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Space Transportation System Cargo Abort and Recovery Operations

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SPACE TRANSPORTATION SYSTEM
CARGO ABORT AND RECOVERY OPERATIONS

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ABSTRACT

The Space Transportation System era has produced a new operational consideration with unique problems: payload/cargo recovery following an aborted mission. This paper addresses: types of aborts, landing sites, classes of payloads, recovery operations, and cargo impacts.

Space Transportation System planning has concentrated on the Orbiter; however, the emphasis is now being focused on payload/cargo concerns. Extensive contingency planning has to be accomplished many months prior to launch. Recovery equipment and personnel have to be identified for all situations. Each payload presents different recovery requirements which must be satisfied. Recovery of flight hardware, data, experiments, and the safing and deservicing of hazardous components must all be provided for. Payload contractors must be concerned with contamination, thermal effects, and delayed physical access.

LANDING/FLIGHT ABORT OPERATIONS

When the Orbiter returns to earth after completing a mission, there are a variety of post-flight activities which involve the payload contractor. In addition to supporting and participating in post-flight operations for planned landings, the payload contractor must plan and be prepared to participate in post-flight operations after an aborted mission. These operations may occur at a variety of landing sites within the Continental United States or overseas. There are a number of abort conditions which are described in the following paragraphs:

RETURN TO LAUNCH SITE (RTLS)

Should an emergency occur on ascent, making orbit insertion impossible, the vehicle continues up to 400,000 feet (approx. 122,000 m) altitude and pitches around to reverse the thrust direction. The horizontal component of velocity is zeroed out and then reversed in direction, while the craft descends to about 230,000 feet (approx. 70,000 m) altitude over 300 nautical miles (approx. 550 km) downrange. The external tank is separated and the Orbiter is flown through a complex and challenging glide path to a manual landing on the shuttle landing facility at Kennedy Space Center.

TRANSATLANTIC ABORT LANDING (TAL)

If an abort is called during ascent and orbit insertion is impossible, the Orbiter continues in a ballistic trajectory. A manual landing is made at the transatlantic abort landing site.

ABORT TO ORBIT (ATO)

If an abort is called after a transatlantic abort landing is no longer feasible, but the capability exists to reach a circular orbit with an altitude greater than 105 nautical miles (approx. 190 km), then circular orbit is achieved. After this basically safe orbit is reached, the mission may be continued, using the Orbital Maneuvering System (OMS) and Reaction Control System (RCS) to maintain or even increase orbital altitude. If system difficulties are not corrected, reentry may be attempted as early as orbit 4.

ABORT ONCE AROUND (AOA)

If an abort is called when a return to launch site maneuver or a transatlantic abort landing is no longer feasible and circular orbit at 105 nautical miles (approx. 190 km) cannot be achieved, but orbital velocity is still achievable, the Orbiter may use the OMS-2 burn to initiate reentry rather than to raise perigee. Landing would then occur about 90 minutes after liftoff.

ON-ORBIT CONTINGENCIES

Situations may occur during the mission which would prevent awaiting a landing opportunity at the primary landing site or secondary landing site. During more than eleven hours per day, the Orbiter cannot make an abort landing in the continental United States due to cross-range limitations of 815 miles (approx. 1300 km) and darkness. A problem developing during this time frame could dictate landing at a contingency landing site.

TYPES OF LANDING SITES

There are several types of landing sites designated for each mission. Edwards Air Force Base, California was designated as the primary landing site during the orbital flight test phase and the shuttle landing facility at Kennedy Space Center was the secondary landing site. Early operational flights will continue to use Edwards AFB as the primary landing site, with the Kennedy Space Center as the secondary landing site. Current planning has most landings at Edwards AFB through at least Mission 12. When the Space Transportation System becomes totally operational, all flights will land at the Kennedy Space Center, utilizing it as a primary landing site. The Western Launch Site at Vandenberg Air Force Base, California is slated to become an additional Primary Landing Site in the late 1980's.

