DEPLOYMENT AT THE SAVANAH RIVER SITE OF A STANDARDIZED, MODULAR, TRANSPORTABLE AND CONNECTABLE HAZARD CATEGORY 2 NUCLEAR SYSTEM FOR REPACKAGING TRU WASTE

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ABSTRACT

This paper describes the conception, design, fabrication and deployment of a modular, transportable, connectable Category 2 nuclear system deployed at the Savanah River site to be used for characterizing and repackaging Transuranic Waste destined for the Waste Isolation Pilot Plant (WIPP). A standardized Nuclear Category 2 and Performance Category 2 envelope called a "Nuclear Transportainer" was conceived and designed that provides a safety envelope for nuclear operations. The Nuclear Transportainer can be outfitted with equipment that performs functions necessary to meet mission objectives, in this case repackaging waste for shipment to WIPP. Once outfitted with process and ventilation systems the Nuclear Transportainer is a Modular Unit (MU). Each MU is connectable to other MUs – nuclear or non-nuclear – allowing for multiple functions, command & control, or increasing capacity. The design took advantage of work already in-progress at Los Alamos National Laboratory (LANL) for a similar system to be deployed at LANL's Technical Area 54.

INTRODUCTION

The Carlsbad Field Office (CBFO) has promoted a national approach to accelerating characterization and disposal of transuranic wastes. One of the cornerstones is the use of transportable systems for characterization and repackaging that can travel to small sites where building a fixed facility is not economical, or to supplement capabilities at large sites.

DOE sites must characterize waste generated by operations for disposal at the Carlsbad Waste Isolation Pilot Plant (WIPP). WIPP has established waste acceptance criteria (WAC) for contact-handled transuranic (TRU) waste, and meeting these criteria requires characterizing the waste to ensure it meets WIPP storage requirements as well as Department of Transportation (DOT) requirements for shipping TRU waste to WIPP. A fraction of the waste must be inspected visually to verify the drum contents or to remove prohibited items or to repackage the waste into more drums to meet the WAC.

Los Alamos National Laboratory (LANL) developed the concept and the engineering basis for the detailed design of a nuclear qualified transportainer that can be used to support repackaging and visual examination operations. The approach is based on a transportable Hazard Category 2 nuclear facility called a Nuclear Transportainer. The Nuclear Transportainer is standardized to minimize fabrication costs and is self-sufficient. All that is required is connection to site's electrical power and communication system. LANL's Nuclear Transportainer design requirements include safety class and Performance Category 3, that is, design basis earthquake, wind and other natural events as well as a 2-hour fire rating. Nuclear Transportainers can be connected to each other in a variety of spatial configuration to fit available space.

Merrick & Company working with LANL, prepared the detailed design and specifications to meet the design basis requirements, authorization basis requirements, and process performance demands. The rigorous requirements of Performance Category 3 at LANL are due to a large inventory of waste contaminated with Pu-238 and the relative proximity to the public. The Savannah River Site needed a Performance Category 2 facility and the LANL design met the requirements easily. In fact, it is expected that this design will meet the requirements of most if not all Department of Energy (DOE) sites because the national inventory is mostly Pu-239, or because the inventory in each Nuclear Transportainer can be limited to Hazard Category 3.

The Nuclear Transportainer is then equipped with process equipment and becomes a Modular Unit (MU). LANL has designed a repackaging MU, called MORK, to visually examine waste, retrieve prohibited items, or divide waste that exceeds the radioactive limit for transportation. MORK contains two 16-feet long gloveboxes. A drum of waste, up to 85 gallon, is bagged on a glovebox and can be repackaged into up to four 55-gallon bag-out drums. Drum lifts are provided for the waste drum and the daughter drums. The glovebox frame and the lifts are seismically designed.

The MORK is one module that may comprise a characterization system used to characterize waste for shipment to WIPP. The MORK is self-sufficient and does not require other MUs to operate, however it can attach to other MUs via a spool, allowing movement between MUs. Other MUs have been designed that provide support capabilities such as monitoring of systems (MOCOSO) and storage of drums (EMU). The SRS characterization system includes two MORKs, one MOCOSO, one EMU, six spools, and three receiving modules. The MOCOSO, includes a room with a full-body monitor, two change rooms, and the command room itself that permits remote visual examination operations in the gloveboxes, and logging and trending of the various signals and alarms from each transportainer. The EMU can be used for temperature equilibration, for example of frozen drums or prior to headspace gas analysis.

PART I - DESCRIPTION OF MODULAR UNITS CAPABILITIES

The National Transuranic Waste Program (NTWP) scheduled goal for TRU waste disposition is 2034. CBFO wants to accelerate disposal by ten years, saving up to $6 billion dollars. CBFO and the National TRU Waste Corporate Board have identified deployment of characterization and remediation systems composed of modular and mobile units as a cornerstone of the implementation approach.

CBFO and the National TRU Corporate Board want to provide systems to sites to process the 240,000 drums located throughout the DOE complex and identified in The National TRU Waste Management Plan, Rev 2. This plan calls for systems to be deployed to 17 small quantity sites (SQS) and support large quantity sites. Systems will provide the equipment necessary to properly characterize, repackage, stabilize, certify, load, and transport to WIPP the waste stored at these site. Ideally the systems will be standardized to achieve flexibility in the composition of a system, and savings in fabrication, document preparation, and operation.

LANL's approach to meet the functional and performance requirements of the TRU National Programmatic needs was to:

1. design a standardized nuclear enclosure that meets Hazard Category and Performance Category needs commensurate with the worst case scenario found at the candidate DOE sites,
2. utilize this "Nuclear Transportainer" to house systems (Modular Units – MU) that meet the operational performance goals for expediting waste shipments to WIPP, and
3. ensure these "Modular Units" are transportable, connectable, and self sufficient.

NUCLEAR TRANSPORTAINER

The Nuclear Transportainer is a standardized protective shell that encloses the interior components and doubles as a transportainer when taking the module from site to site. The Nuclear Transportainer is the foundation designed to make the MU a self-sufficient mobile system that is designed for radioactive operation and can be augmented at will by attaching other MUs.

Nuclear Safety Requirements

The Nuclear Transportainer must be able to withstand external risks and ensure confinement of the nuclear material during operations. A review of the waste at the candidate sites, the likely locations for sitting the systems, and the natural phenomenological design basis requirements resulted in the following Nuclear Safety design requirements for the Nuclear Transportainer:

- **Hazard Category 2**
  The Material at Risk (MAR) limits for design of the transportainer are 1000 PE-Ci per waste container and 2000 PE-Ci per Nuclear Transportainer based upon available acceptable knowledge (AK) for the various sites. Most sites have lower MAR limits as their wastes does not contain PU-238 or has lower loadings per drum, more in line with Hazard Category 3.

- **Performance Category 3**
  Locations at the sites identified for setting the MUs, the expected MAR, and the proximity to the public drive the Performance Category (PC) requirements. The LANL sitting and MAR limits were restrictive enough to set the PC 3 requirement. Other sites benefit from sittings further from the public and/or lower MAR limits, resulting in a reduced PC2 requirement.

