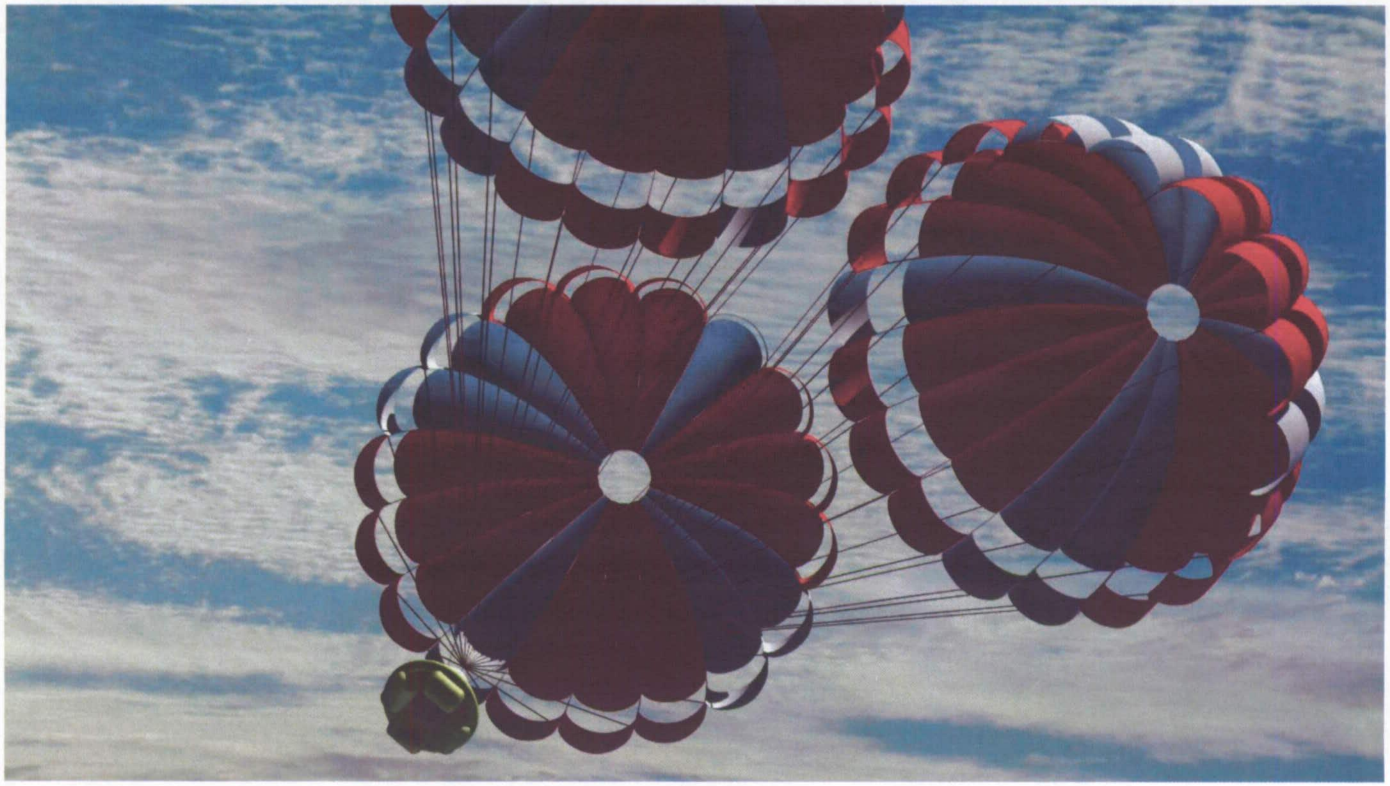
## KSC Constellation Project Office

# Crew Exploration Vehicle Landing and Recovery Scenarios



# Presentation Outline

- **CEV End of Mission Landing and Recovery**
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    - Influential Factors
    - Ground Rules and Assumptions
  - CEV Generic Nominal EOM Recovery Process
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  - Launch Ascent Abort, Open Atlantic Ocean
  - Launch Abort, Post Open Atlantic Ocean
  - Early Mission Termination/Unplanned Contingency Landing
  - Ballistic Landing Contingency
- **CEV General Desirable Landing and Recovery Design Characteristics**

# CEV End of Mission Landing and Recovery

- At the End of Mission (EOM), the CEV will return to earth as planned at the designated landing site.
- Current documentation baselines a CONUS terrestrial landing with parachutes and retro-rockets.
  - Recent CxP sponsored CEV Land vs. Water Study recommended maintaining the baseline. In addition, consideration is being given to initial water landing to gain confidence in landing accuracy and attenuation systems.
- Landing and recovery procedures will be developed based on final CEV configuration and requirements.
- CEV Landing Site analysis is being conducted by a JSC led team in accordance with current requirements. Factors of consideration involve:
  - Acceptable terrain and environmental conditions such as temperatures and precipitation
  - Supporting infrastructure including airfield and medical support
  - Jettisoned hardware and other imposed hazards such as commodities spills or brush fires
  - Landing site opportunities, cross-range, and phasing/propellant budgeting.
  - LaRC is supporting with landing site surface analysis to aid in design of the landing attenuation system

# CEV Recovery Key Driving Requirements

CONSTELLATION

- Constellation Architecture Requirements Document dated Sept 18, 2006:
  - Ground Systems shall perform rescue and recovery operations independent of ambient lighting conditions. [CA0306-PO]
  - The Constellation Architecture shall perform search and rescue operations following a landing outside of the designated landing sites, independent of ambient lighting conditions. [CA0172-PO]
  - Ground Systems shall locate and rescue the flight crew in the event CEV Crew Module lands at a site other than a designated landing site. [CA0146-PO]
  - Ground Systems shall recover the CEV Crew Module in the event CEV Crew Module lands at a site other than a designated landing site. [CA4123-PO]
  - The CEV shall perform a guided entry that results in landing within 2.7 (TBR-001-040) nmi (5 km) of the intended target at a designated CONUS landing site. [CA0329-PO]
  - Ground Systems shall recover the flight crew and recoverable flight elements at designated landing sites. [CA0145-PO]
  - Ground Systems shall provide ground-based imagery of flight vehicles during launch operations, ascent, descent, and landing. [CA0858-PO]
  - Ground Systems shall recover the flight crew within 1 (TBR-001-161) hour after landing at a designated landing site. [CA4122-PO]
  - Mission Systems shall provide communication services to enable crew and system recovery. [CA4132-PO]

# CEV Recovery Key Driving Requirements

- Constellation Architecture Requirements Document dated Sept 18, 2006 (Continued):
  - Ground Systems shall rescue the crew within 24 (TBR-001-047) hours after landing at a site other than a designated landing site. [CA5146-PO]
  - The Constellation Architecture shall provide safe haven for the crew for at least 36 hours post touchdown on Earth while awaiting rescue and retrieval. [CA0312-PO]
  - The CEV shall land, remain intact, and float for a minimum of 36 hours in wind and sea state conditions as defined in CXP 70023 Constellation Design Specification for Natural Environment, Section 3.6.18, following a launch abort. [CA0983-PO]
  - The CEV shall maintain communications with Mission Systems for up to 36 hours post landing. [CA0344-PO]
  - The CEV shall communicate using an independent, dissimilar, voice only system during contingencies. [CA3280-PO]

- CEV System Requirements Document dated February 3, 2006:
  - The CEV shall provide a communications system capable of communicating with recovery forces pre- and post-landing. [CV0179]
  - The CEV shall provide communication with the Search and Rescue (SAR) team. [CV0180]
  - The CEV SAR communication equipment shall be interoperable with international civil and U.S. Government SAR systems. [CV0463]
  - The CEV shall provide a locator signal for recovery. [CV0181]
  - The CEV shall provide a SAR emergency locator beacon. [CV0182]
  - The CEV shall have the capability to maintain communications with the MPTFO Element for 36 hours after landing. [CV0183]
  - The CEV shall be self-righting for water landing. [CV0095]

# CEV Recovery Key Driving Requirements

- CEV System Requirements Document dated February 3, 2006 (Continued):
  - The CEV shall automatically initiate vehicle safing upon landing. [CV0096]
  - The CEV shall complete safing of the vehicle within 5 min (TBR-002-010) upon landing. [CV0097]
  - The CEV shall provide crew with unimpeded access to emergency equipment from prelaunch through recovery operations. [CV0278]
  - The CEV shall be recoverable by ground personnel without inducing hazardous work environments to the ground crew. [CV0282]
  - The CEV shall provide for crew survival for at least 36 hours (TBR-002-009) with the hatch closed following landing. [CV0093]
  - The CEV shall meet its functional and performance requirements during and after exposure to descent and landing phase clouds and fog environments as defined in the CXP-00102, Constellation Program Design Specification for Natural Environments (DSNE) section 3.5.16. [CV0225]
  - The CEV shall provide night time visual aids to support search and rescue operations following any night landing. [CV0184]
  - For water landings, the CEV shall provide crew recovery in environmental conditions as defined in the CXP-00102, Constellation Program Design Specification for Natural Environments (DSNE), Section 3.6.2 [CV0238]
    - Was Beaufort 8, change in work to Beaufort 6.