When the Kennedy Space Center becomes the primary landing site, then Edwards AFB will be a secondary landing site. The White Sands Space Harbor, New Mexico is designated as a backup landing site. Due to adverse climatic conditions that exist at Edwards AFB during certain times of the year, the lakebed there may not be suitable for a Shuttle landing site. At such time, the White Sands Space Harbor can be designated as a landing site for a particular mission. White Sands Space Harbor can be designated as a primary landing site, abort-once-around landing site or contingency landing site, depending on mission requirements.

A transatlantic abort landing site is designated for each mission. This is to provide for a safe landing area in the event of an Orbiter main engine failure and when an abort-to-orbit or abort-once-around is not possible. Dakar-Yoff International Airport at Dakar, Senegal is planned for a transatlantic abort landing site for most low orbit inclination angles. Rota Naval Air Station at Rota, Spain is designated as the transatlantic abort landing site for high orbit inclination angles.

Contingency landing sites are identified for each mission to provide landing opportunities when the primary landing site or secondary landing sites are not available. The currently identified contingency landing sites are:

Rota Naval Air Station, Rota, Spain

Dakar-Yoff International Airport, Dakar, Senegal

Kadena AFB, Okinawa, Japan

Hickam AFB, Honolulu International Airport, Hawaii

CLS PAYLOAD POLICY

The current NASA contingency landing site policy for payloads provides that payloads will be removed from the Orbiter and transported in their shipping container to the primary launch site for return to the user. NASA will provide for payload ground support equipment and personnel transport to and from the contingency landing site within the transportation provisions for the Space Transportation System on a space available basis. After payload removal from the Orbiter and prior to transport, all user required payload unique operations (data removal, safing, modifications for transport, etc.), and personnel to conduct them are the responsibility of the user.

SHUTTLE CARRIER AIRCRAFT FERRY LIMITATIONS

Many payloads are constrained from being ferried back to the launch site in the orbiter payload bay by weight and center of gravity (c.g.) limitations. The current Orbiter ferry weight is limited to 192,000 lbs. (approx. 87,000 kg).

That weight limitation was increased by a waiver for the Continental United States to 220,000 lbs. (approx. 100,000 kg) through the STS-6 mission. Possible extension of that waiver is under analysis. The ferry weight from contingency landing sites in Europe and Africa is constrained to approx. 192,000 lbs. (approx. 87,000 kg). The ferry weight from the Pacific contingency landing sites is further constrained to 154,000 lbs. (approx. 70,000 kg). This requires not only removal of the payload but removal of Orbiter main engines, tires, landing gear and other components as well. In addition, the Orbiter Z axis (vertical) and X axis (longitudinal) center of gravity location must be within a limited envelope, as shown in Figure 1.

PAYLOAD CLASSES

Payloads have been classified in different forms such as automated free-flyers, planetary, sortie, horizontally installed, vertically installed, etc.; however, the most common method of classification is attached payload or deployable payload. Attached payloads are those which are launched and returned with the Shuttle. Examples are Spacelab and the MBB SPAS structure. Deployable payloads are those which are removed/ejected from the payload bay and operate at some distance from the Shuttle. All payloads with propulsive stages are deployable. Other examples of deployable payloads are the Long Duration Exposure Facility (LDEF) and Gamma Ray Observatory (GRO).

PAYLOAD RECOVERY OPERATIONS

PLANNED LANDINGS

Some of the tasks required for planned landings and aborted flights are identified. The operations and activities to be accomplished for a generic payload program, with a planned landing at the primary landing site, are described in the following paragraph:

The Orbiter will land at the shuttle landing facility at Kennedy Space Center. Preliminary securing and crew egress will be accomplished. If the payload requires purge, then a unit will be connected on the runway that will provide continuous purge to payload bay until switched over to facility purge. The Orbiter will be towed a short distance to the Orbiter Processing Facility where safing and deservicing operations will be completed. The payload bay doors will be opened, access stands will be installed and payload removal operations will be started. The payload elements will be lifted out of the cargo bay, using facility hoists and standard slings and the hoisting strongback. The payloads will be positioned in the payload canister or in their own transporters and returned to the Operation & Checkout Building, Satellite Assembly Building or Payload Processing Facility for further processing. Airborne support equipment, installed in the cargo bay or in the aft flight deck, will also be removed and returned to the payload contractor for disposition.