Performance Requirements

The Nuclear Transportainer must meet various performance requirements associated with movement, sitting, functionality, and life cycle issues. Performance requirements play an important role in constraining many characteristics of the MUs. Identifying all of the performance requirements was an iterative and on-going process. The following performance requirements were identified for the Nuclear Transportainer.

- **Transportable –** The Nuclear Transportainer must be capable of being moved across roads and being relocated from one site to another. This limits its height, width, length, and weight and it must be be lifted and set in place once it reaches its destination.

- **Connectable –** The Nuclear Transportainer must be self sufficient and also capable of being connected to other MUs to provide for expanding capability, throughput, and additional characterization. Doors and openings need to be sized and located to allow for maximum flexibility, allow for installation and removal of equipment, support anticipated maintenance activities, and accommodate potential process related requirements. Connecting MUs must ensure the Safety Class nuclear envelope in case of a seismic or wind related event.

- **Flexible –** The Nuclear Transportainer must accommodate various operations and be useable at all candidate sites with minimal additional infrastructure. Utilize as much interior space as is possible to accommodate process related systems for mission needs given the constraints provided by exterior dimensions. The number, size, and location of the doors and the location of utilities such as ventilation ducting and HEPA filters should be configured so as to maximize operational space.

Potential waste characterization operations that may be placed in a Nuclear Transportainer include drum storage, repackaging, visual examination, head space gas analysis, drum coring, sample analysis, RCRA treatments and activities such as oversight and change rooms.

- **Standardized** – The Nuclear Transportainer including the utilities and ventilation system will become the standardized envelope that processes are placed into. Standardization will reduce production and design costs and ensure MUs can be connected regardless of who funds fabrication or deploys the MU. Connection to site utilities and communication systems should be standardized such that all sites know what to expect when preparing for a deployment. Fire suppression and alarms should be designed to meet all sites requirements.

- **Life Cycle Friendly** – The design and fabrication must include life cycle issues including reuse and disposal. The Nuclear Transportainer should be configured for ease of decontamination and reuse by selecting materials and incorporating design concepts that promote reuse. Disposal costs for the MU are minimal when compared to a fixed facility as the MU can be disposed as is and the interior space used for storage of other waste items.

Process Operations Requirements

Waste characterization operations have certain basic requirements that are related to the waste, its movement, and containers. The Nuclear Transportainer must be designed to ensure these requirements are met and the necessary operations can be performed.

- **Drums** – Waste is typically packaged in 55 gallon and 85 gallon drums and can contain up to 1000 pounds of material. Access to the MU and within the MU must ensure these containers can be accommodated in a manner that allows for performing necessary operations and meeting production goals.
- **Waste** – Waste contains transuranic nuclides including PU 238 and may contain other materials that can be reactive. Drums are always vented and have been examined via non-destructive examination before they are accepted. The mobility of PU-238 and the potential for reactive waste are risks the design must accommodate.

- **Throughput** – Production is the main driver for these systems so they must provide for the productivity demands the sites have identified. This can be achieved by providing space for operations, allowing for connecting additional systems, and providing simple safe operating environments.

- **Communication** – The MU must be capable of communicating with the site and with other MUs that are connected. This is necessary from a productivity and safety perspective.

General Configuration

Nuclear Transportainers internal dimensions are 12 ft wide by 11 ft high and 45 ft 6 in. long. Walls and ceilings are approximately 4-in. thick. Floors are about 6-in. thick. The framework is made entirely of metal. Transportainers are insulated with non-combustible insulation, and the inside (ceiling, walls, roof) is lined with 16-gauge stainless steel, which provides a radioactive material release barrier that can readily be decontaminated. All stainless steel seams are sealed. Figure 1 shows a general layout of the transportainer. All transportainers are equipped with fusible-link dampers to cover the high efficiency particulate air (HEPA) filter penetrations. This provides complete isolation of the transportainer in the event of a fire. Transportainers must meet performance category (PC) 3 criteria for LANL natural phenomena hazard events.

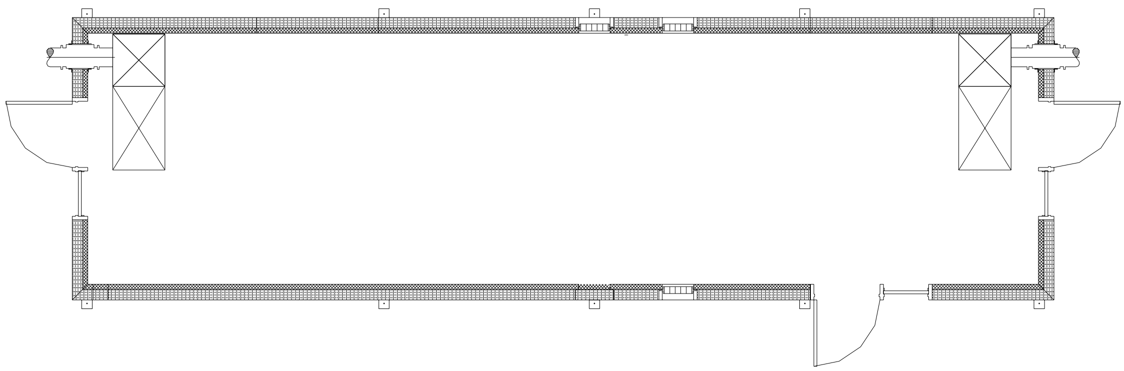

Fig. 1 Nuclear Tranportainer Floor Plan

Transportainers have one exterior door opening at each end, and two door openings on each side. Doors not in use can be sealed with a blind plate. All doors open to the outside and provide a tight seal. Exterior doors, panels and frames are stainless sheet steel and insulated with an R value of 10. They are SDI-100, Grade III, extra heavy-duty, Model 2, minimum 16-gauge faces, insulated–fire rated B label. Closed top and bottom edges of exterior doors are integral parts of door construction or by addition of minimum 16 gauge inverted steel channels.

Frames, concealed stiffeners, reinforcement, edge channels, louvers, and moldings are from either cold-rolled or hot-rolled stainless steel. Frames are a minimum of 16-gauge cold-rolled stainless steel. They are designed with mitered and welded corners. Door silencers are drilled to receive three silencers on strike jambs of single doorframes and two silencers on heads of frames with pairs of doors.

Penetrations through the exterior walls include ductwork, electrical conduit, and personnel doors. All transportainer penetrations, such as for ventilation and exhaust system ducts, pipes, and conduits, are sealed. Pipes, ducts, and valves are weld-type or flanged when it is impossible to weld such components.

Because the MU transportainers are intended to be moved and relocated, lifting points are designed for cranes. Equipment that might be attached to a transportainer includes instruments, piping, ducts, conduits, emergency lights, standard lights, elevated HEPA filters, and bracing.

Penetrations through the transportainer shell permit gases or fluids required for operations to be piped inside. Nitrogen is needed to inert the glovebox. These penetrations are sealed with a Thru-Wall Barrier® cable/conduit sealing device and threaded at both ends so they can be capped when not in use. Three sets of stainless steel penetrations are provided.