# CEV EOM Recovery Process Influential Factors

- The following factors will significantly shape the CEV EOM Recovery Process
  - Location and number of landing sites to be supported
    - Existing infrastructure and services (including Medical, Security, and Fire Rescue)
    - Proximity to ports/Military Bases
    - Environmental Conditions/Terrain
  - Department of Defense (DoD) and United States Coast Guard (USCG) Support Posture
  - CEV design and requirements including
    - Landing/Recovery Systems
    - Post landing requirements
  - Flight Rate
  - Flight Crew Post Landing/Medical Requirements
  - Payload Requirements
    - Time Critical De-stows / Delivery to customer
    - Support Requirements (i.e. power, special handling)
  - Contingency Requirements
    - Probabilities for Ballistic Landing or other landing outside of target location
    - Response time requirements

# KSC Recovery Ground Rules and Assumptions

- DOD/USCG EOM Contingency/MedEvac Support for land and water modes
  - EOM support would contain contingency assets for a local area response. Local area is defined by the response range of these EOM assets.
  - Contingency response outside of the local area would default to the Air Force Rescue Coordination Center (AFRCC) and TBD DoD/USCG contingency agreements
- **Crew Module Configuration**
  - **Diameter – 16.5'**
  - **Height - ~11'**
  - **Weight (including crew and cargo)**
    - **Launch – 17,300 lbs**
    - **Landing – 12,004 lbs**
      - **Heat shield – 2,600 lbs additional**
      - **Docking Mechanism – 670 lbs additional (LIDS)**<br>**~1,000 lbs additional (APAS)**
      - For water landing additional weight anticipated for flooding of the plenum
  - No Hypergols or Toxic Commodities
  - GOX/Ethanol RCS
  - Pyrotechnics
  - High Pressure Gases
  - Current baseline for terrestrial landing attenuation system is parachutes and retro-rockets

# KSC Recovery Ground Rules and Assumptions

- Nominal Landing within a 5 km radius landing zone for terrestrial and water landings.
- Recovery Personnel on scene rendering assistance within one hour
- Initial Flight Crew medical assessment capability goal of within two hours
- Flight Crew transport to definitive medical care goal of within three hours
- Time critical cargo/payloads will be removed from the CM upon landing within the specified timeframe (just after crew egress and before CM power down) due to power, temperature, limited life, etc. concerns.
- No quarantine required for Flight Crew, Hardware, or Payloads
- Water Specific Assumptions:
  - EOM weather requirements reflect more realistic operational constraint (i.e. 25 knot winds/8 feet waves as used in Apollo)
  - Water temperatures at least 50 deg F in recovery zone
- No CEV CM extended power up requirements identified
- No Ground Operations Control Room requirements identified
- PAO/TV requirements not assessed
- Range and Weather Requirements not addressed
- Ground Ops receives the CEV CM in the same condition subsequent to contractor refurbishment for either mode

# Generic Nominal CEV EOM Recovery

Recovery Preps

- Prepare Recovery Site/Equipment/ Vehicles
- Verify Ground Ops Recovery Communications
- Prep/Stage Contingency SAR, EMS Fire Rescue Support
- Establish Site Security

Assemble, Brief, And Stage Recovery Team → **CEV CM LANDING** → Locate CEV CM and Deploy Recovery Response Assets → Verify Recovery/ Flt Crew Comm → (A)

# Generic Nominal CEV EOM Recovery

(A)

- Initial Safing and Ground Safety Assessment → (B)
- Install any required Recovery Aids (i.e. stabilizers, etc)
- Provide Hatch Opening Capability
- Perform Initial Flt Crew Med Eval And Flt Crew Egress
- Transport Flt Crew to Post-Landing Location
- Establish CM Purge (If required)
  - Perform Destow of Time Critical Cargo and Turnover to POC
  - Perform any required Data Dumps/CM Cockpit Configuration
- Power Down CEV CM
- Close CM Hatch
- Install Protective Coverings (i.e. thruster plugs, Connector savers)
- Prep Systems For Transport (i.e. vent/drain sys, remove pyros, config landing attn sys
- Washdown CEV CM (if required)

(C)

**NOTE**
Sequence of events may vary for landing mode and assets utilized.

# Generic Nominal CEV EOM Recovery

B → Locate and Recover Parachutes (if required) / Locate and Recover Heat Shield (If required) → Configure Hardware for Transportation → Load Hardware On Transport Vehicle → Transport Hardware To Refurb Location

C → Configure CM/ Install Lifting Sling → Place CEV CM on Transportation Fixture → Load Hardware On Transport Vehicle

# CEV EOM Recovery Options

| EOM Recovery Asset Options | | |
|---|---|---|
| **NASA Owned** | **Commercial** | **DoD/USCG** |
| Advantage:<br>Dedicated resource with consistent specialized capabilities.<br>Risk:<br>Cost of procuring, maintaining and Operating | Advantage:<br>Potential cost savings<br>Risk:<br>Availability and some reduced Control of actual services Provided | Advantage:<br>Potential cost saving and immense Capabilities<br>Risk:<br>DoD role and mechanism to NASA is TBD; current resources heavily tasked |

A Hybrid combination is the likely the solution.

*Re-entry*


Terrestrial or Water Landing

Terrestrial Landing (A)

Water Landing (B)

# Terrestrial EOM Recovery Options

A

Prime or Alternate Site

Alternate Landing Site Duplicate Asset Options

Prime Landing Site Asset Options

Fixed or Mobile Site

| Ground Vehicle Response | Helicopter Response | Hybrid Response |
|---|---|---|
| Advantage:<br>Cost Effective<br>Stable Work Conditions<br>Risk:<br>Site Terrain, Substrate, and Env Conditions may Limit response Capability/time | Advantages:<br>Greater tolerance For Site Specific Challenges and May Provide a Quicker Response<br>Risk:<br>Helicopters are Expensive and Have Reliability Concerns; DoD Support Cannot Be Assumed | Potential Option Based on Site Specific Trade Studies and Maturing Requirements |

| Fixed Site | Mobile Site |
|---|---|
| Alternate Site with Duplicate Capabilities As Landing Prime Site | Equip and Personnel Deployed to Alternate Site Via Ground, Air, or Hybrid Transport |
| Advantage:<br>Standby Alternate Ready to Support<br>Risk:<br>Costs of Supporting Multiple Sites | Advantage:<br>Potential Cost Saving by Minimizing Recovery Sites, Personnel and Equip<br>Risk:<br>Costs of Transport, Potential Problems In Transit That Could Jeopardize EOM Support |

# Water EOM Recovery Options

B

Water Landing

**Ship Based Response**

Advantage:
Landing Site Flexibility; Mobile Landing Site
Risk:
Risk of Injury to Flt Crew and Recovery Personnel due to Dynamic Marine Environment. Potential Increased Risk to FltHardware Damage during Recovery. Careful Consideration must be given to Ship Requirements, Options, and Associated Costs

Process Options:
Recover Flt Crew and CM
- Separate – more timely crew egress and med eval/support. Potential elevated risk during sea ops including CM saltwater exposure
- Together – more timely CM removal from water. Risk of lifting a live load

