TRANSPORTABILITY FOR BETTER DEPLOYABILITY

TEA PAMPHLET 70-1

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Military Surface Deployment and Distribution Command
Transportation Engineering Agency
Building 1990, 709 Ward Drive
Scott AFB, IL 62225
www.tea.army.mil

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Table of Contents

Chapter

Introduction

Properly applied transportability engineering is essential to the deployment of military equipment. An item of equipment is of little value if it cannot be transported rapidly and efficiently to where it is needed. This publication is a guide to transportability. It is intended for everyone interested in transportability: decision makers, materiel developers, combat developers, equipment designers and users, logisticians, and transporters. It is not designed to make you an instant transportability expert, but to help you understand the Engineering for Transportability program and the various transport modes. Detailed transportability criteria are given in **MIL-STD-1366**. This pamphlet will explain how new or modified equipment can affect force deployability, show some examples of lessons learned from past deployments and exercises, as well as cover the following areas of transportability and deployability:

Transportability Definition

This pamphlet provides insight into the Engineering for Transportability program, transport modes and limitations, and the definition of a transportability problem item. It will answer the following questions:

What is transportability?
Why is it important?
What are the limits and restrictions of the transportation infrastructure and assets?
What qualifies as a transportability problem item?

Transportability In Acquisition

This pamphlet explains how transportability fits into the materiel acquisition cycle. It will answer the following questions:

When should TEA become involved in a program?
How should transportability requirements be determined and how are they written?
What is transportability approval, when is it required, and how is it obtained?
How can modeling and simulation be used during acquisition?
What types of tests are required?

1 Background

Transportability and Deployability Questions

What is it?

Transportability is the inherent capability of an item or system to be effectively and efficiently moved by required transportation assets and modes. Deployability is the ability to move forces and materiel anywhere in the world in support of a military operation. Deployability depends on the interplay among transportability, the available transportation assets, and the supporting infrastructure: installations; worldwide road, rail, waterway and air networks; air and sea terminals; and other transshipment points.

Why do it?

The end of the Cold War and the increasing threat of terrorism have enormously increased the scale and complexity of force projection. The threats can be asymmetric, and the probable battlefields can lie in areas surrounded by rugged terrain and served by fragile transportation infrastructure. Reaching the battle, and arriving within the highly compressed time frames required to conduct decisive operations, is a major technical and operational challenge. It is often necessary to balance combat effectiveness against transportability. Materiel developers and force designers are fully aware that the most sophisticated and capable weapon system is useless if it cannot be moved swiftly to its place of employment, and that minimizing the total force movement requirement is vital to effective force projection.

Who does it?

Every official involved in the development and acquisition of military hardware must consider transportability and deployability as essential features. Project managers are key players.

When is it done?

Transportability engineering begins prior to concept refinement and continues throughout the acquisition process. The modes of transportation required for the item and the impact of transportability on total force deployability should be determined by Milestone A of the acquisition process. Transportability characteristics of developmental and commercial-off-the-shelf (COTS) items must be forwarded to TEA no later than 90 days prior to each milestone.

Where are the directives and guidance?

DODI 4540.7, *Operation of the DOD Engineering for Transportability and Deployability Program*, designates the Transportation Engineering Agency (TEA) as the Army's transportability agent, responsible for providing transportability assessments and approvals. **AR 70-47**, *Engineering for Transportability* establishes TEA as the single point of contact for Army agencies in securing transportability engineering analyses and assistance. **MIL-STD-1366**, *Interface Standard for Transportability Criteria*, lists the requirements for all modes of transport.

How does transportability engineering analysis influence design?

Transportability is both an Integrated Logistic Support (ILS) element and a design element. The influence of transportability engineering analysis on the design is greatest, and most effective, at the beginning of the acquisition cycle, because the costs for design changes are minimal during conceptual design. Once the conceptual design is converted to hardware, modification costs increase dramatically. The design engineer should therefore incorporate transportability elements into the item design as early in the cycle as possible.

Equipment items normally enter the inventory with some associated support items. The transportability of all these items must also be planned for as early as possible. Early coordination with TEA transportability engineers is the best way to ensure that the equipment and its associated support items will meet their deployability requirements.

Showing that a proposed weapon system can improve the deployability of the mission force is a powerful justification for proceeding with development and fielding. Transportability considerations are therefore crucial in advanced technology demonstrations and conceptual studies, where tomorrow's military power is first sketched and shaped. The lives of our soldiers and our Nation's success on future battlefields demand no less.

2 Modes and Limitations

Transportability is the inherent capability of an item or system to be effectively moved by required transportation assets and modes. This chapter provides insight into the transport modes and assets. It also includes a discussion of transport limitations and their impacts.