MODULAR UNITS

The Modular Units to be deployed to SRS and LANL are designed to meet critical mission goals associated with characterizing and packaging waste destined for disposal at WIPP. The Modular Units are specifically designed to help achieve these goals quickly and cost effectively.

Description Mission Needs

The TRU wastes under consideration for characterization and possible repackaging represent a volume of about 5,000 m^3 at LANL alone. They are contaminated with many radioisotopes, the largest fraction being contaminated with one or more of plutonium 239, plutonium 238, and americium 241. The total population of waste drums—85 gallons or less—is about 26,000. Of this population, about 60% contain prohibited items—typically large capped bottles that must be uncapped before putting back in the drum—and a few hundred drums contain high-wattage waste contaminated with Pu-238 that needs repackaging to meet the wattage limit. On average, the latter will generate 4 to 5 daughter drums per drum of waste.

When drums are repackaged, they must meet three limits related to the radioisotopic content: Pu-239 fissile gram equivalent (FGE), Pu-239 equivalent activity (PE-Ci), and wattage, which is a limit that varies with the matrix. The population of Pu-238 waste contained a high number of drums above the wattage limit for combustibles (paper, plastic, rags, etc.), which is one gram of Pu-238.

Detailed information on the high Pu-238 waste drums is not always available. During NDE or repackaging it may be found that the Pu-238 has been packaged separately from the combustibles. In this case, it may be advantageous and easier to repackage Pu-238 in cans and then in pipe overpack, which increases the TRUPACT-II loading. The design of the repackaging glovebox located in the MORK will permit repackaging in cans, and the cans in pipes as well as in 55-gal drums.

The MAR limits for determining consequences are 1000 PE-Ci per waste container, 2000 PE-Ci per MU, and 4000 PE-Ci per Facility

The Nuclear Transportainers serve as the base standardized design of the outer containment enclosure, while internal systems, fittings, and operational equipment are designed to perform the specific functions and make up the Modular Unit or MU. The SRS MU system is designed to link and integrate together. Spools are used to connect the MUs and a receiving module is used as a shipping/receiving dock. The following components makeup the SRS system and a proposed configuration is shown in Fig. 2:

1. Two MUs equipped with gloveboxes and the necessary support and systems to process drums of waste in the waste characterization operations, such as visual examination and waste repacking (MORK);
2. An MU designed to stage waste drums and prepare them for MORK operations (EMU)
3. An MU equipped with radiological monitoring equipment, warning and communications systems from the other MUs, and computer systems to capture and record characterization data (MOCOSO);
4. A receiving module used to unload waste drums and prepare them for operations or for shipment to other onsite location(s) after characterization (Receiving Module); and
5. Spools that link MUs together.

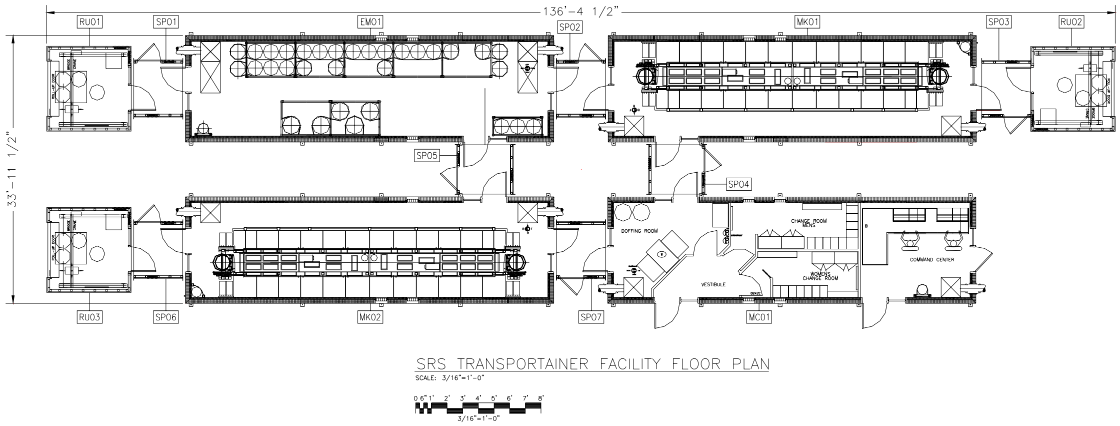

Fig. 2 Proposed SRS site layout

Visual Examination and Repack Modular Unit – MORK

The MORK is an MU that houses two gloveboxes used to (1) open drums (2) examine their contents and (3) repackage the waste in drums for shipment and disposal at WIPP. The MORK is designed to accommodate the needs of operators tasked with characterizing waste and at the same time ensure their safety as well as protect the environment and the public. A conceptual floor plan and elevation view of the MORK is shown in Fig. 3.

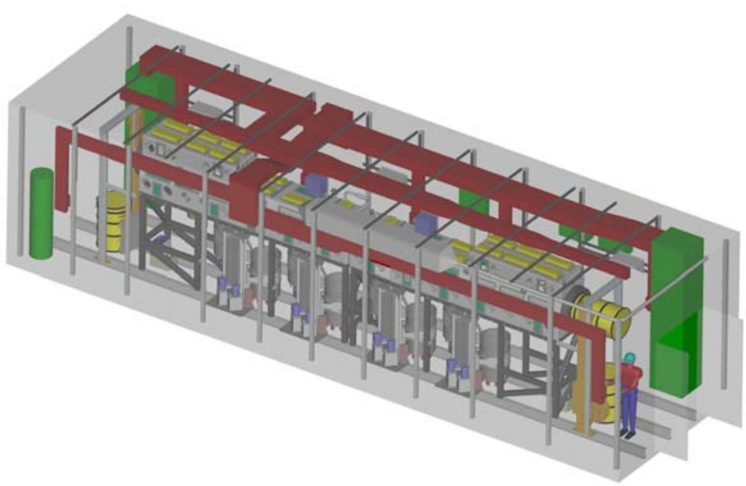

Fig. 3 MORK Configuration

The MORK can attach to other MUs via a spool that allows movement between MUs. Other MUs provide support capabilities such as monitoring of systems, storage of drums, or other waste characterization equipment. The MORK benefits from connecting to (1) a support and control MU (MOCOSO) that provides space for monitoring characterization operations and change rooms for the workers, and (2) a drum storage MU (EMU) that makes staging and preparation of drums for characterization more efficient. Each MU can be joined easily to other MUs.

Within the MORK, two gloveboxes are aligned end-to-end and are fastened to the floor of the transportainer. The glovebox is composed of 11-gauge stainless steel and presents a significant load. The total weight for the two gloveboxes loaded with drums is expected to be up to 1600 kg. The supporting structure of the glovebox attached to the floor must withstand the stresses involved with transportation.

