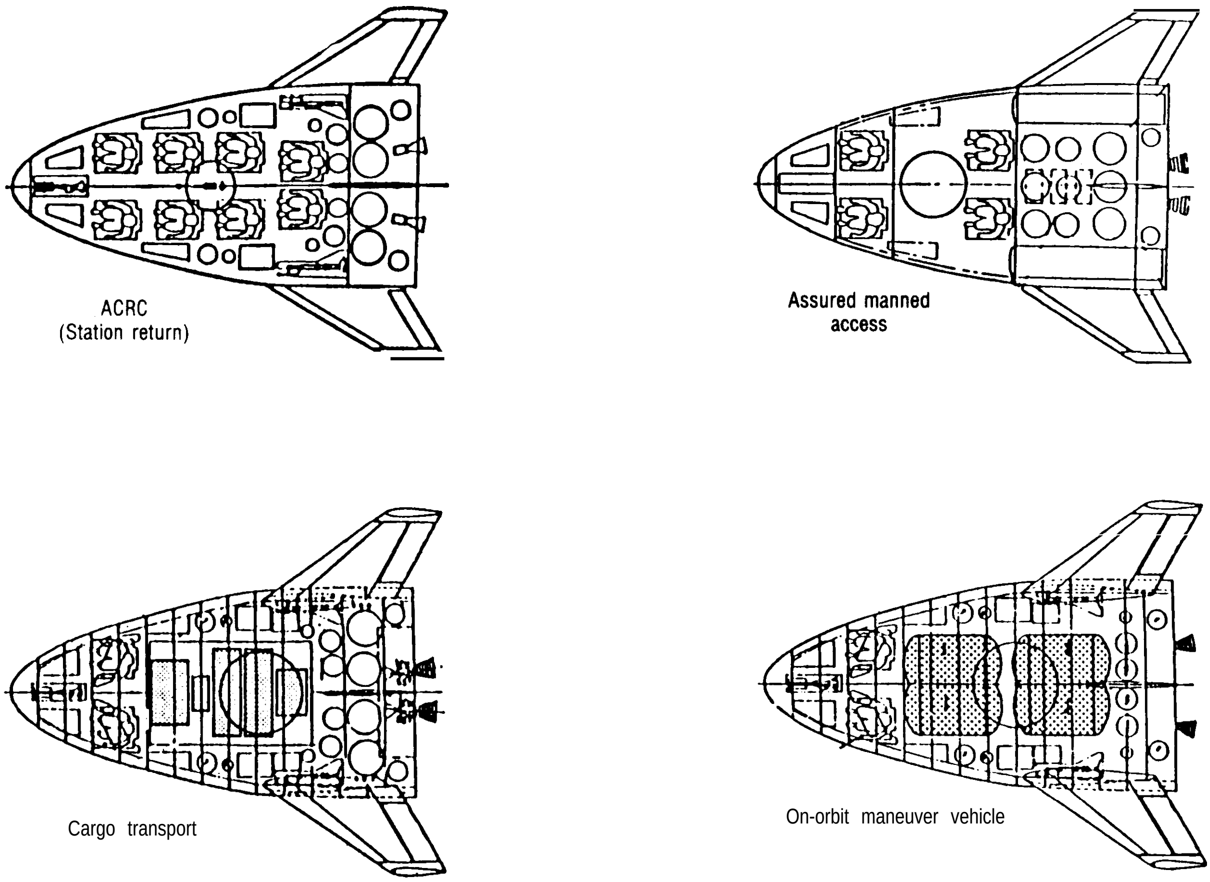
SOURCE: National Aearonautics and Space Administration.

**Figure 6-3--CERV Glider Configured for Water Recovery**




SOURCE: National Aeronautics and Space Administration, Langley Research Center.

**Figure 6-4--Assured** Crew Return Capability (ACRC)/Space Taxi and Return (STAR) Vehicle Options




**SOURCE: National Aeronautics and Space Administration, Langley Research Center.**

If the United States wants to develop an escape or rescue capability independent of the Shuttle, and if Space Station deployment remains on schedule, a decision should be made within the next 2 years concerning whether to pursue capsules or gliders. **The fastest, cheapest way to allow crew escape from the Space Station would be to dock reentry capsules of proven capability--shaped like NASA's Apollo or Viking capsules or the Department of Defense's Discoverer capsules-to the Space Station for emergency use.** Development costs could run between $300 million and $500 million. NASA estimates that development and testing of a capsule would take about 5 years. However, capsules have less development potential than gliders since gliders could be eventually upgraded to perform tasks other than crew escape.

