Apollo Recovery Operations
Objectives

Describe the organization of recovery force command and control and landing areas.

Describe the function and timeline use of the Earth Landing System (ELS).

Describe Stable 1 vs Stable 2 landing configurations and the function of the Command Module Uprighting System.

Explain the activities of the helicopter and swimmer teams in egress and recovery of the crew.

Explain the activities of the swimmer teams and primary recovery ship in recovery of the Command Module.

Describe several landing incidents that occurred during Apollo.
Recovery Operations Overview

Recovery Force Organization
Location of Operations/Landing Areas
Walkthrough of Recovery Activities
ELS/Parachute Timeline
Stable 1 or 2 Attitude
  Recovery into Stable 1 Attitude
Finding the Command Module
Helicopter Operations
Swimmer Operations
  Flotation Collar
  Recovery Raft
  Crew Egress and Air Lift
CM Recovery Operations

Apollo 16 Recovery Timeline
Apollo Landing Incidents
  Apollo 15 ELS Incident
Earth Landing System (ELS)

Consisted of various parachutes and deployment mechanisms to decelerate the Command Module for a safe landing.

- Forward Heat Shield Separation Parachute (Apex Cover)
- 2 Drogue Parachutes
- 3 Pilot Parachutes
- 3 Main Parachutes

Activation of system through barometric switches and time delays, as well as backup crew switches.

System was designed to safely operate with only two main chutes.
Apex cover jettisoned at 24,000 ft.
2. Drogue parachutes deployed reefed at 24,000 ft +2 sec.
Parachute Timeline

3 Drogue parachute single-stage disreef (10 sec after deployment).
At 10,000 ft. the drogue were released and the main parachutes were deployed reefed via three pilot parachutes.
Main parachute initial inflation.
Main parachute first-stage disreef (6 sec after deployment).
Parachute Timeline

1. VHF recovery antennas deployed
2. Flashing light deployed
3. Main parachute deployment
4. Intermediate parachute deployment
5. Final parachute deployment
6. parachute recovery
7. VHF recovery antennas and flashing light deployed (8 sec after main parachute deployment).
Main parachute second-stage disreef (10 sec after main parachute deployment).
Parachute Timeline

1
2
3
4
5
6
7
8
9

Main parachutes released.
Stable 1 versus Stable 2 Attitude

Stable I (apex up)  Stable II (apex down)
If the system failed to upright the CM, a helicopter could be used to pull the CM upright using a line and the recovery hook which swimmers would attach.
Finding the Command Module

Airborne and Ship RADAR
CM VHF Beacons
Crew VHF Radio Communications
CM Flashing Light
CM Sea Dye Marker
### Finding the Command Module

#### Airborne and Ship RADAR

<table>
<thead>
<tr>
<th>Mission</th>
<th>Distance</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apollo 10</td>
<td>5.4 km</td>
<td>(3.3mi)</td>
</tr>
<tr>
<td>Apollo 11</td>
<td>24 km</td>
<td>(14.9mi)</td>
</tr>
<tr>
<td>Apollo 12</td>
<td>7.2 km</td>
<td>(4.5mi)</td>
</tr>
<tr>
<td>Apollo 13</td>
<td>6.4 km</td>
<td>(4mi)</td>
</tr>
<tr>
<td>Apollo 14</td>
<td>7 km</td>
<td>(4.4mi)</td>
</tr>
<tr>
<td>Apollo 15</td>
<td>10 km</td>
<td>(6.2mi)</td>
</tr>
<tr>
<td>Apollo 16</td>
<td>5 km</td>
<td>(3.1mi)</td>
</tr>
<tr>
<td>Apollo 17</td>
<td>6.4 km</td>
<td>(4mi)</td>
</tr>
</tbody>
</table>

#### CM Flashing Light

- Apollo 10 - 5.4 km (3.3mi)
- Apollo 11 - 24 km (14.9mi)
- Apollo 12 - 7.2 km (4.5mi)
- Apollo 13 - 6.4 km (4mi)
- Apollo 14 - 7 km (4.4mi)
- Apollo 15 - 10 km (6.2mi)
- Apollo 16 - 5 km (3.1mi)
- Apollo 17 - 6.4 km (4mi)

#### CM VHF Beacons

- Apollo 10 - 5.4 km (3.3mi)
- Apollo 11 - 24 km (14.9mi)
- Apollo 12 - 7.2 km (4.5mi)
- Apollo 13 - 6.4 km (4mi)
- Apollo 14 - 7 km (4.4mi)
- Apollo 15 - 10 km (6.2mi)
- Apollo 16 - 5 km (3.1mi)
- Apollo 17 - 6.4 km (4mi)