The glovebox assembly comprises the following systems:

- **Glovebox -** The glovebox is the most contaminated zone in the MORK MU configuration, and the glovebox exhaust and ultimately the MORK MU glovebox exhaust HEPA filter system are subject to contamination. Glovebox exhaust system must be sufficient to maintain negative pressuresinside the glovebox in the event of a breached glove(s). The general dimensions for each glovebox are 40-in. wide by 48-in. tall, by 16-ft long. Each glovebox has the following features:

  - inerting gas supplied to the glovebox interior to prevent fires;
  - a tray to collect free liquids from the parent drum is located under the parent drum port mouth;
  - five stations on each side, one bag-on port for waste drums located on the vertical end face and designed for both 55-gal and 85-gal overpack waste drum, and 4 bag-out ports for 55-gal daughter drums;
  - a trolley to lower objects weighing up to 500 lb into a daughter drum;
  - a high purity Germanium (HPGe) counter, to measure the amount of radioactive material;
  - electrical connections for tools;
  - seismically glovebox designed stand

  A video camera is mounted outside a top window and is aimed at the sorting area. Hooks are provided to hang lead blankets in front of the underside of the glovebox. A LANL exposure study[1] shows that for the high wattage drums lead glass is required on the windows, the stainless steel thickness is sufficient and no shielding is required behind it.

- **Drum lifting mechanism -** The glovebox is equipped with an electric drum lift fixture. It performs vertical and horizontal translation on a drum that can weigh up to 1000 lb. The waste drum lift is designed to hold either a 55-gal or an 85-gal drum securely and lift it to and from the glovebox waste drum receiving port. The lift is provided with mechanical features preventing the drum and its platform from dropping in case of a power failure. The drum lift mechanism includes a PC-3 seismically designed frame, seismically designed frame guards, limit switches, and locking mechanism should the electrical power be interrupted.

- **Daughter drum lift -** The daughter drum lift is designed to move the drum vertically from its position on the cart. A daughter drum is an empty drum without a lid into which a plastic bag is inserted (a plastic rigid liner in the plastic bag will prevent sharp objects from tearing the bag). Once the drum is brought to the glovebox bag-out station, the drum will be attached to the lift and the bag will be attached to the bag-out port. Then the drum will be lifted vertically until the mouth of the drum is at about the same level as the glovebox floor. After waste has been placed into the drum, the drum will be lowered back onto the cart, bagged out, and the lid installed.

- **Inerting system for the glovebox -** The glovebox inerting system provides an oxygen deficient atmosphere that prevents ignition of pyrophoric, reactive or other materials that may be present in the processing glovebox. Supply in the form of liquid nitrogen comes from a Dewar through pressure regulator. A flow-limiting orifice limits the nitrogen flow. It is planned to use a maximum of 5 cfm of nitrogen for the initial inert flush, and a few CFH through for routine operation. The pressure switch closes a supply solenoid valve in case the pressure exceeds a set value in the glovebox. An oxygen monitor is supplied in the glovebox to monitor oxygen concentration within the box and initiate a local alarm should the concentration exceeds approximately 2% O_2 by volume. Normal O_2 concentration during operations is expected to be about 1% or less.

- **Personnel work platform -** A platform is attached to the floor of the MORK MU and runs alongside the glovebox so that operators are at the proper elevation to use the gloves. This platform is segmented, and each segment can be lifted to allow drums to be placed and removed from the receiving ports underneath the glovebox. On one side of the glovebox a hinge is attached to the wall to lift the platform. On the other side, the hinge is attached to a freestanding frame/railing. A locking mechanism prevents the platform from falling back when in the up position. The underside of the platform has plastic or rubber protection so drums are not scratched when they are moved into or removed from their position underneath the glovebox.

Modular Command and Safety Oversight Modular Unit – MOCOSO

The **MO**bile **CO**mmand and **S**afety **O**versight unit, shown in Figure 4, is a transportainer divided into four rooms. There are no characterization operations in MOCOSO and no safety equipment; therefore, the structure need only be commercial grade. Operators coming out of a MORK enter an airlock where a hand and foot monitor is located. Operators then scan themselves in a full-body monitor in the doffing room of MOCOSO. This is the only MOCOSO room where potentially contaminated personal protection equipment is handled. This room is protected by small nuclear grade HEPA filters on supply and exhaust and it is maintained under negative pressure vis-à-vis the airlock and the foyer. The foyer is practically at outdoor pressure and is used to either exit, or go to a change room. There are 2 change rooms with lockers.

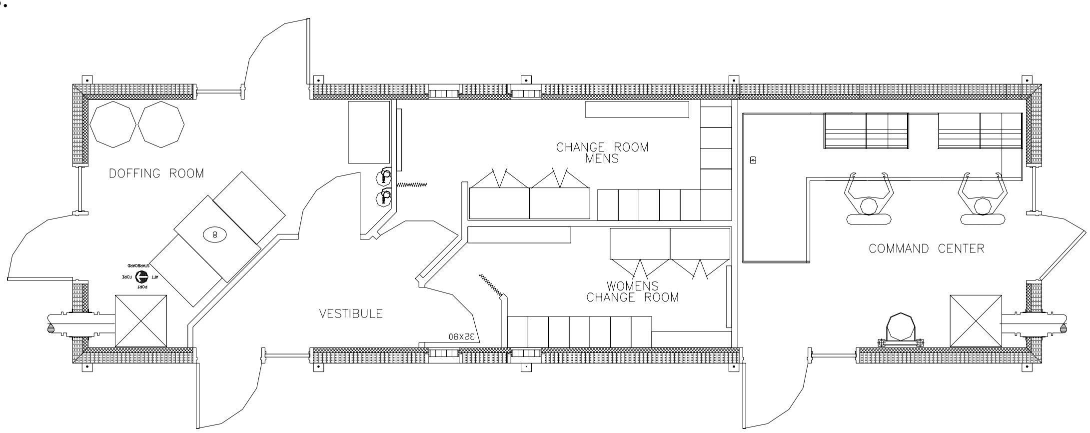

Fig. 4 MOCOSO Configuration

The fourth room, which does not communicate with the first three, is the command center. All signals from a MORK are repeated in the command center and logged. The command center is <u>not</u> a control room. Its purpose is to allow supervisors to review long-term trends of signals logged, examine images transmitted from the glovebox during repackaging operations, inform operators of incoming deliveries of drums, or a truck coming to remove repackaged drums, inform other operators or site personnel.

The command center is equipped with instruments and computers, and its pressure is slightly positive vis-à-vis the outdoor. Ventilation is provided through a non-nuclear HEPA filter.