**Helicopter Response**

Requires Landing Zone Within Range Of Helicopter Response

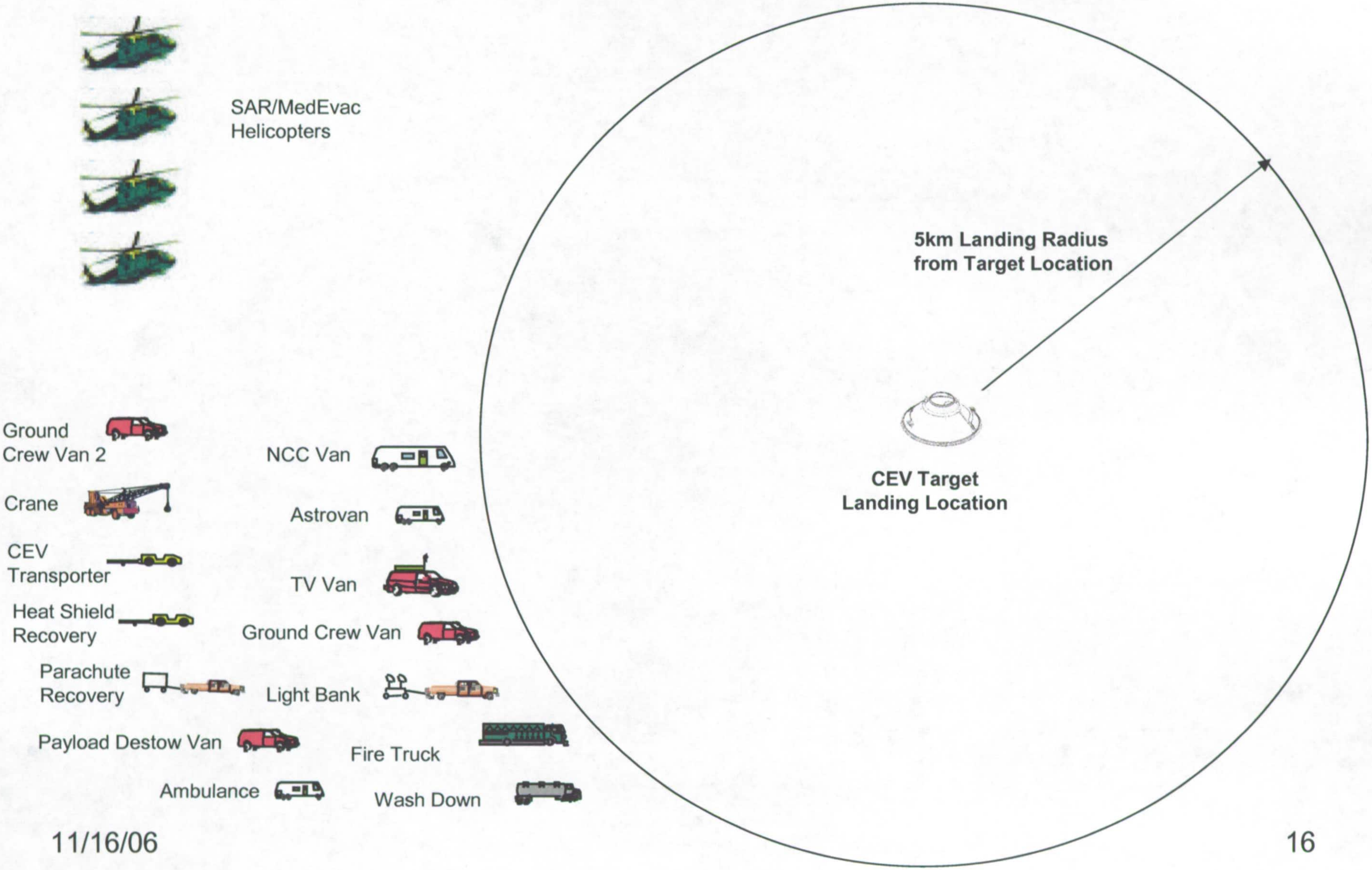
Advantage:
Provides Potential Expedited Return of the Flt Crew and CM to Land
Risk:
Same Dynamic Marine Environment Concerns Listed for Ship. Additional General Helicopter Risks and Risk of Personnel Injury and CM Damage during any Hoisting/Slinging Ops. Careful considerations of Costs and Options Required for Helicopters. Reliability May Require Additional Assets

**Hybrid Response**

Advantage:
Offers the Greatest Water Recovery Options
Risk:
Considerable Costs

Process Options:
- Ship Based Helicopter
  - Advantage:
    Offers the Greatest Flexibility and Likely the Timeliest Response
  - Risk:
    Cost of Both, Including the Considerable Impact on Ship Selection to Accommodate a Helicopter
- Ground Based Helicopter
  - Requires Landing Within Range of Helicopter

# CEV EOM Recovery - Scenario I
# Notional Ground Vehicle Terrestrial Support

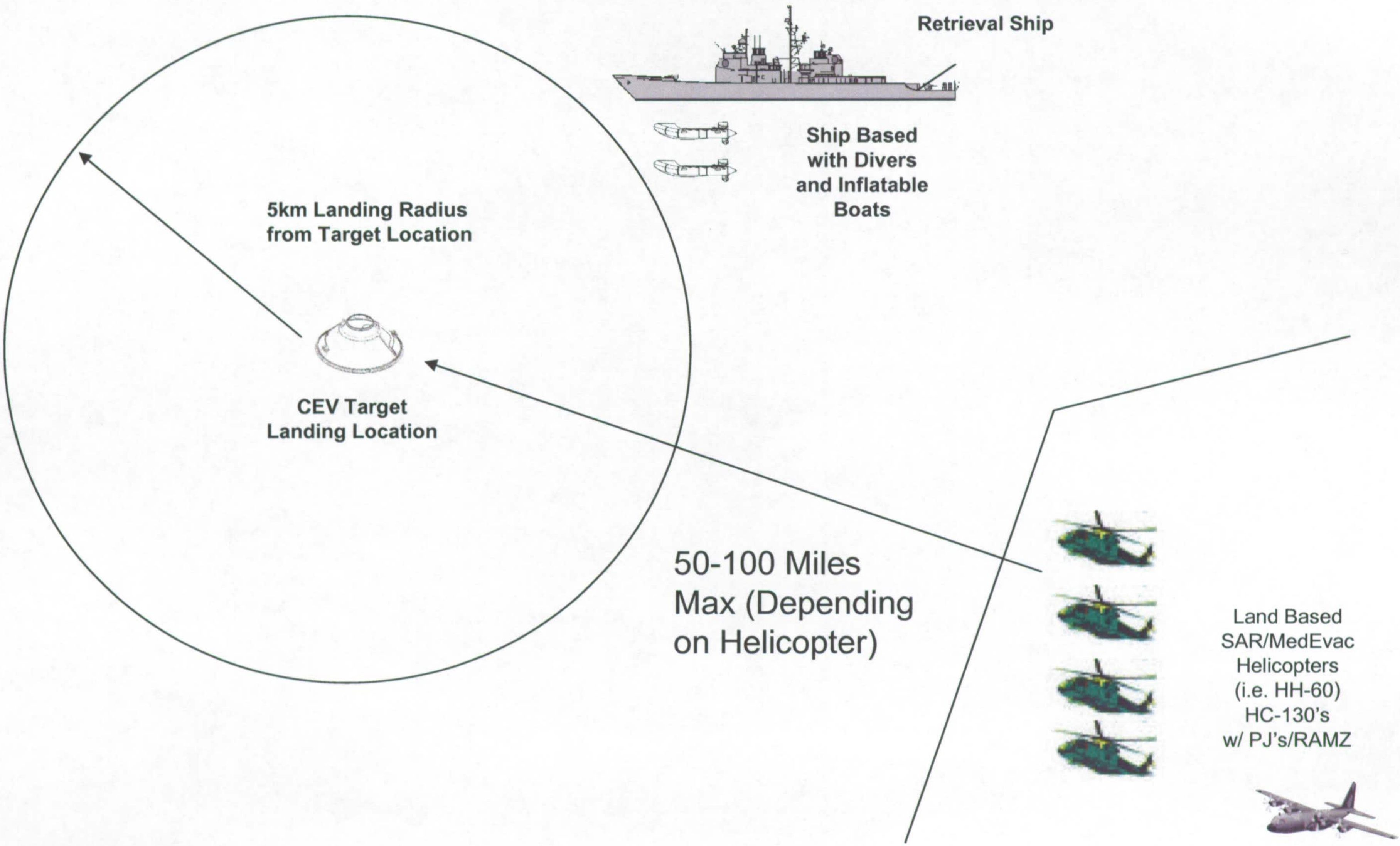


# CEV EOM Recovery – Scenario I
# Notional Ground Vehicle Terrestrial Support

CONSTELLATION

- Vehicles represent Recovery Convoy capabilities to include:
  - Command
  - Recovery Personnel/Equipment Support
  - Flight Crew Egress/Medical Evaluation/Transport
  - Payload Destow
  - Heat Shield and Parachute Recovery
  - CM Recovery
  - Fire Rescue and EMS Contingency Support
  - Lighting for Night Recovery Operations
- Response requires accessibilities by ground vehicles throughout the entire landing zone
- Local area contingency response provides MedEvac and SAR capability within the range of the EOM contingency assets, approximately 50 – 100 mile radius from the staging location, depending on helicopters utilized (i.e. UH-1, HH-60)
  - Utilize SSP model of one Helicopter for every two Flight Crew members and an Airboss.
  - Range can be extended, at a cost, if air refueling capability is employed or other assets are utilized
- Contingency response outside of the local area would default to the Air Force Rescue Coordination Center (AFRCC) and TBD DoD/USCG contingency agreements