ABORTED MISSION LANDINGS

Aborted mission landings may occur at Kennedy Space Center immediately after launch (return to launch site abort) or during later passes in the mission. This is the preferred landing site for cargos as complete payload facilities and equipment are available. Post landing operations at Kennedy Space Center after an abort are very similar to standard Orbiter post-flight activities, except that operations may occur at an accelerated pace. In the case of an aborted landing, all tasks will be based on the following priorities:

a. Flight Crew and Ground Crew Safety

b. Orbiter Safety

c. Payload Safety

Payload operations will not begin until all crew safety and Orbiter safing operations are completed, the Orbiter has been towed to the Orbiter Processing Facility and verification of safe conditions in the payload bay has been completed. The payload contractor will verify that the payload is safe to handle (power off, ordnance safed and no toxic leaks). The payload will be removed from the Orbiter and transported to a facility for deservicing of propellants and ordnance, if needed. The payload will then be prepared for shipment back to the factory. Figure 2 is a typical payload flow sequence and schedule for abort and return to primary landing site. It shows the payload tasks starting with removal from the Orbiter payload bay through preparation for return to the factory.

SECONDARY LANDING SITES

When the Kennedy Space Center becomes the primary landing site, then Edwards AFB will be a secondary landing site. A convoy crew for the Orbiter may not be provided unless a 72 hour notification of intent to land at Edwards AFB is provided. If a landing occurs with less than 72 hours notice, then the flight crew will power down the Orbiter and local equipment and personnel will be used to close the hatch and tow the Orbiter off the runway. No cooling, purge or power will be immediately available unless prior arrangements have been made for those requirements.

The baseline payload plan of operation is for the down cargo to remain in the payload bay for ferry to the Kennedy Space Center. The cargo would then be removed in a normal manner at the Orbiter Processing Facility. However, various requirements may dictate that the cargo be removed in the field. If the combined weight of the Orbiter and the cargo exceeds the capacity of the Shuttle Carrier Aircraft, then all or part of the cargo will have to be removed to meet the weight limitations. Certain hazardous cargo elements will require removal. Other cargo elements may have requirements which will dictate removal such as: heat sensitive film or data; life science specimens, animals, biological samples, etc. A typical operational flow is shown in Figure 3. The Orbiter is safed, deserviced, and towed into the Shuttle hangar at the Dryden Flight Research Facility at Edwards AFB, California. It is jacked, leveled, and the payload bay doors are opened. The payload is removed, deserviced, and prepared for shipment. No cleanliness level is provided at the hangar.

The activation of White Sands Space Harbor is similar to that for a contingency landing site. All the ground support equipment and personnel must be transported to the site. This facility was used as a landing site for the STS-3 mission when the lakebed at Edwards AFB was too wet for landing. If it is determined that White Sands Space Harbor will be the landing site, then it will take a minimum of three days to move in the personnel and equipment just to support a post-landing convoy. It will take approximately eighteen days advance notice, prior to launch, to support a rapid Orbiter turnaround operation.

A special train is required to transport all of the support equipment that is currently in place at Edwards AFB. Cargo operations will be similar to those at a contingency landing site. At White Sands, all cargo operations will take place outdoors, as there is no hangar available. Payload contractors must be prepared for contamination, due to the gypsum and winds which are prevalent. There are no provisions for cargo protection from climatic conditions.

CONTINGENCY LANDING SITES

No Shuttle missions are programmed for landing at contingency landing site locations. The decision to terminate a mission at a contingency landing site is made in flight, in response to a specific mission-related situation. It is assumed that the Orbiter lands in condition for ferry and permission from foreign governments, to initiate recovery operations, will be available after landing.