Equilibration Modular Unit – EMU

Equilibration occurs in an MU dedicated to that purpose called an EMU. Drums are brought into the airlock spool, rolled into the EMU, and stored on each side of the MU if they are non-RCRA, or in one row on each side and one row in the middle if they are RCRA and therefore must be inspected daily. The EMU configuration is portrayed in Figure 5.7

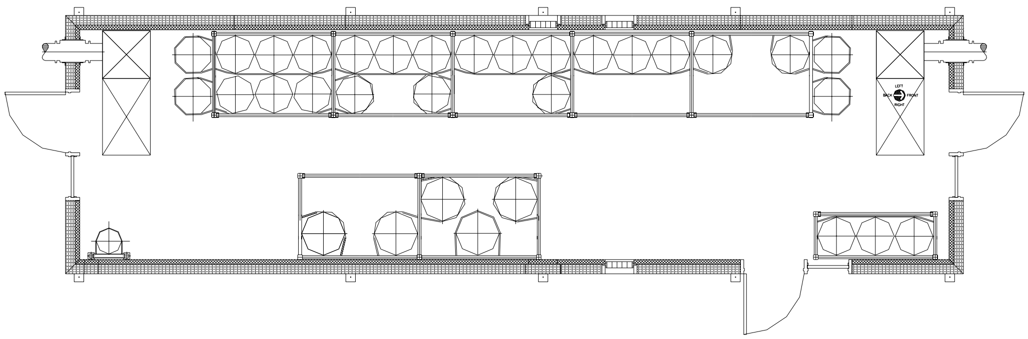

Fig. 5 EMU Configuration

Certain modifications are required to a standard MU that is to be used for equilibration. Hooks are attached to the wall for strapping the drums to prevent their moving during a seismic event. One removable railing is installed in the center to hold RCRA drums. Hooks are used to suspend the railing on a wall when it is not in use.

"Elephant trunk" exhausts are made available at various locations to vent drums found to be generating flammable gas. These trunks are connected to the MU's exhaust system and have a magnetic ring at the open end to attach the trunk to the drum around the vent filter.

Flammable gases are monitored in real time in the room and the exhaust system. The detector activates an alarm before the concentration reaches the lower explosion limit (LEL) for the volatile organic compounds (VOCs) and other gases of concern.

All waste processed is of the contact-handled (CH) type, but up to 60 drums can be accumulated in one MU (non RCRA). Calculations are made of exposure as a function of radioactive inventory and distance and are used to determine if shielding is necessary. At a minimum, lead blankets are available for drums that are high gamma and neutron emitters.

Containers at a wide range of temperatures are brought from storage to the equilibration MU. In this temperature-controlled environment, the containers will breath through their vent filters. Therefore:

- the ambient air turnover rate in the equilibration MU must meet OSHA regulations;
- used air must go through an activated-carbon filter in case some VOCs are released; and
- workers must be protected from exposure to the gases.

Receiving Module

The receiving module, shown in Figure 6, is a small (10 ft × 10 ft) module through which drums of waste and daughter drums transit into and out of a MORK via an airlock spool. Drums are not stored in this module. A single waste drum, or two at the most, is brought inside the module through the overhead door via a forklift. The drum is lifted a maximum of one foot from the floor by a non-stationary lifting device not attached to the structure, a plastic sleeve is then connected to the drum and the drum lowered onto a cart. The waste drum is rolled into a MORK through the airlock spool. Because no storage of waste drums is allowed in a MORK, completed daughter drums must first be removed through the receiving module before another drum can be brought inside the module, unless an EMU is used for staging.

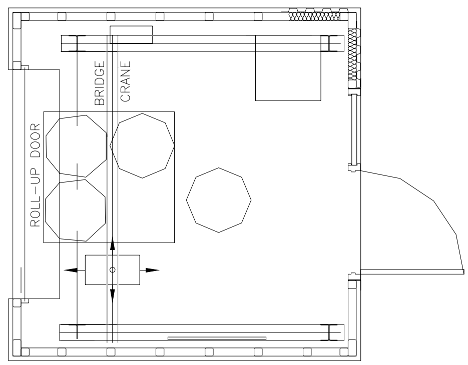

Fig. 6 Receiving Module Floor Plan

Spool

A connecting spool, shown in Figure 7, is a standardized module whose principal function is as an airlock that connects transportainers to each other. The spools provides an unimpeded smooth surface to allow drums to be rolled drums between MUs, the capability of being decoupled from the MUs, and the capability to separate from the transportainers during an earthquake or high winds, thus protecting the integrity of the MU(s) to which they are attached.

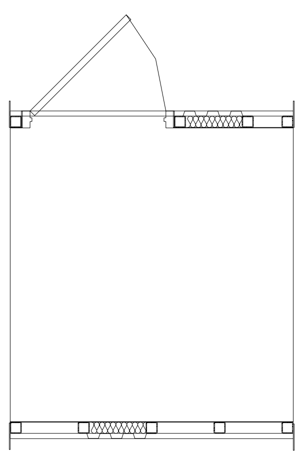

Fig. 7 Spool Floor Plan

PART II – ENGINEERING

Selection of LANL criteria as the design basis for the Nuclear Transportainer provides a level of conservatism that will make it adaptable at many sites. The safety categorization of systems in accordance with LANL procedures appropriate for hazard category 2 facilities also supports adaptation of the design at other sites. Application of the LANL Nuclear Transportainer design at all DOE sites will require further evaluation and likely additional engineering. A review of DOE Standard 1020 reveals that site-specific natural phenomenon hazards are more demanding at certain locations. For example, a number of DOE sites must consider the effects of tornado, whereas the Los Alamos design is not required to do so. Wind missiles contemplated under a design basis tornado are propelled at much higher maximum wind speeds, and are of significantly greater mass. Similarly, seismic design requirements also vary at DOE sites. Maximum horizontal ground surface accelerations at Los Alamos will be higher than the majority of other DOE sites but not in all cases.

Hazard categorization and system safety categorization was made based on LANL operations and proximity to site boundaries. These two attributes play an important role in the applicability of the engineering utilized for the LANL Modular Units and must be considered when contemplating adaptation at other DOE sites.

HOW SITE SPECIFIC REQUIREMENTS CHALLENGE THE DESIGN

LANL Site Specific Requirements

The Transportainer structural systems were designed to provide a confinement envelope for a hazard category 2, performance category 3 facility. Table I provides an over view of the site-specific requirements employed for the structural confinement envelope of the Nuclear Transportainer. In addition to the natural phenomenon hazards described in DOE Standard 1020, the LANL project also contemplated an external fire resulting from local wildfire.

The confinement envelope of the Nuclear Transportainer was designed to accommodate forces and insults resulting from external fire, seismic and wind design basis accidents. Other LANL site-specific requirements played a role in the development of protective systems for the Nuclear Transportainer and Modular Units. These requirements covered topics such as lightning protection and grounding, fire protection, and special facility equipment design such as gloveboxes and drum lifters. The LANL site-specific requirements for the engineered systems comprising the modular units, are based in part upon experience, judgment and standards originating at Los Alamos National Laboratory.

Table I Structural Site Specific Requirements

System	Performance Category	Safety Category	Other DBA/System
Foundation/Anchorage	PC-3	Safety Class	
Structural Steel Frame	PC-3	Safety Class	
Exterior Cladding	PC-3	Safety Class	Exterior Fire/ 2-Hour Rating
Roof System	PC-3	Safety Class	Exterior Fire/ Class A Roof
Doors	PC-3 [1.]	Safety Class [1.]	Internal/External Fire/ 1 ½ Hour Rating
Stainless Steel Liner	PC-3	Safety Class	See Note 2.
Notes: 1. Commercially available doors utilized with stringent QA Requirements. 2. Liner provides cleanable interior surface.			