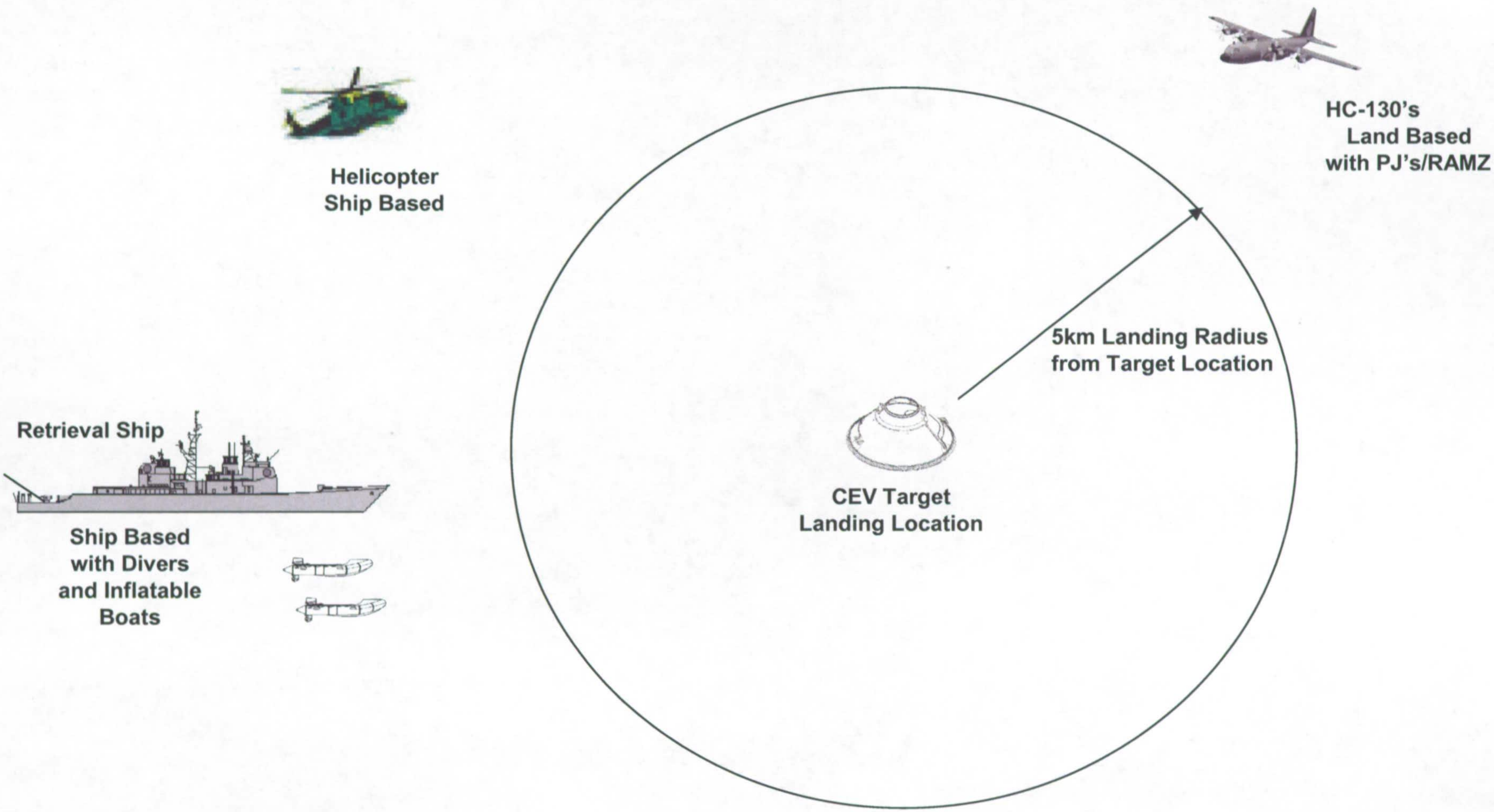
# CEV EOM Recovery - Scenario II
# Notional Water Support Inshore



# CEV EOM Recovery - Scenario II
# Notional Water Support Inshore

- Recovery mode depicts a ship as the recovery platform with deployable small boats (i.e Rigid Hull Inflatable Boats) to insert recovery personnel to perform required water activities
  - Assumes Flight Crew and Spacecraft return to land via the ship
  - Mission specific time critical cargo requirements must be assessed
- Inshore is defined as the range of ground based contingency SAR and MedEvac helicopters
  - Estimated to be 50 – 100 mile radius from the staging location, depending on helicopters supporting (i.e. UH-1, HH-60's)
  - Range can be extended, at a cost, if air refueling capability is added
- Additional contingency SAR capability is expected for landings outside of the target zone but within the local area.
  - HC-130 will PJ's and RAMZ packages are notionally shown for this support. It is noted that this response can locate and insert contingency recovery personnel, but would require a ship or helicopter to extract personnel from the water
  - Other DoD assets (i.e. V-22 Osprey) may provide an enhanced capability by the time of CEV operations
- The main cost discriminator in this mode is the recovery ship.
  - A wide range of options exists from DoD, Commercial, and NASA procured.
  - The final solution requires better definition of the noted recovery process influential factors.
  - A range of explored options is summarized in a KSC Logistics Study
- Depending on location and implementation, this option could pose challenges to potential Flight Crew medical requirements (accessibility to definitive care in a timely manner) and time critical cargo delivery to customers.

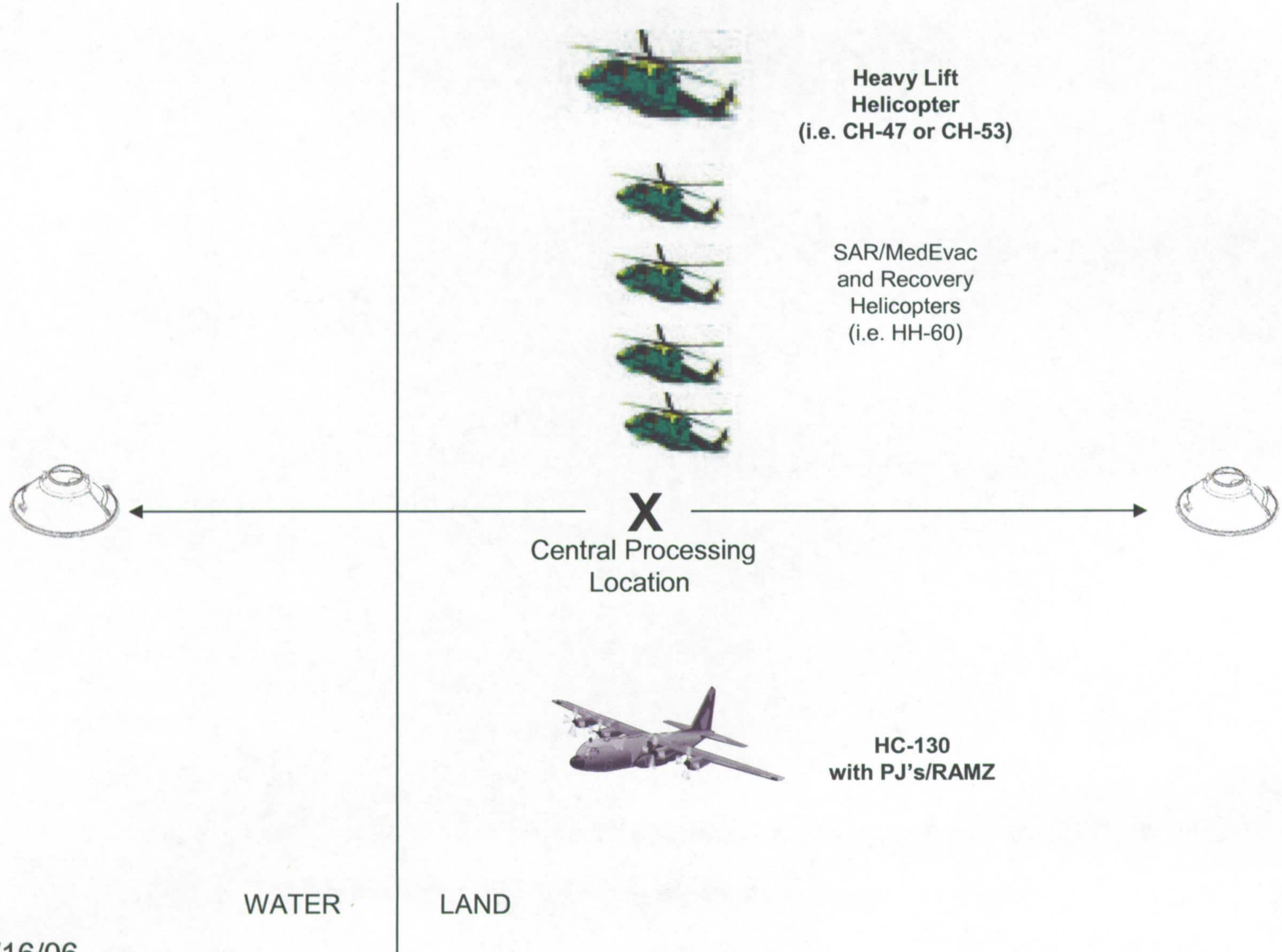
# CEV EOM Recovery - Scenario III
# Notional Water Support – Offshore