The contingency landing sites are preselected airfields that can provide for crew and passenger survival, with no Orbiter vehicle unique support specifically implemented. Orbiter post-landing processing at contingency landing site locations consist of the minimum operations to render the vehicle safe and prepare it for return to the Kennedy Space Center.

Turnaround time from Orbiter landing to return to the Kennedy Space Center is several weeks time as shown in Figure 4. This is a success oriented schedule and does not allow for operational problems or adverse weather. No deservicing equipment is prepositioned at the site and no payload bay purge, cooling, or power is available for several days. The high altitude return ferry flight requires complete Orbiter hypergol deservicing, including freeze proofing.

The primary objectives of initial contingency landing site post-landing operations are Orbiter flight crew safety and identification of abnormal Orbiter and/or payload hazards. After landing, the flight crew powers down and secures the Orbiter. The flight crew egresses and a control radius is established and maintained by security forces to restrict personnel around the Orbiter/cargo.

The Landing Recovery Director at the Kennedy Space Center and the contingency landing site Commander are to be notified prior to a contingency landing. In turn, the Kennedy Space Center Transportation Office and the Deployed Operations Team (DOT) are alerted. An advanced party, called the Rapid Response Team (RRT) is assembled and dispatched to the contingency landing site as quickly as possible. The team consists of government and contractor personnel who are expected to arrive at any contingency landing site within 24 (twenty-four) hours of Orbiter landing. The team: inspects the Orbiter and requests the support equipment needed to correct problems; contracts for local heavy equipment needed on the scene; contracts for construction of concrete foundations for some of the disassembly equipment and arranges for quarters for the follow-on crew and the warehousing of ground support equipment.

As aircraft are made available for transportation, ground crews load the ground support equipment and related supplies under the observation of the Deployed Operations Team members. The first aircraft arrives with the Orbiter hazardous fluid deservicing equipment. The ground operations crew, required for such deservicing, arrives with or before this equipment.

The remaining Deployed Operations Team members continue loading the equipment. As aircraft are loaded, a portion of the team departs with them. On arrival, they assemble, check out, and validate the support equipment. Sling kits, payload strongback, hydrasets, transportation containers, protective covers, deservicing equipment, rotational devices, and special equipment are shipped to the landing site, used as required, and returned to their normal resident locations. Provisions are made at the landing site for dual crane (2-hook) hoisting capability.

Orbiter deservicing and mechanical operations at the landing site are conducted on a continuous basis (3 eight hour shifts per day) following landing, until return ferry to the Kennedy Space Center. Payload deservicing and mechanical operations are currently planned on a one-shift-per-day basis. The Orbiter is jacked and leveled and access equipment is positioned. Ground power is connected and initial Orbiter power-up is accomplished. The cryogenic fluids in the Orbiter are deserviced first. If hypergolic systems are damaged and hypergolic fluids are draining or venting, or these systems are in danger of freezing, then the hypergolic systems are deserviced first. The Orbiter is vented, drained, purged, and the subsystems and ordnance are safed. It is at least fifteen (15) days after the abort landing before the cargo can be removed from the Orbiter payload bay.

Payload and Orbiter operations are then conducted in parallel. All Orbiter and payload operations are outdoors (no hangar is provided). No particular cleanliness level is provided for payload removal operations. Mobile cranes are used to open the payload bay doors. The cranes are also used for lightning protection of the Orbiter and payload.

Payload bay access platforms are installed to provide access to: payload/Orbiter attach fittings (longerons); payload/-Orbiter electrical interfaces; and payload/strongback attach points. Limited payload bay access equipment may delay the initial payload safing until after the payload is removed from the Orbiter.

Cargo elements are removed from the payload bay by NASA and are normally turned over to the user for disassembly and packaging for transportation. For cargo made up of multiple elements, the elements are removed individually. Orbiter preparations for mate to the Shuttle Carrier Aircraft proceed parallel with payload disassembly operations. When payload and Orbiter operations are complete, all work platforms and ground support equipment are removed. Rental equipment is returned to the lessor. All waste fluids are disposed of by NASA. The area is cleaned and restored to the satisfaction of the local Base Commander. The current plan is to return all ground support equipment by chartered ship.