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In applying LANL site-specific requirements to the SRS Modular Unit Project, it was found that the LANL requirements met or exceeded those of the Savannah River Site project. The SRS project employed a Nuclear Transportainer with a hazard category 3, PC-2 designation. Because of the reduced site-specific requirements at SRS, the LANL Modular Unit design was found to be readily adaptable. The application of the LANL Nuclear Transportainer design to SRS contributed to a significant reduction in engineering cost associated with the development of the Modular Units for SRS.

Bounding Conditions of LANL Site-Specific Requirements

The LANL site-specific requirements and application of standards, judgment and experience provides for a Nuclear Transportainer with significant adaptability at various DOE sites. The bounding conditions of the LANL design are expressed in Table II.

The data in Table II are drawn from DOE Standard 1020-94 for design basis earthquake ground motion and DOE standard 1020-2002 for peak gust wind speeds. In regard to seismic design, each DOE site must rely upon its site specific seismic criteria. Table II is intended to provide only a relative comparison of site seismisity for PC-3 SSCs.

Table II indicates those DOE sites which possess higher demand criteria for seismic and wind design. These sites will likely require further engineering to ascertain the applicability of the basic transportainer for use in a PC-3, hazard category 2 facility. Other DOE sites with equal or lower demand criteria for wind and seismic design will likely be able to utilize the LANL Nuclear Transportainer design on a very economical basis. Minimal additional engineering of the LANL design package may be anticipated. For sites with tornado design requirements, the LANL design may not be adaptable. The LANL Transportainer design has not considered design requirements associated with Performance Category 4.

Table II. LANL Design Bounding Conditions

DOE Sites with Higher PC-3 Seismic Criteria	DOE Sites with Higher PC-3 Basic Wind Criteria	DOE Sites with PC-3 Tornado Criteria
Paducah, Kentucky	Rocky Flats Plant, Colorado	Kansas City Plant, Missouri
Nevada Test Site, Nevada	Brookhaven National Laboratory, New York	Mound Laboratory, Ohio
Sand, Livermore, California	Princeton Plasma Physics Laboratory, New Jersey	Pantex Plant, Texas
Lawrence Berkley Laboratory, California	Lawrence Livermore National Laboratory, Site 300, California	Rocky Flats Plant, Colorado
Lawrence Livermore National Laboratory, California		Argon National Laboratories – East, Illinois
Lawrence Livermore National Laboratory, Site 300, California		Brookhaven National Laboratory, New York
Energy Technology and Engineering Centers		Princeton Plasma Physics Laboratory, New Jersey
Stanford Linear Accelerator Center, California		Oakridge, X-10, K-25, and Y-12, Tennessee
		Paducah Gaseous Diffusion Plant, Kentucky
		Portsmouth Gaseous Diffusion Plant, Ohio
		Energy Technology and Engineering Center, California
		Savannah River Site, South Carolina

ENGINEERING ASSOCIATED WITH PROXIMITY TO SITE BOUNDARIES

LANL Hazard and Safety Categorization

The selection of LANL Hazard and Safety Categorization of Structures, Systems, and Components (SSCs) relied upon the quantity and nature of materials to be processed as well as the facility's proximity to the site boundaries. The design safety analysis was performed in conjunction with the evolving engineering package.

The LANL project is located within a few hundred yards of the LANL site boundary separating areas of public access from LANL operations. With due consideration to the hazards inherent in the operation as well as the proximity of the site boundary the SSCs comprising the MORK Modular Unit were categorized as shown in Table III. An approach to achieving passive safe shutdown of the facility was incorporated into the design. A confinement envelope for the hazardous materials was provided through primary and secondary confinement systems. (i.e. gloveboxes and the Nuclear Transportainer structural envelope.) The modular unit requiring the highest level of safety in the engineered systems was the MORK. Other modular units at LANL were designed with systems of lower performance and safety categorization than those shown in Table III.

Table III Systems Identification for LANL & SRS.

	LANL MORK		SRS MORK	
SYSTEM	**SC/SS/GS**	**PC**	**SC/SS/GS**	**PC**
HVAC				
Fans & Motors	GS	1	GS	1
Supply HVAC Unit	GS	1	GS	1
HEPA Filter Housing	SC	3	SS	2
HEPA Filters, General Exhaust	SC	3	SS	2
HEPA Filters, General Supply	SC	3	SS	2
HEPA Filters, Glovebox Exhaust	SC	3	SS	2
Ducts (boundary Penetration)	SC	3	SS	2
Dampers (fire)	SC	3	SS	2
Ducts (other than boundary)	GS	2	GS	1
Exhaust Stack	GS	3 [1]	GS	2 [1]
I & C				
HVAC (Fan Shutdown Contactor)	SS	2	SS	2
CCTV	GS	1	GS	1
O2 Monitor/Alarm MORK GB	SS	2	SS	2
O2 Sensor in MORK	GS	1	GS	1
PLC & HMI	GS	1	GS	1
ELECTRICAL				
CAMs	GS	1	GS	1
Normal Power	GS	2/1	GS	1
UPS	GS	2/1	GS	1
Emergency Egress Lighting	GS	2/1	GS	1
Lightning Protection	GS	2/1	GS	1

STRUCTURAL				
MU Envelope	SC	3	SS	2
Equip. Anchorage (Interior varies)	SC/GS	3/2 [2]	SS/GS	2/1 [2]
Glovebox Access/Work Platforms	GS	2	GS	2
Duct/Conduit Supports	SC/GS	2 [3]	SS/GS	2
HEPA Filter Housings	SC	3	SS	2
Glovebox Stands/Shells	SS	3/2	SS	2
SPECIALTY GASES				
N^2 (Inerting in GB)	GS	1	GS	1
FIRE PROTECTION				
Suppression (FM 200)	SS	2	SS	2
Detection/Discharge Relays	SS	2	SS	2
Fire Alarm	GS	2	GS	1
SECURITY				
Door Management System	GS	1	GS	1
Penetration Man-Proofing	GS	1	GS	1
COM & DATA				
PA	GS	1	GS	1
Telephone/Intercom	GS	1	GS	1
LAN/WAN	GS	1	GS	1

Legend
GS – General Service
SC – Safety Class
SS – Safety Significant

Notes:

1. Stack design PC-3 to prevent overturning onto MORK.
2. Gloveboxes, Waste Drum Lifters and equipment weighing > 400lbs designed to PC-3 criteria.
3. Ductwork connecting the HEPA Filter housing to the Transportainer exterior wall designed to SC/PC-3 criteria.

SRS Hazard and Safety Categorization

Selection of hazard and safety categorization for SSCs at Savannah River was based upon the materials to be processed within the modular units as well as the proximity to the site boundary. The resultant performance category and safety categorization considered that plutonium 238 would likely be present in processed materials as well as the fact that the modular unit facility would be located a significant distance from the site boundary. Accordingly, the SSC performance and safety categorizations shown in Table III were utilized to govern the SRS Project. The large distance from the site boundary allowed reduction in the categorizations.