# CEV EOM Recovery - Scenario III
# Notional Water Support – Offshore

- Nominal recovery mode is as described in the inshore option
- Offshore is defined as that area outside the range of ground based contingency SAR and MedEvac helicopters
  - Assumed to drive a ship embarked helicopter(s) and onboard definitive medical care and potentially onboard time critical cargo processing
- Local area contingency SAR and MedEvac (to the ship) is the embarked helicopter and a ground based long range asset (i.e. HC-130)
- This option is deemed unfavorable from a cost perspective
  - DDMS/DoD has expressed reluctance to provide primary recovery assets
  - Ships to accommodate an embarked helicopter and definitive medical care and the associated equipment and personnel are very expensive to own, maintain, operate, and lease (if available)
    - Procurement of such vessels can be in the hundreds of millions of dollars
    - Potential exists to procure older Naval Vessel still requiring annual O&M costs in the tens of millions of dollars
  - Would likely require a NASA owned or contracted helicopter(s) due to DoD reluctance to operate from a Non-DoD platform.
    - Procurement of helicopter(s) can be in the tens of millions of dollars
    - Would drive significant training for proficiency
- This option may also impose additional operational constraints due to helicopter launch and landing requirements which is a factor of the ship/helicopter combination
  - Smaller, less stable ship would impose greater restrictions

# CEV EOM Recovery - Scenario IV
# Notional Helicopter Response



# CEV EOM Recovery - Scenario IV
# Notional Helicopter Response

- This option provides a recovery option utilizing helicopters to recover the Flight Crew and CM for an inshore water landing or a ground vehicle inaccessible terrestrial landing.
  - SAR/MedEvac Helicopters (i.e. HH-60's) would recover the Flight Crew
  - Heavy Lift Helicopter would recover the CM and deliver to a central processing location
    - Consideration was given to recovering the crew and CM together. However, slinging a live load is prohibited
- The distance of this option is limited by the Heavy Lift Helicopter range to depart and return with the CM from the central location
  - The range is still be defined as helicopter load slinging is generally restricted to the minimum distance required to transport the load via another means. It is expected that this range will not exceed 50 miles from the staging location.
  - This range could also be further reduced by flight path restrictions while slinging a load
- Contingency SAR and MedEvac within the local area would be performed by the Flight Crew Recovery Helicopters
- This option is likely unfavorable from a cost perspective
  - DDMS/DoD has expressed reluctance to provide primary recovery assets
  - Helicopter procurements are in the tens of millions per unit with significant O&M costs
    - KSC currently pays almost $2M total annual O&M costs for the four NASA UH-1's
    - Additional helicopters would likely be required to insure minimum EOM assets are available
  - Lease options identified to date for terrestrial operations only
    - Heavy Lift $5,000/flying hour with guaranteed hours and deployment/return to home base
    - SAR/MedEvac $1,500 - $2,000 flying hour with guaranteed hours and deployment/return to home base
- Depending on CM post landing requirements, a cost effective hybrid, derivative could be to recover the flight crew via helicopter and then recover the CM with a recovery/salvage ship.

# CEV EOM Recovery - Scenario IV
# Notional Helicopter Response

- This option is deemed the highest risk
  - Potential to inadvertently drop personnel
  - Potential to drop CM with an increased risk due to unknown tracking characteristics of CM; potential to swing and spin and produce unstable flight for Heavy Lift Helicopter
    - DoD considers long range slinging of a load to be a poor plan
    - A commercial service has not yet been identified for water recovery of hardware or personnel

# CEV Contingency Landing and Recovery

- The following potential contingency scenarios have been identified:
  - Launch Pad Abort utilizing Launch Abort System (LAS)
  - Launch Ascent Abort, North American East Coast
  - Launch Ascent Abort, Open Atlantic Ocean
  - Launch Abort, Post Open Atlantic Ocean
  - Early Mission Termination/Unplanned Contingency Landing
  - Ballistic Landing Contingency
- It is possible, if not likely, that the rescue of the Flight Crew and recovery of the Spacecraft will be separate operations.
  - Rescue Flight Crew via Search and Rescue (SAR) forces
  - Recovery Spacecraft with Recovery/Salvage Ship or other land based assets

# CEV Contingency Landing and Recovery
## Launch Pad Abort with LAS

- Subsequent to hatch closure and access arm retraction, there is potential for a crew abort utilizing the LAS to boost the CEV crew module (CM) away from the launch vehicle and landing in the ocean to avoid land obstacles.
- Although such an abort is planned to be in the water, the possibility exists for a terrestrial landing due to onshore winds or other anomalous conditions.
- Planned support of this would likely utilize rescue forces already in place to maintain a clear launch zone and support pad contingencies. Typical launch support includes:
  - NASA/DoD Helicopters (UH-1/HH-60)
  - NASA SRB Retrieval Ships
  - Coast Guard and/or Naval Vessel
  - DoD Aircraft including HC-130 with PJ's
  - KSC Fire/Rescue Forces
  - KSC Emergency Medical Services (EMS) Convoy
- A vessel will likely be equipped with recovery equipment and personnel and positioned off the launch pad to recover both the crew and spacecraft. Since only one NASA SRB Retrieval Ship will be required for the CLV first stage, the second ship is a candidate for this role.

# CEV Launch Ascent Abort
## North American East Coast

- Subsequent to lift off of the launch vehicle, the opportunity exists for an abort along the North American East Coast resulting in an Atlantic Ocean landing.
  - This is particularly true for ISS mission 51.6 degree launch inclination
  - Lunar missions would be closer to a 90 deg launch azimuth and have a greater open ocean exposure
- Recovery of the crew would be performed by land based Search and Rescue (SAR) forces.
- A joint US/Canadian SAR capability would be required for the northern exposure.
- Recovery of the CEV CM requires additional planning as resources vary along the abort path.
- The following chart is from a study performed for the Space Launch Initiative (provided by JSC DM) and depicts SAR capabilities based on Shuttle plans along a 51.6 degree launch inclination.
  - These assets are not activated to support Shuttle launches
  - An effort has been initiated with the DoD Manned Space Flight Support Office to analyze current capabilities and available resources based on a CEV recovery.
    - New potential capabilities, such as the V-22 Osprey, will also be considered.