TYPICAL CONTINGENCY LANDING SITE PAYLOAD RECOVERY OPERATIONS

The Tracking and Data Relay Satellite/Inertial Upper Stage payload has been selected to illustrate contingency landing site payload recovery operations. These tasks are shown in the bar chart (Figure 5).

TRACKING AND DATA RELAY SATELLITE (TDRS)

A Tracking and Data Relay Satellite is one of a series of communication satellites, built by TRW. The TDRS is boosted into a geosynchronous orbit by the Inertial

Upper Stage carrier so it can provide dedicated tracking and relay services to NASA for Space Transportation System Operations. The TDRS is a 3-axis stabilized spacecraft, using biased momentum wheels. The structure is totally modular, including an antenna module, communications module and a support system module. Electrical power is supplied by deployable sun oriented panels and batteries. All interfaces with the Orbiter are via the Inertial Upper Stage and associated airborne support equipment. The TDRS weighs 5,000 pounds (approx. 2250 kg) of which approximately 1,500 pounds (approx. 680 kg) is hydrazine (N_2H_4) propellant which is pressurized to 340 psig (approx. 24 kg/cm^2).

INERTIAL UPPER STAGE (IUS)

The Inertial Upper Stage is a solid rocket booster, developed by the Air Force and built by Boeing to add to the Space Shuttle the capability to place satellites in high orbits. The major components are two sizes of solid rocket motors and an avionics bay. The IUS weighs approximately 32,500 pounds (approx. 14700 kg), of which about 27,400 pounds (approx. 12400 kg) is solid propellant motors. The payload is structurally supported in the payload bay, by the IUS Airborne Support Equipment (ASE). The total weight of the IUS/TDRS and associated ASE is approximately 45,000 pounds (approx. 20,000 kg).

Access to the payload is initially through a panel in the righthand Orbiter wheel well. The payload bay liner is opened and protective covers and limited access equipment are installed. The payload bay doors are opened approximately 15 days after landing. Payload bay access equipment is lowered and positioned to access payload interfaces. All of the payload to Orbiter electrical interface cables are disconnected. Protective covers are installed on the IUS reaction control motor nozzles, first stage solid rocket motor nozzle and antennas where accessible. The payload mechanical interfaces to the Orbiter are disconnected. A large payload strongback is positioned by two cranes over the payload bay. The strongback is attached to the payload airborne support equipment trunnions. The combined IUS/TDRS is then hoisted out of the payload bay and lowered into a modular payload handling fixture (Figure 6). This device is the only major element that has been designed and built solely for contingency payload operations. The strongback is detached and removed. Some initial safing operations take place and additional protective covers are installed. The payload handling fixture is towed to a propellant deservicing area. The TDRS propellant tanks are drained. The payload handling fixture is then towed to a payload processing area. Access platforms are installed, the handling fixture is attached to a base, and the payload and handling fixture are rotated to vertical by a crane. Access panels are opened and the flight avionics and utility batteries are removed. Ordnance devices are removed, and preparations are made for demating the TDRS from the IUS. The Spacecraft access platform is removed, the TDRS is demated from the IUS, and lowered onto a transporter, where it is rotated to horizontal and secured for shipment.

IUS operations continue in parallel with TDRS deservicing. A lifting fixture is connected to the IUS and preparations are made for removal from the payload handling fixture. A crane hoists the IUS away from the payload handling fixture and positions it on an assembly stand. The IUS is then disassembled into its major component parts:

- Forward ASE frame
- Equipment Support Section
- Navigation Subassembly
- Second Stage Rocket Motor
- Interstage Assembly
- First Stage Rocket Motor
- Aft Skirt and Aft ASE Frame

