AIAA Conference Abstract
Manned Spacecraft Landing and Recovery
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As recent history has tragically demonstrated, a successful space mission is not complete until the crew has safely returned to earth and has been successfully recovered. It is noted that a safe return to earth does not guarantee a successful recovery. The focus of this presentation will be a discussion of the ground operation assets involved in a successful recovery.

The author's experience in land and water-based recovery of crewed vehicles and flight hardware at Kennedy Space Center (KSC), Edwards Air Force Base, international landing sites, and the Atlantic Ocean provides for some unique insight into this topic. He has participated in many aspects of Space Shuttle landing and recovery operations including activation of Transatlantic Abort Landing (TAL) sites and Emergency Landing Sites (ELS) as an Operations Test Director, execution of post landing convoy operations as an Orbiter Move Director, Operations Test Director, and Landing and Recovery Director, and recovery of solid rocket boosters, frustum and their parachutes 140 miles offshore in a wide range of sea states as a Retrieval Diver/Engineer.

The recovery operations for the Mercury, Gemini, and Apollo were similar from a landing and recovery perspective in that they all were capsules with limited "flying" capability and had a planned End of Mission (EOM) in an ocean with a descent slowed by parachutes. The general process was to deploy swim teams via helicopters to prepare the capsule for recovery and assist with crew extraction when required. The capsule was then hoisted onto the deck of a naval vessel. This approach required the extensive use and deployment of military assets to support the primary landing zone as well as alternate and contingency locations.

The Russian Soyuz capsule also has limited "flying" capability; however, the planned EOM is terrestrial. In addition to use of parachutes to slow the reentry descent, soft-landing rockets on the bottom of the vehicle are employed to cushion the landing. The recovery forces are deployed via helicopters and the capsule is transported by a specialized all-terrain vehicle.

The Space Shuttle Orbiter landing and recovery process is considerably different. The added lift capability and maneuverability allow the Orbiter to land at an exact location/runway for a nominal EOM. This allows for a timely response of recovery/contingency rescue forces, centralized staging of personnel and equipment, and assured access by ground vehicles. The well defined landing zone also provides for far more options when selecting landing sites for EOM and emergency returns and the relatively large cross-range capability increases the number of landing opportunities at the preferred sites.

However, the vehicle complexity, hazardous commodities, and reusable function of the Orbiter generate its own challenges to the recovery operation. Maintaining vehicle power is highly desirable to provide system visibility and better prepare it for turnaround for the next flight. The result is a "live", potentially hazardous vehicle that has just returned from space and requires trained personnel and specially designed equipment to affect the recovery. In the case of a landing at the alternate site, Edwards Air Force

Base, a week of safing/preparation is required before the Orbiter begins its trip back to KSC on the Shuttle Carrier Aircraft. For a TAL or ELS landing, the level of effort and timelines would be considerably greater.

Based on knowledge gained from our experiences to date, a list of general, desirable landing and recovery design considerations for future manned vehicles can be developed. Such topics would include:

- Safely return the crew
- Minimize hazards to the crew and ground personnel
- Minimize civilian exposure to debris/jettisoned components
- Ease of crew extraction for Fire Rescue and Emergency Medical Services
- Provide fast, simple and safe abort recovery procedures
- Simplify post-landing safing
- Minimize landing constraints (weather and ground based assets)
- Minimize landing sites
    - End of Mission
    - Medical Emergency
    - Contingency
- Provide well defined landing zones (small diameter for timely response and centralized location for equipment)
- Simplify recovery process by minimizing:
    - Equipment
    - Personnel
    - Activities
- Expedited return of vehicle to launch site

In support of the new National NASA Vision, the intent is to utilize a spiral design development process and address such issues early in the process. Discussions such as this will contribute to the success.