# CEV Launch Ascent Abort

# North American East Coast

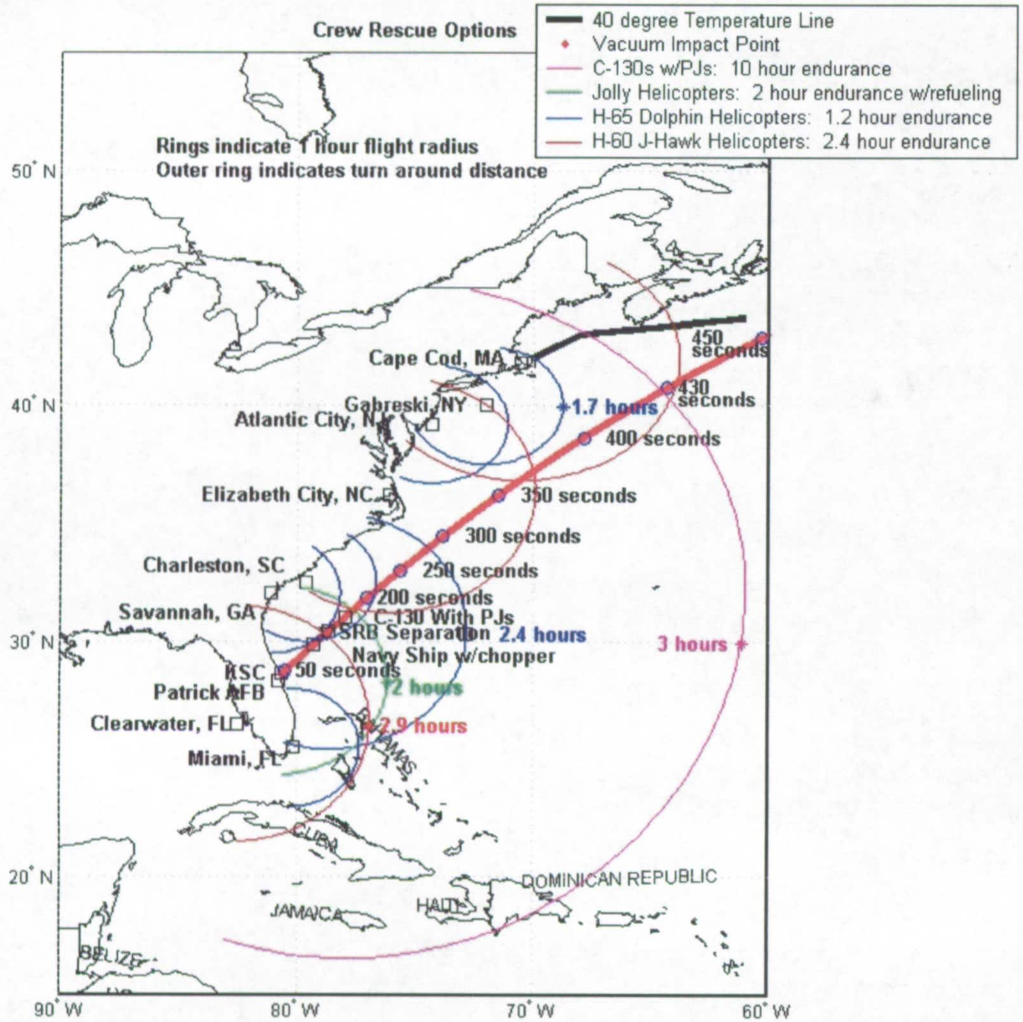
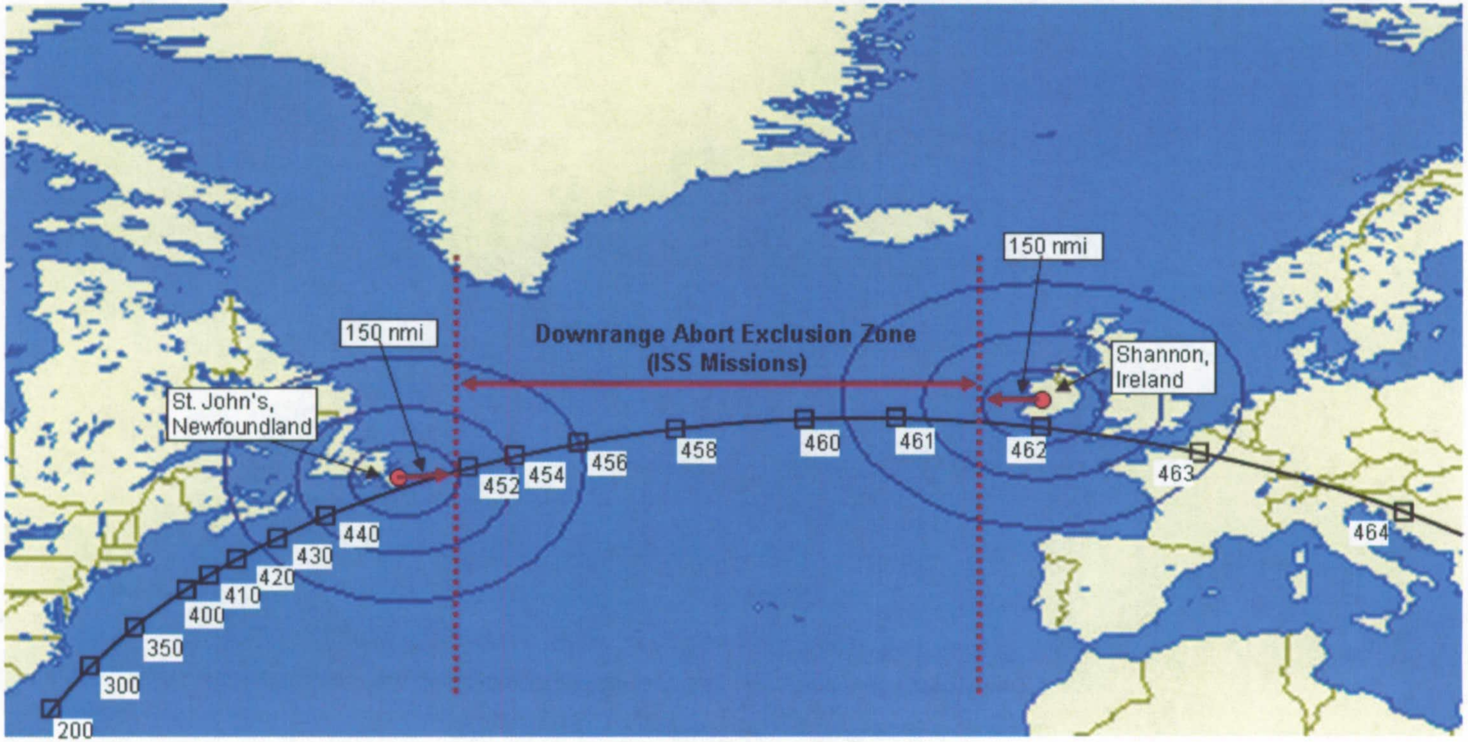



**Table 1: Ascent Search And Rescue Options**

| Site | Vehicles | | |
|---|---|---|---|
| | Helicopter Rescue | Fixed-Wing Search | Coast Guard Ship |
| Portsmouth, NH | NA | NA | 378 ft ship & 210/270 ft ships |
| Cape Cod, MA | H-60 J-Hawk | NA | NA |
| Boston, MA | NA | NA | 378 ft ship & 210/270 ft ships |
| Otis, MA | NA | C-130 & HU 25 | NA |
| Gabreski, NY | H-65 Dolphin | NA | NA |
| Atlantic City, NJ | H-65 Dolphin | NA | NA |
| Elizabeth City, NC | H-60 J-Hawk | C-130 & HU 25 | NA |
| Charleston, SC | H-65 Dolphin | NA | NA |
| Savannah, GA | H-65 Dolphin | NA | NA |
| Patrick AFB, FL | Jolly | NA | NA |
| Clearwater, FL | H-60 J-Hawk | C-130 & HU 25 | NA |
| Miami, FL | H-65 Dolphin | | NA |
| Navy Ship at 150 nm down track | H-65 Dolphin | NA | NA |
| Orbiting C-130 w/PJs at 200 nm down track | NA | C-130 | NA |

# CEV Launch Ascent Abort, Open Atlantic Ocean

- The following figure, from the Constellation Architecture Glossary and Acronym List, illustrates an area of the North Atlantic, well over 1,000 miles long, that the CEV CM could abort during an ISS launch inclination of 51. 6 deg.
- This area is problematic due to limited support by land based SAR forces and the potential for inclement weather.



# CEV Launch Ascent Abort
## Open Atlantic Ocean

- Due to recovery concerns, this area has been designated as a Downrange Abort Exclusion Zone (DAEZ) as an area to be avoided per the Constellation Architecture Requirements Document.
- CEV and CLV flight dynamic studies will determine this abort probability and drive consideration for pre-staging of recovery assets along this path.
  - There is an expectation that the SM engine would be used to burn posigrade or retrograde after SM/CM separation from the LV. Would move the landing footprint up or downrange – closer to land
- The Automated Merchant Vessel Emergency Rescue (AMVER) sponsored by the US Coast Guard may be considered for this zone, but is not be a good primary plan since there is no guaranteed support and the capabilities of merchant vessels are highly variable and obviously untrained for such a response.

# CEV Launch Ascent Abort, Open Atlantic Ocean

- The figure below illustrates the ground track range from window open to close for Apollo 11 launch. Although a much tighter range is expected for CEV lunar missions, due to rendezvous requirements, it is representative of an lunar launch open Atlantic Ocean abort exposure.
- This scenario will likely require the deployment of maritime SAR forces to protect for such an abort. The actual support requirements can determined subsequent to abort zone identification and probabilities and development of water recovery procedures.

# CEV Launch Aborts
## Post Open Atlantic Ocean

- Following the open ocean exposure, an opportunity to land in the water within International SAR capabilities exists.
  - This scenario would likely involve a joint response of DoD and Foreign SAR forces
  - NASA HQ and the State Department involvement may be required to develop applicable Country to Country agreements.
- As the CEV flight dynamics mature, there may be launch abort modes that would require additional ground based support/planning such as:
  - Trans Atlantic Landing (TAL) resulting in a terrestrial landing in Europe or Africa or water landing in the Indian Ocean.
  - Abort Once Around (AOA) if a stable orbit cannot be achieved.
- Some consideration is being given to implementing a TAL mode to the Indian Ocean to avoid potential adverse weather in the Northern European region.