Because of the robust nature of the LANL Nuclear Transportainer design it was efficient and effective to deploy the MUs at SRS with minimal additional engineering. The significant engineering adjustments consisted of verifying that the LANL structural systems were compliant with SRS PC-2 criteria, adjusting the HVAC design to accommodate higher humidity at SRS and provision of a breathing air system within the MORK Modular Unit.

NATURAL PHENOMENON HAZARD CONSIDERATIONS

External Fire

Perhaps as a result of the Los Alamos experience during the Cerro Grande Fire of 2000, a need to provide a facility with significant resistance to external fire was foremost in the minds of the project team. In order to resist the effects of an external wildfire, the Nuclear Transportainer design provides resistance for up to two hours to such an event. Fire dampers and exterior metal sandwich panels comprise the PC-3 safety confinement barrier for the Nuclear Transportainer under the external fire scenario. Furthermore, design attributes are provided to prevent the migration of smoke and heat to the interior of the Nuclear Transportainer. These design features are accomplished by a two-hour rated exterior "sandwich" panel constructed of 0.20 gauge galvanized metal and mineral wool fiber. These panels are fastened directly to the structural steel frame of the Nuclear Transportainer. The panels were procured from Advance Insulation Concepts Inc. and tested by Underwriters Laboratories for the fire resistant configuration employed in the Transportainer design.

To prevent heat and gases of combustion from entering the Nuclear Transportainer, an external UL listed, two-hour rated fire damper was provided at the HVAC supply and exhaust penetrations. The external fire dampers are actuated by heat (fusible links set to activate at 165°F), so as to close early in a design basis fire scenario. All penetrations into the Nuclear Transportainer are provided with a fire resistant caulking. The access and emergency doors in the Nuclear Transportainer are 1 ½ -hour fire rated as required by code to achieve the two-hour fire rating for the exterior of the envelope.

Seismic Design

The seismic design of the LANL PC-3 confinement envelope employed analysis requirements and other criteria found in DOE Standard 1020 as well as LANL site-specific engineering requirements. Accordingly, a three-dimensional, dynamic, finite element analysis was performed. The analysis utilized a LANL ground input response spectra as well as appropriate industry codes and standards for safety related nuclear facilities. Because the primary framing is comprised of structural steel tubes, AISC N690 was relied upon for design basis load combinations and other criteria appropriate for a hazard category 2 facility.

The Nuclear Transportainer design will utilize a slab on grade foundation for anchoring the modular units. Foundation design will be in accordance with PC-3 requirements at LANL and will utilize ground surface accelerations based upon typical LANL soil conditions. Soil-structure-interaction analysis need not be performed because there are no subsurface components of the Transportainer structure and the site soils provide a firm, elastic foundation media.

The majority of other structural systems supporting the various modular unit configurations are designated PC-2 or less. Notable exceptions include the gloveboxes and drum lifters, designated PC-3 and located within the MORK Modular Unit. Also, the HEPA filter housing and ductwork connections immediately attached to the Nuclear Transportainer external structural envelope are designated PC-3.

Each of these subsystems is analyzed and designed in accordance with DOE Standard 1020 requirements that employ dynamic analyses and system modeling.

Of particular interest to the project team, was the appropriate qualification of the emergency and access doors to the Nuclear Transportainer. These doors serve as a component within the structural confinement boundaries. The doors are required to be of a robust nature with a high degree of certainty of closure upon evacuation or other off normal event. The doors are specified as solid core, steel skin with a steel frame welded to structural steel supports comprising the Nuclear Transportainer envelope framework. The door openings are strengthened to reduce deformation during a seismic event thereby assuring proper door function. A high-grade, robust door closer is specified to assure proper closing of the doors. The facility operation will also incorporate a regular testing requirement for the door closers.

Wind Design

The structural systems and exterior cladding of the Nuclear Transportainer comply with DOE Standard 1020 requirements for LANL, PC-3 design basis wind speeds. A tornado component is not included in the design basis. The design basis wind speed at LANL is 93 mph. Missile criteria for LANL PC-3 wind design is a 2X4 timber plank weighing 15 lbs traveling at approximately 50 mph horizontally.

Achieving an engineered system to meet the wind missile design requirements posed a significant challenge for the project. The recommended missile barrier for the LANL wind missile per DOE Standard 1020 is an 8" CMU wall with trussed horizontal joint reinforcement at 16" on center or a singly wythe brick veneer with stud wall. These construction materials do not lend themselves to modularity or transportability. Consequently, the design team was faced with the challenge of identifying a cladding system for the Transportainer which would be light weight, easily fabricated in an offsite fabrication shop, and transportable to DOE sites.

The design team selected a steel and mineral wool panel manufactured by Advance Insulation Concepts, Inc. The panels incorporated Insulrock brand, mineral wool core material, which is manufactured from volcanic rock and recycled steel slag heated to 2700°F and spun into thin individual fibers. Panel facings are permanently bonded to the mineral wool core with heat polymerizing adhesive. Both the exterior and interior facings are constructed of 0.020" minimum, galvanized steel and coated with a nominal 0.001" thick silicon modified polyester finish with a stucco emboss. The exterior facing has a continuously roll formed rib/groove configuration consisting of 1.375" x 0.10" ribs alternating with 0.06" deep grooves spaced so that the joint between the panels simulates a groove. This allows the panels to be joined together and fastened securely to the structural steel framing thereby providing a weather tight and fire resistant surface.

In order to assure that the Insulrock panels would resist the prescribed LANL wind missile, Texas Tech University was contracted to provide wind borne missile testing. The Wind Science and Engineering Research Center at Texas Tech University, in conjunction with protocol established by Merrick & Company and the Los Alamos National Laboratory, performed a series of tests which employed an air gun to propel a prescribed wind missile at an assembly of two Insulrock panels supported by structural steel tubing. This assembly represented identical installation techniques employed by the design.

The first series of tests revealed that the Insulrock panel could withstand the direct impact of the wind missile in the field of the panel. The wind missile was propelled at a joint between two panels and the panel system failed allowing the 2" x 4" to penetrate completely through the assembly.

In a final series of tests, Merrick & Company and Texas Tech arrived at an assembly that incorporated a seam reinforcement plate applied to the exterior panel skin at the joint between the panels. A galvanized steel sheet of 0.020" thickness and 3" width was attached to the exterior of the Insulrock panels at the joints. Number 8 by 1" self-tapping screws at 6" on center secured the plate to the panel. Wind missile testing demonstrated that this assembly resists the design basis wind missile.

Figures 8 and 9 show the Wind Missile Test Assembly. The InsulRock Panels are oriented horizontally to facilitate testing. Vertical orientation is used in the actual Transportainer fabrication. Figure 8 provides a view of the test assembly with the 2"x4" wind missile penetrating completely through the panel joint. Figure 9 shows the assembly with the seam plate added for testing.