As noted, glider development would cost more and would probably take longer (although it could still be ready in time for Space Station use). At even greater cost, NASA could procure extra Shuttle orbiters and keep one docked to the Space Station.[10] Other options might be available in the next century. For example, NASA could rely on "NASP-derived" spaceplanes[11] for crew rescue.

[10] However, leaving the Shuttle at the Space Station would be expensive and have a major impact on the Station's operations and logistics. For example, there would be increased station drag and inertia changes that would require use of more attitude control fuel. The Shuttle itself would probably require major modifications to achieve long stays in orbit.

[11] These would probably not be available until 2010. See ch. 5.

Photo credit: National Aeronautics and Administration

Artist's conception of a glider-type escape vehicle about to touch down at sea after reentry.

## DOCKING ISSUES

As noted above, one or two escape vehicles could be docked at the Space Station or a rescue vehicle could wait on a launch pad[12] on Earth. Both basing modes have their proponents. An escape vehicle docked at the Station could be used rapidly. NASA estimates that emergency response times would range from 17 minutes in the best case to 48 minutes if an accident occurred while crew was involved in extra vehicular activity. *[3] Once the escape vehicle is freed, it could be launched towards Earth as soon as a landing window is available. However, an escape vehicle might be sitting idle in the space environment for long periods of time-up to 2 to 4 years-which could adversely affect its reliability.[15]

Basing a rescue vehicle on a launch pad could provide added flexibility for rescue, for example, to send personnel or supplies to the Space Station, to provide medical assistance, maintenance, or to dispatch a replacement crew. Maintenance and replacement of critical systems is also easier when a rescue vehicle is based on Earth, but it could not be used for emergencies requiring quick response. The rescue spacecraft and its launcher would need a dedicated launch pad and would take a relatively long time to reach the Station and return. Under existing launch operations conditions, a launch vehicle would also take weeks to prepare, even if it were ready and able to use a dedicated launch pad. NASA has not estimated comparative costs or safety benefits for all of these options. However, pad basing does not meet NASA's medical requirement of returning a sick or injured crew member to Earth-bound medical care within 24 hours. Thus, NASA has decided not to pursue pad-basing concepts, although others believe that this option should remain open for further study.

## OPERATIONS SUPPORT

Before committing to a rescue strategy, system designers will have to address the costs of developing the necessary support infrastructure and operating the chosen system. Because a rescue system, if built, would be needed for the life of the Space Station, its total recurring costs could easily exceed its development costs. Support infrastructure might include ground operations hardware and personnel at the mission control site, landing site crews located around the world, and the necessary subsystems and logistics support to resupply, replenish, and possibly repair a CERV on orbit. Depending on the detailed design of the CERV, each of these factors can seriously influence the operational characteristics and costs of the system.

As illustrated by the Space Shuttle, operating costs can constitute a major component of the life-cycle costs of a system.[16] Decisions made early

12' 'Pad basing'' as used here means having a launch vehicle stored on-site with a launch pad suitable for it available on demand. In practice, a vehicle would not be routinely sitting on a launch pad for long periods because the environment at existing launch sites is corrosive.

13' 'ACRC—CERV Phase A Studies, Book 1,'' NASA Johnson Space Center, JSC- 23265, Nov. 15, 1988, p. 4.18. See sec. 4.0 Reference Conjuration Operations Studies/ 4.1 Emergency Timelines for Use of CERV.

14Ibid. sec. 5, General (operational Studies/ 5,3 CERV Daylight baling Study.

15For initial work on this see, ibid, sec. 2.8, CERV Maintenance.

16Life-cycle costs include both the nonrecurring costs of development and procurement and the recurring costs of maintenance and operations.

in the development of the Shuttle to minimize "up-front" costs led to greatly increased operating costs.[17] In order to avoid mortgaging future generations, any rescue system should be designed from the outset to minimize operational costs.

## OTHER RESCUE EXAMPLES

The need to provide means for rescuing crews working in isolated, hostile environments is not new. Other experiences with designing and using rescue capability might provide useful data for examining the risks and benefits of providing alternative crew rescue vehicles for the international Space Station.