# CEV Early Mission Termination/ Contingency Landing

- While on orbit, scenarios, such as major system problem or crew health issue, may exist that require an early mission termination and contingency landing.
- A mission support plan must be developed based on landing site selections and CEV requirements.
- It is assumed that such landing sites could be terrestrial or water.
- No such requirements exist, that I am aware of, including the need for emergency medical facilities.
- A study was performed to identify Emergency Landing Sites and associated medical capabilities by EMS and DDMS in 1989 in support of the Crew Emergency Return Vehicle. This study could be revisited and updated as required based on CEV applicable CEV requirements.

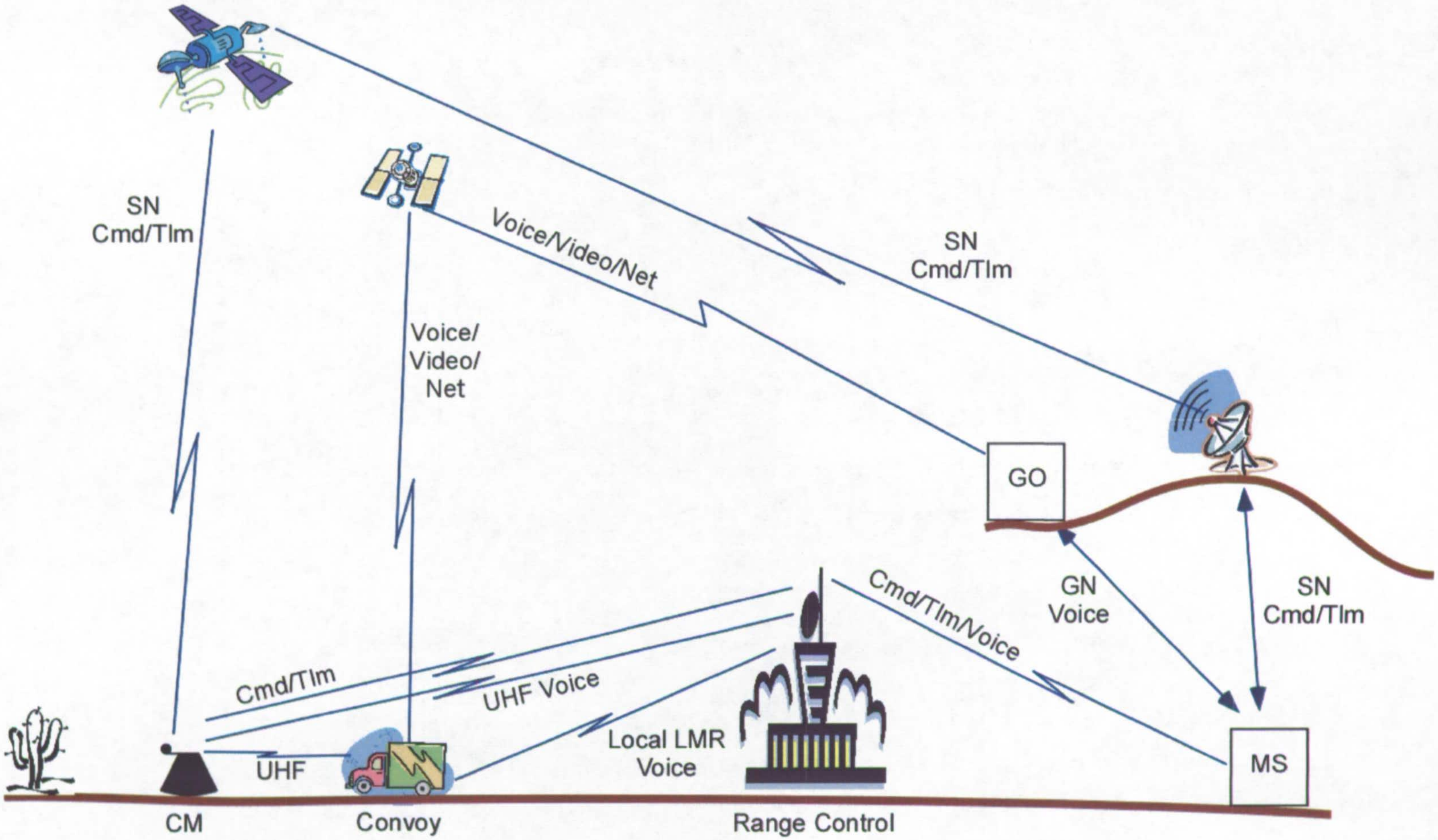
# CEV End of Mission
# Ballistic Landing Contingency

- A capsule design allows for the desirable characteristic of a safe reentry without active attitude control. This results in a ballistic landing contingency.
- In a ballistic landing, the CEV CM could land over 500 miles short of the intended landing site; this would likely result in a water landing.
- Depending on landing zone determinations, probabilities, and associated CEV requirements, pre-staged maritime assets with the capability to recover the crew and spacecraft could be made available.

Soyuz Ballistic Landing

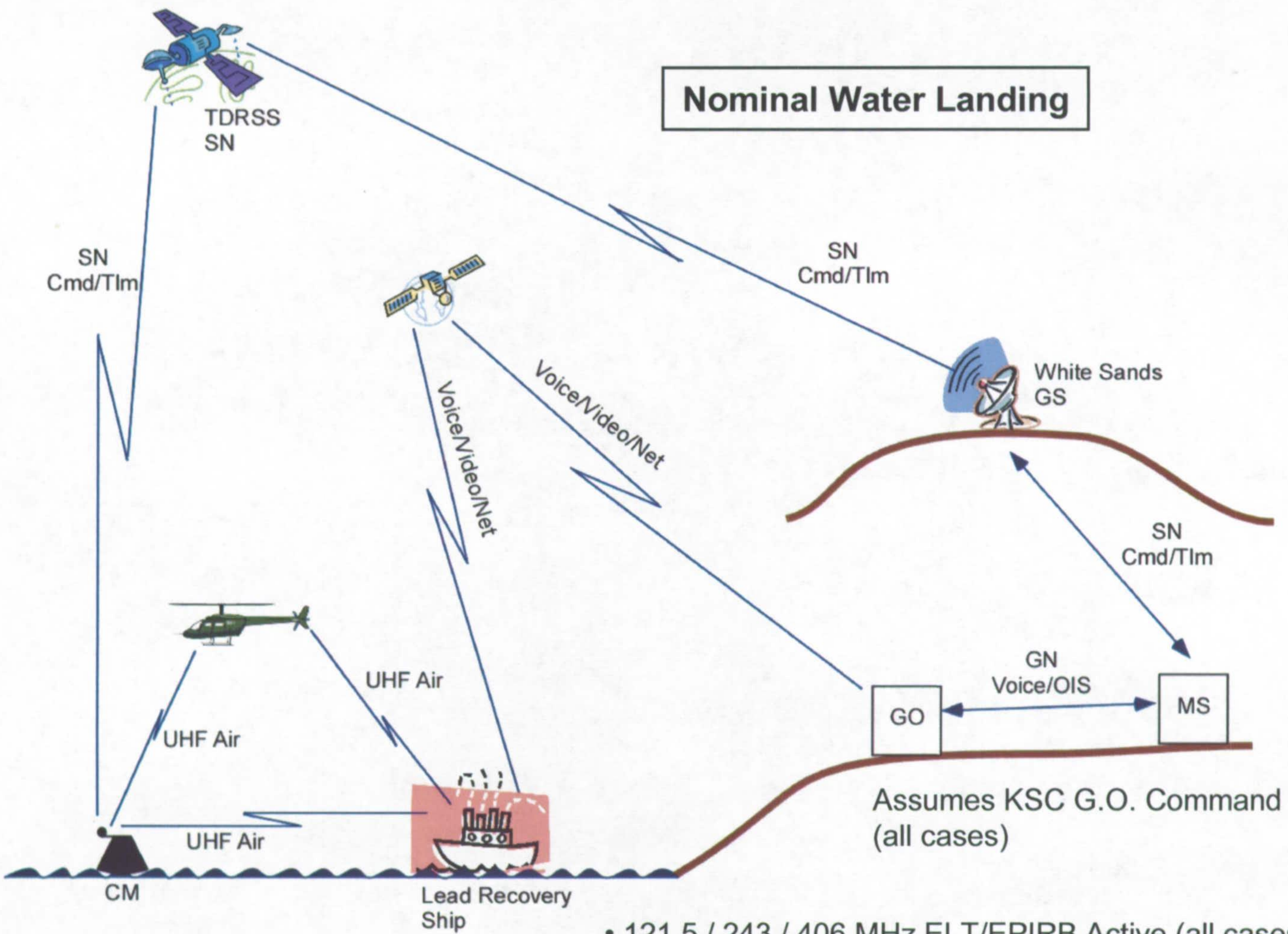
# BACKUP MATERIAL

# Ground Operations Landing Scenarios – Nominal Land




• LMR – Land Mobile Radio (on range)