CARGO IMPACTS

The manpower and equipment needed to support a payload recovery operation after an aborted mission will come from the launch operations team and the launch site facilities. This will have a disruptive effect on the operational flow of follow-on missions. At most locations, there will be no post landing cooling, environmental control, or power available for the cargo. There will be a long delay before the payload can even be accessed. The cargo will have to be removed outdoors, where it will be exposed to all the environmental elements and the corresponding contamination. Limited payload bay access may dictate that part or all of the initial payload safing functions be delayed until after payload removal from the Orbiter. Various hazardous operations such as ordnance safing and propellant drain may take place in less than optimum conditions. Overseas landing sites will have only limited communications available. Payload recovery, from a remote location, will be a major logistics operation. It is currently estimated that it would take approximately 27 C5A and 14 C141 aircraft to airlift all of the Orbiter and payload support equipment to a contingency landing site. As a consequence, payload contractors must plan for recovery operations well before each mission. It is incumbent on the payload contractor to develop a payload recovery plan and the procedures to support that plan.

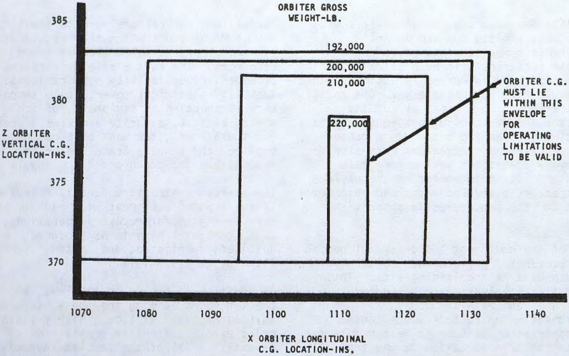
All of the equipment and personnel needed to recover the payload and Orbiter must be transported to the landing site. This operation involves several hundred personnel and massive amounts of support equipment. The Kennedy Space Center Transportation Officer is responsible for arranging transportation to and from all off-site locations for both personnel and support equipment. The payload contractor is responsible for identifying the recovery personnel they need to support the Deployed Operations Team. Each member of the team and their alternate must have the appropriate training for the tasks they are to accomplish and the equipment they are to use. In addition, they are to have the required training for access, safety, security and area orientation. Contractors are responsible for obtaining their own passports, appropriate visas and international drivers licenses. Each team member must also obtain the proper immunization. Contractors are to submit a detailed recovery personnel listing well in advance of launch.

Payload contractors must identify all of the ground support equipment which they will require for payload recovery operations. The payload contractor must specify such things as: current equipment location, weight, volume, hazardous contents, and when required on the recovery site. This listing must also be submitted well in advance of launch. The contractor must further identify all of the Government furnished support equipment which he will need for payload recovery. This would include such items as: cranes, forklifts, payload strongback, high rangers, payload handling fixture, scaffolding, etc. The concept for support equipment is to take only the minimum equipment necessary and to cross-utilize Orbiter/payload equipment when possible.

The payload contractors need to identify all of the support which they require for payload recovery, which exceeds their resources. The host airfield is tasked to provide various facility support items, such as: electrical power, fuel, temporary warehousing of equipment, office space, medical, security and fire support. For those items, the host base can not provide, the Kennedy Space Center is responsible for procurement and supply.

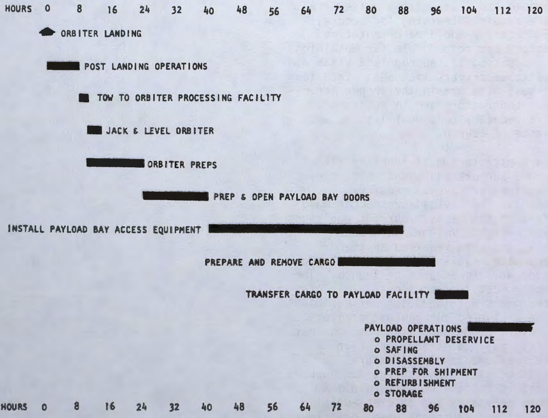
The payload contractors need to determine if any support equipment will have to be developed just for recovery operations. Such items will have to be procured, designed, fabricated, and tested. Early planning is essential.