Fig. 8 Complete penetration of wind missile through joint

Fig. 9 Assembly with Seam Plate at Joint

ENGINEERING RELATED TO INTERNAL FIRE

Design Basis Internal Fire

A fire internal to a transportainer, specifically the MORK Modular Unit, was considered as a design basis accident. Internal design basis fire was considered the result of a reactive or a pyrophoric waste ignition or caused by a mishap resulting in an electrical fire. A pyrophoric waste ignition was considered to occur internal to the glovebox located within the MORK while an electrically initiated fire was considered external to the glovebox.

Mitigative and Preventative Systems for Internal Fire

A number of engineering controls are provided to mitigate the internal fire scenarios. In the case of a fire internal to the glovebox, a nitrogen purge system is provided. This system keeps the glovebox atmosphere at less than 6% oxygen at all times during operations. Controls for the HVAC system provide for the passive safe shutdown of supply and exhaust in the event of the design basis fire. Whether fire is internal or external to the glovebox the HVAC system will shutdown by closing fire rated dampers and disabling the supply and exhaust fans.

A complete grounding system is provided to arrest lightning strikes and prevent build-up of static electrical charge. In order to prevent fires induced by arcing circuits, arc-fault current interrupting circuit breakers are used. The electrical design also provides a Farraday Cage system which prevents flash-over during a lightning strike.

A fire suppression system is provided within the MORK Modular Unit to mitigate fires external to the glovebox. An FM-200 fire suppression system is utilized which employs an inerting gas with constituents minimizing the hazard to occupants of the space.

SITE DEVELOPMENT REQUIREMENTS

General Requirements

Each set of MUs manufactured for deployment at a specific site will require appropriate site development. A foundation suitable for the performance category of the modular units as well as other general site development needs such as grading, drainage, vehicle access, etc., must be provided. MUs as currently designed are readily connected to electric, HVAC, telephone and data/comm. These utilities must be provided at the site. Workers located at the site will require restroom and other comfort facilities. The modular units as designed do not currently provide this function. Nearby facilities are required or a transportainer may be outfitted as needed. Other requirements for the site may include consideration for flooding, control of traffic, area access control and security.

Site Specific Requirements

A critical aspect of selecting the location of MUs is the nature of the soils which will be encountered when providing a foundation. A detailed soil analysis should be performed in order to properly analyze and design a foundation. Certain DOE sites may need to consider liquefaction, proximity to tectonic plates, flooding or wildfire. Proper review of site conditions, determination of foundation requirements, availability of utilities, access control and other local factors must be reviewed carefully and provided via appropriate engineering.

ISSUES RELATED TO ERGONOMICS

Throughput

The quest for modularity and transportability places geometric constraints upon the design. The LANL standardized Transportainer is provided with dimensions of 47' L x 13'6" W x 13'9" H. The design and installation of special facility equipment supporting the mission of the Transportainer is thereby constrained by the volume and floor space available.

Programs for the characterization and repackaging of transuranic waste will likely have schedules dictating throughput requirements. The current LANL MORK design accommodates two gloveboxes outfitted with one waste drum lifter and four daughter drum lifters. This arrangement presents trade offs between throughput and ergonomics. Users will need to determine the best arrangement of special facility equipment to achieve their desired throughput. Maximizing SFE will constrain floor space and the option to perform unplanned or future operations. Conversely, minimizing the amount of gloveboxes located within a modular unit such as MORK will provide a more open floor plan, thereby reducing the potential for interferences and aiding unimpaired movement of personnel and equipment within the Transportainer.

By way of example, LANL contemplates utilizing one MORK to meet throughput requirements. The LANL MORK provides an absolute minimum of space between pieces of equipment in order to maximize throughput. Minimum dimensions between equipment components was dictated by life safety code and other industry standards. Moveable platforms and access stairs were designed to allow operations to be performed in varying configurations. If a permanent building were used to house the operation, additional floor space is recommended to improve ergonomics. By way of comparison, the SRS site chose to procure two MORKs in order to meet their programmatic requirements on schedule.

Life Safety

In selecting a configuration for the MUs, life safety considerations are important. Egress to and from the modular units must be considered. Equipment layouts must allow for two means of exiting each modular unit within the prescribed maximum distances as defined in the NFPA Life Safety Code. Furthermore, the modular nature of the MUs allows for various configurations of the completed facility. Exiting from one MU during a design basis accident into a MU of equal or higher hazard categorization or potential threat to the worker is not permitted. The structural framing system of the transportainer provides for several options in locating emergency exits or routine egress pathways. This feature enhances the user's ability to comply with Life Safety requirements as well as provide flexibility for operations.

A Spool piece is used to interconnect each modular unit. An exit door is provided on the side of each Spool piece. This allows doors of adjoining modular units to open into the spool piece without violating life safety code requirements. A person exiting one modular unit may pass into a spool and then exit through the side door during an emergency condition.

ISSUES RELATED TO TRANPORTABILITY

Basic Transportation Requirements

Designing a standard, modular, transportable unit requires that geometry and weight be compliant with maximum criteria for travel on US highways. The design weight of the LANL MORK will be approximately 100,000 lbs. Geometry of the unit, 47' L x 13'6" W x 13'9" H, places the transportainer at the maximum limits of transportability. The Department of Transportation requires that weight be reduced as much as possible. This implies that components which do not necessarily require installation in the transportainer prior to shipment should be shipped separately.

The MORK when loaded on a truck bed, will need to be capable of clearing overpasses and bridges. Trucking companies consulted for this project have recommended that the total height of the load be kept to 15'6" or less. This will require utilization of a 2', or lower, lowboy trailer. Lowboy trailers of this geometry are not commonly available, but can be found within the US. Scheduling and cost planning for utilization of this specialized equipment will be necessary.

Over-width, over-height or over-weight loads require special permits and special routing. The DOT regulation governing such conditions is 23 CFR 658-Part 658. This governs truck size and weight, route designations, length, width and height limitations. Appendix A to these regulations identifies the National Network of Federally designated routes for loads greater than 80,000 lbs or over-dimension loads. Special routing for shipment of the transportainer will be required.

A crane will be required to load and offload the MUs. A crane capable of lifting approximately 110,000 lbs and possessing a Boom of approximately 86' will be needed. A crane with 200-ton capacity is recommended. These cranes are readily available throughout the US. A strong back/spreader bar is required to assure that loads placed on the transportainer are uniform and applied to lift points designed for the purpose.

Options Related to Transportation

One obvious option for shipment of a transportainer is to utilize US railway systems. Railway cars are available to accommodate the geometry and weight of the transportainer. Use of rails for shipment will likely result in longer shipment durations. The cost for transportation should be lower. Use of a lowboy for transportation over US highways will likely be required to get the shipment to and from the railhead. Use of rail for shipment may require rental of the 200-ton capacity crane as well.

Another option to consider when planning deployment of a transportainer is reducing the total weight shipped. Equipment which does not require installation at the transportainer fabrication facility can be installed once the transportainer has reached its destination. Such equipment might include gloveboxes, HVAC systems, ductwork, fire suppression components, etc. Reducing the total weight of the shipment will facilitate the location of, and reduce the costs associated with, the rental of handling equipment during the transportation phase.