- *U.S. Skylab:* During the Skylab space station missions, the United States maintained the ability to launch a rescue Apollo craft and outfitted it with a prepared "kit' kept in readiness at Kennedy Space Center. However, this rescue mission probably could not have been launched in less than 2 weeks under the best of circumstances. Also the Apollo vehicle that transported the crew to Skylab was kept attached to the space station during each mission, providing the crew with the means to reach Earth independent of ground launched systems.
- *U.S.S.R.* Soyuz: The Soviet Union keeps a Soyuz capsule attached to its space station *Mir* at all times when there is a crew on board. When a visiting crew reaches *Mir, the* older Soyuz, already at the space station, is used to return crew members to Earth. The Soviets have used their emergency return capability several times to return ailing crew.
- *Antarctic Research Stations.* Antarctic stations provide interesting analogues of the Space Station. Each research station typically maintains a backup station, kept physically separate from the main station. Usually, an old research building (some dating from the early 1950s) is kept supplied and operational in case of fire or other disaster that would cause the research crew to abandon the operational station. These older stations are physically separated to avoid the spread of fire and only maintained well enough to provide a backup capability. During the winter months, the stations are very isolated, but a few emergency rescue missions have been performed and supply drops are possible.[18] The various countries that maintain Antarctic research stations have also cooperated to rescue research parties in emergencies.

## COOPERATION ISSUES RELATED TO STATION SUPPLY OR RESCUE

The United States has always maintained a vigorous program of international cooperation in space. As noted in an earlier OTA report:

> "U.S. cooperative space projects continue to serve important political goals of supporting global economic growth and open access to information, and increasing U.S. prestige by expanding the visibility of U.S. technological accomplishments. '

The Space Station is a major cooperative program in which the United States will provide the basic 'core station, ' and Canada, ESA, and Japan will contribute sizable subsystems.[20]

Today, because other countries have developed their own indigenous launch capability, and because progress in space will continue to be expensive, cooperating on space transportation could be highly beneficial to the United States. For example, the United States could share responsibility for resupply of the international Space Station with its Space Station partners, and it could begin to share launch technology in a variety of areas where such sharing could be mutually beneficial.

ESA has proposed using the Ariane 4 and 5 launchers as alternative means for carrying cargo to the Space Station. The United States would gain additional assurance that critical cargo could reach the Space Station in the event the Shuttle or U.S. expendable launchers are for any reason unable to do

17 U.S. Congress, Office of Technology Assessment, Reducing *Launch Operations Costs: New Technologies and Practices,* OTA-TM-ISC-28 (Washington, DC: U.S. Government Printing Office, September 1988).

18 Delays of up to 2 weeks are not uncommon as a result of weather and equipment problems.

19 U.S. Congress, office of Technology Assessment, *International* Cooperation *and Competition* in *Civilian Space Activities,* OTA-ISC-239 (Washington, DC: July 1985).

20 Canada will contribute a servicing module and ESA and Japan will contribute pressurized laboratory modules.

so, which could save money and make the Space Station more effective. Europe would gain experience in automated docking systems and be able to use Ariane to make inkind contributions for Space Station operations, a much more attractive arrangement for European governments than one in which they contribute funding alone.

In order for other countries to use their launch systems to supply the Space Station, or to dock with it, these countries will have to reach agreement with the United States on appropriate standards for packaging, docking, and safety. ESA and NASA have established a working committee to discuss these matters. If discussions prove successful, the experience of the committee could eventually be used as a basis for extending cooperative agreements to include cooperation on more sensitive aspects of space transportation.

In addition, Europe has proposed using the Hermes to carry crews to the Space Station and to service its Columbus module. Japan is also interested in using its H-II launcher for supplying the Space Station, and would eventually wish to employ its proposed spaceplane, HOPE, for the same purpose.

Cooperation could assist U.S. efforts in other ways. NASA estimates that developing a crew emergency return capability would cost between $1 billion and $2 billion, depending on its level of sophistication. NASA could potentially rely on space vehicles being developed by foreign partners for crew rescue. These include Hermes, HOPE, Saenger, or possibly Hotol (ch. 4). Several factors must be remembered, however. The Hermes crew would nominally be only three or four people, limiting its CERV capabilities in case the full Space Station contingent (8 crew) had to return.[21] Also, the scheduled date for permanently manning the Space Station is 1996 (although this date could slip). Hermes operational flights would start in 1999 or 2000 and its nominal orbit would be at 2 degrees inclination, far from the 28.5 degree Space Station orbit-making rescue more difficult and time consuming. The initial Japanese HOPE vehicle will not carry crew; a crew-carrying version may be developed early in the 21st century. A prototype Saenger could be finished by 2000 with an operational vehicle coming several years later. Hotol for most missions would be launched in an automated configuration and would not be ready until at least 2000. Use of an off-the-shelf Soviet spacecraft for rescue has been suggested as another international approach, although NASA has no plans to pursue this option.

21 Some have suggested that the United States could fund part of the European Heroes in order to speed up its development and to incorporate station rescue provisions in the design. This could cost the United States less than developing its own rescue vehicle.