#### CM Sea Dye Marker

- Apollo 10 - 5.4 km (3.3mi)
- Apollo 11 - 24 km (14.9mi)
- Apollo 12 - 7.2 km (4.5mi)
- Apollo 13 - 6.4 km (4mi)
- Apollo 14 - 7 km (4.4mi)
- Apollo 15 - 10 km (6.2mi)
- Apollo 16 - 5 km (3.1mi)
- Apollo 17 - 6.4 km (4mi)

#### Crew VHF Radio Communications
<table>
<thead>
<tr>
<th><strong>“Recovery”</strong></th>
<th><strong>“Swim”</strong></th>
<th><strong>“ELS”</strong></th>
<th><strong>“Apex”</strong></th>
<th><strong>“Photo”</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary helicopter for crew retrieval</td>
<td>Backup to the prime recovery helicopter</td>
<td>Recover the Main Chutes</td>
<td>Recover drogue chutes and apex cover</td>
<td>Provide photographic support</td>
</tr>
</tbody>
</table>
Swimmer Operations

Sea Anchor attachment
Flotation Collar attachment
Recovery Raft attachment
Assist with Astronaut Egress from CM
Assist with Astronaut Retrieval by Helicopter
Assist with CM Ship Recovery
Recovery Raft

Raft specially designed to attach to the contour of the flotation collar.

Served as a staging area for swimmer operations and astronaut egress and recovery.
After recovery raft was attached to the flotation collar, the crew opened the hatch and received life vests from the swimmer.

Swimmer assisted astronauts into the recovery raft.

Swimmer signaled recovery helicopter to move in and recover the crew.
Crew Egress & Helicopter Pickup

Helicopter hoist operator lowered recovery net to the raft.

Crew were extracted one at a time to the helicopter.
When all were onboard, the helicopter would take them to the primary recovery ship.

Swimmers would then prepare for Command Module recovery operations.
Recovery ship maneuvered to within 100-200 ft of CM.

In-Haul line was shot to swimmers.

Swimmers attached in-haul line and deflated the sea anchor.
Recovery ship crane pulled CM alongside.

Recovery hook line and steady lines lowered to swimmers.

Swimmers connected lines to CM.
CM lifted onto recovery ship.

Flotation collar removed.

The CM was then placed on the Apollo CM Transport Dolly.
### Apollo 16 Recovery Timeline

<table>
<thead>
<tr>
<th>EVENT</th>
<th>Landing Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>RADAR contact by Ticonderoga</td>
<td>-00:11</td>
</tr>
<tr>
<td>Visual Contact</td>
<td>-00:06</td>
</tr>
<tr>
<td>VHF recovery beacon contact by Ticonderoga</td>
<td>-00:05</td>
</tr>
<tr>
<td>Voice contact with Apollo 16 crew via VHF</td>
<td>-00:04</td>
</tr>
<tr>
<td>Command module landing</td>
<td>00:00</td>
</tr>
<tr>
<td>Swimmers deployed to command module</td>
<td>00:05</td>
</tr>
<tr>
<td>Flotation collar installed and inflated</td>
<td>00:15</td>
</tr>
<tr>
<td>Hatch opened for crew egress</td>
<td>00:19</td>
</tr>
<tr>
<td>Flight crew aboard helicopter</td>
<td>00:31</td>
</tr>
<tr>
<td>Flight crew aboard Ticonderoga</td>
<td>00:37</td>
</tr>
<tr>
<td>Command module aboard Ticonderoga</td>
<td>01:39</td>
</tr>
</tbody>
</table>

**Average recovery time was a little over two hours**
Apollo 7, 8 and 11. Went to Stable 2 configuration after landing due to wind filling the main parachutes and pulling the CM over.
Apollo 12. Harder than normal landing due to the angle at which the CM entered the water. High winds and rough seas contributed to this problem. The CM then went to a Stable 2 configuration.
Apollo 15. Loss of a main parachute. (More on this incident in a moment.)
Apollo 16. Went to a stable 2 configuration. Uprighting was initiated, but the crew reported that it seemed to delay in a partially uprighted position for longer than expected.

This was caused by the center uprighting bag only being partially inflated.
All three main parachutes deployed normally.

After Reaction Control System depletion firing one of the chutes was noticed to be streaming at 6000 ft.

CM landed with only two main parachutes.

This resulted in a harder than normal landing and about 32 seconds sooner than expected.

The good news was that the ELS had been designed to work safely with only two main parachutes operational.
The prime suspect was the propellant damage from the RCS depletion firing.
A couple of other possibilities were looked at, tested, and discarded as cause.

RCS testing had shown that cold/raw fuel (monomethyl hydrazine) expulsion through a hot engine would burn.
The failed parachute was positioned above one of the roll engines during the fuel expulsion.

Based on RCS testing they determined that propellant damage from the RCS depletion firing probably caused the failure.
To mitigate this issue:

- Landings could now occur with propellants onboard.
- Biasing the propellant load to provide a slight excess of oxidizer.
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