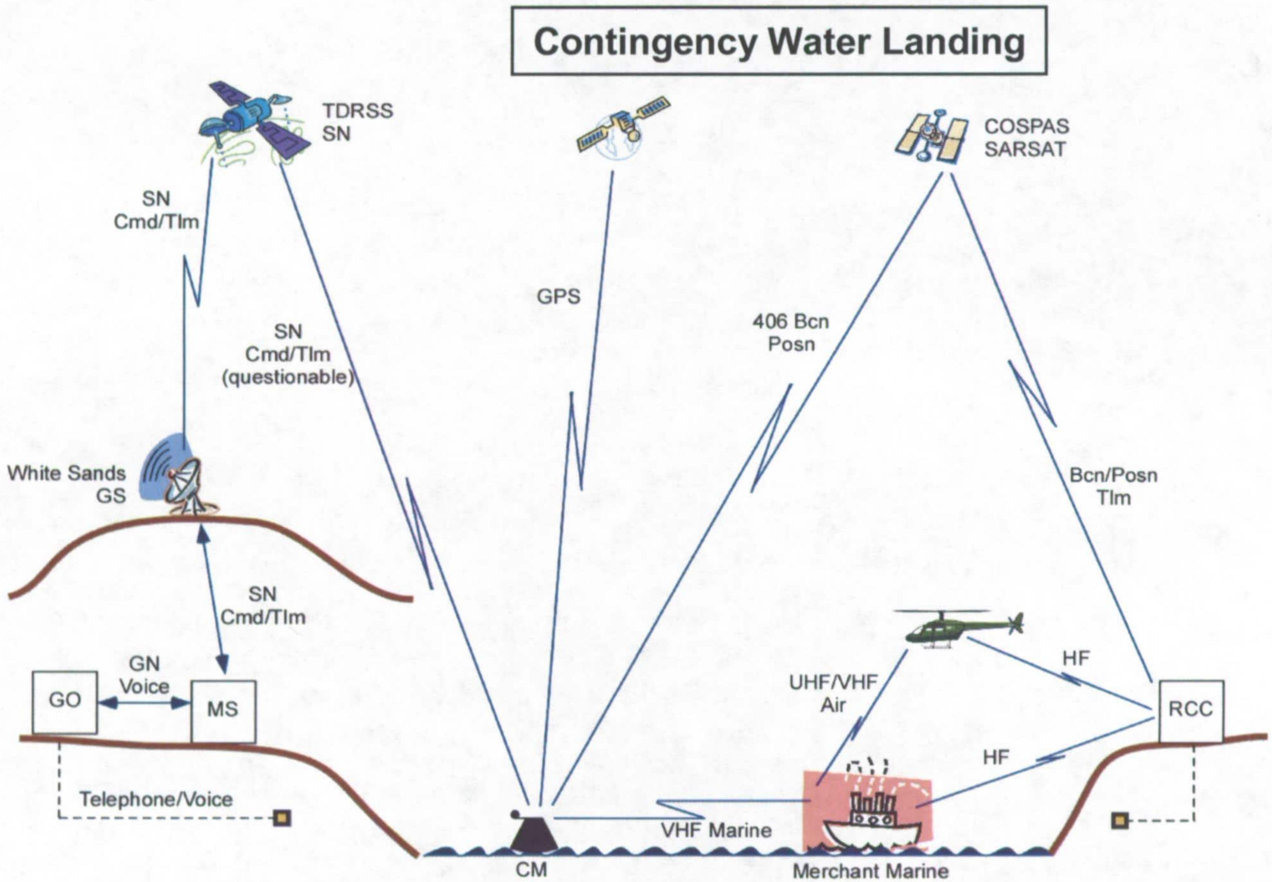
# Ground Operations Landing Scenarios – Nominal Water




Assumes KSC G.O. Command Post (all cases)

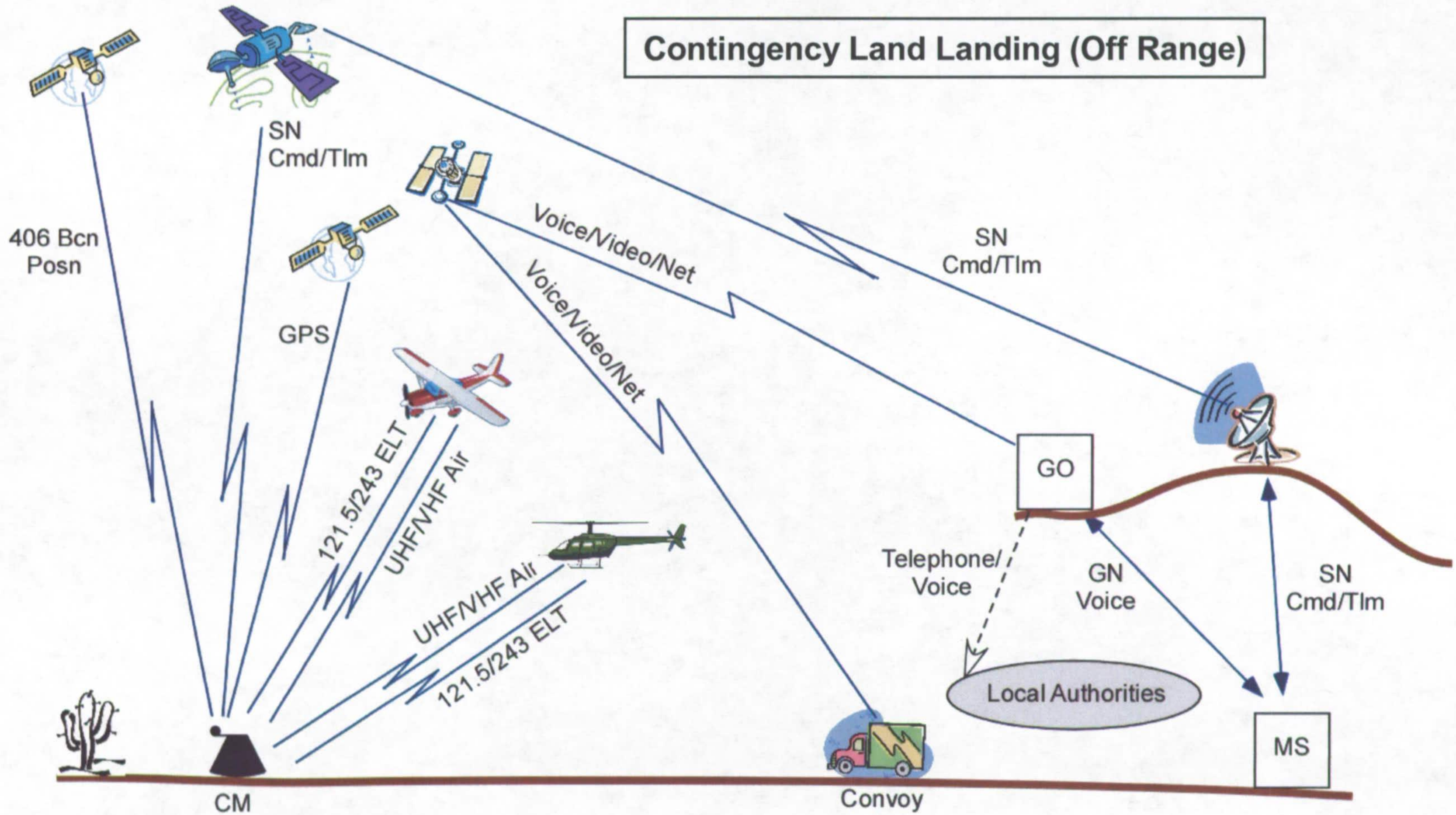
- 121.5 / 243 / 406 MHz ELT/EPIRB Active (all cases)
- Cmd / Tlm Link to Recovery Ship Relay Possible

# Ground Operations Landing Scenarios – Contingency Water




- RCC – Rescue Coordination Center (multiple locations)
- Merchant Marine assumed First Responder via AMVER
- Helicopter is RCC dispatched / Vessel is 2nd Responder
- CM salvage – TBD
- Command Post (G.O.) could be entirely shipborne
- Successful TDRSS link unlikely in rough seas
- Assumes crew rescue takes precedence over CM recon

# Ground Operations Landing Scenarios – Contingency Land




- Assumes convoy within recovery range; otherwise, no convoy

# CEV General Desirable
# Landing and Recovery Design Characteristics

CONSTELLATION

- 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
- Ease of locating in a contingency scenario
- Ease of access by ground based access for terrestrial landings
- Provide fast, simple and safe water recovery
- 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