In addition to the other problems, an Orbiter abort landing and the subsequent payload recovery will be a highly visible media event. Extensive preplanning is essential. All of the problems associated with a complex operation will be magnified by the remote locations and long distances from the launch site.



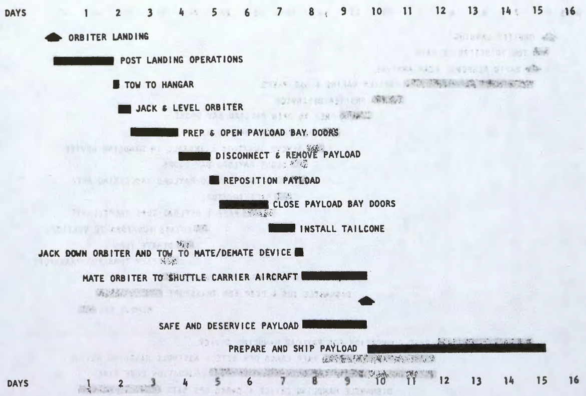
PERMISSIBLE C.G. LIMITS
FOR HEAVY ORBITER FERRY

FIGURE 1



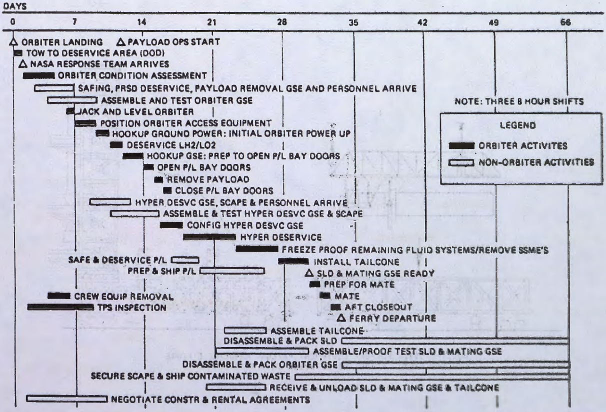
TYPICAL PAYLOAD REMOVAL AT PRIMARY LANDING SITE (KSC)

FIGURE 2



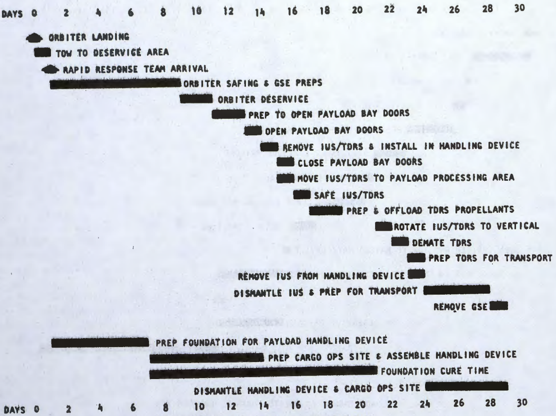
TYPICAL PAYLOAD REMOVAL IN ORBITER HANGAR, EDWARDS AFB

FIGURE 3



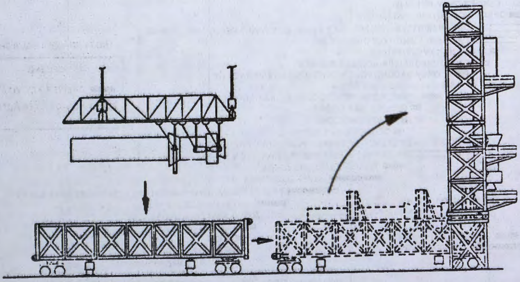
TYPICAL ORBITER AND PAYLOAD RECOVERY FROM A CONTINGENCY LANDING SITE

FIGURE 4



IUS/TDRS CONTINGENCY LANDING SITE OPERATION

FIGURE 5



MULTI-MISSION SUPPORT EQUIPMENT PAYLOAD HANDLING FIXTURE
PAYLOAD INSTALLATION AND ROTATION TO VERTICAL.

FIGURE 6