Air (Fixed Wing)

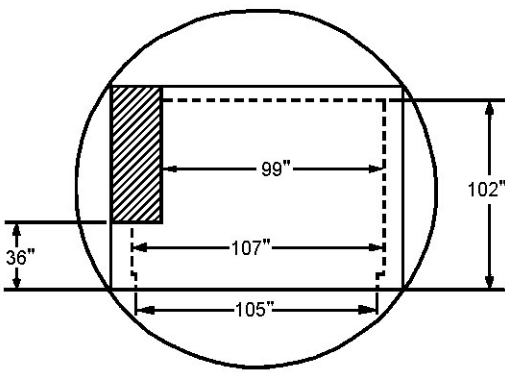
Air transport by fixed wing aircraft is the most important transport mode in terms of rapid strategic mobility. This mode has the greatest demand and the most limited assets. The fixed wing aircraft available for transporting military by equipment are the U.S. Air Force C-130, C-141, C-17, C-5, and the Civil Reserve Air Fleet (CRAF). All of these aircraft except the C-141 are expected to remain in service well into the 21st century. The USAF retired all C-141s and therefore it has been removed from this pamphlet. If you require this information, refer to previous editions of this pamphlet or the Second Edition of TEA PAM 55-24, *Vehicle and Equipment Preparation Handbook for Fixed Wing Air Movements.* When air transport of military equipment is a requirement, the dimensional and weight limitations of each aircraft must be considered. All vehicles that require air transport must be able to negotiate a 15º ramp for roll-on/roll-off (RORO) loading and unloading. To ensure worldwide strategic transport, an aircraft range of 3,200 nautical miles is required. The data in this section are general. Specific requirements are in **MIL-STD-1791**, *Designing for Internal Aerial Delivery in Fixed Wing Aircraft* and **MIL-STD-1366**, *Interface Standard for Transportability Criteria.*

C-130

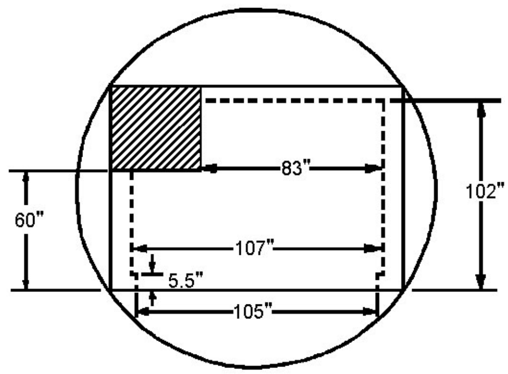
The C-130, a four-engine, high-wing aircraft, is used mainly as a tactical, intratheater aircraft. It is not intended for use as a long-haul aircraft to strategically deploy military equipment, and the cargo versions are not capable of air refueling. The C-130 is loaded through an aft cargo door. Most of the cargo versions of the C-130 in the Air Force inventory are C-130E’s and C-130H’s. The newest C-130 models are the C-130J(s) and the C-130J (formerly the C-130J and the C-130J-30, respectively). Equipment requiring C-130 transport should not exceed the following:

Height:	102 inches
Width:	107 inches
Length:	468 inches (C-130E/H/J(s))
	636 inches (C-130J)

The height and width design limits allow for 6 inches of clearance between the equipment being loaded and the aircraft ceiling and sidewalls, except where the width is 105 inches. The item length must allow space for restraint to the aircraft deck. An adequate safety aisle is required so that, during flight, the aircraft loadmaster can move from the forward to the aft end of the cargo compartment. Safety aisle dimensions should be 14 inches wide by 72 inches high (safety aisle A) or 30 inches wide by 48 inches high (safety aisle B); the 6-inch safety clearance is included.

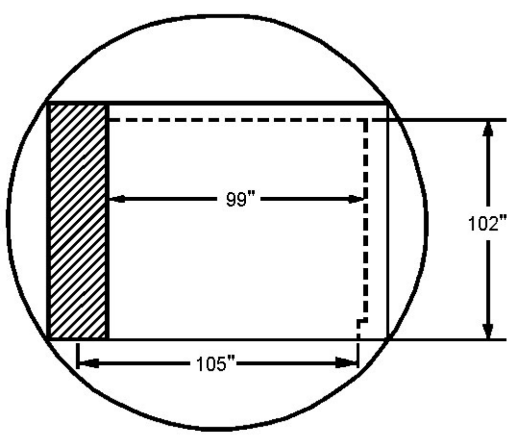


Safety Aisle A



Safety Aisle B

If passengers are required to be transported with the equipment, a 14-inch-wide passenger safety aisle beginning at the floor between the aircraft wheel well and the equipment must be provided as shown below; the 6-inch safety clearance is included.



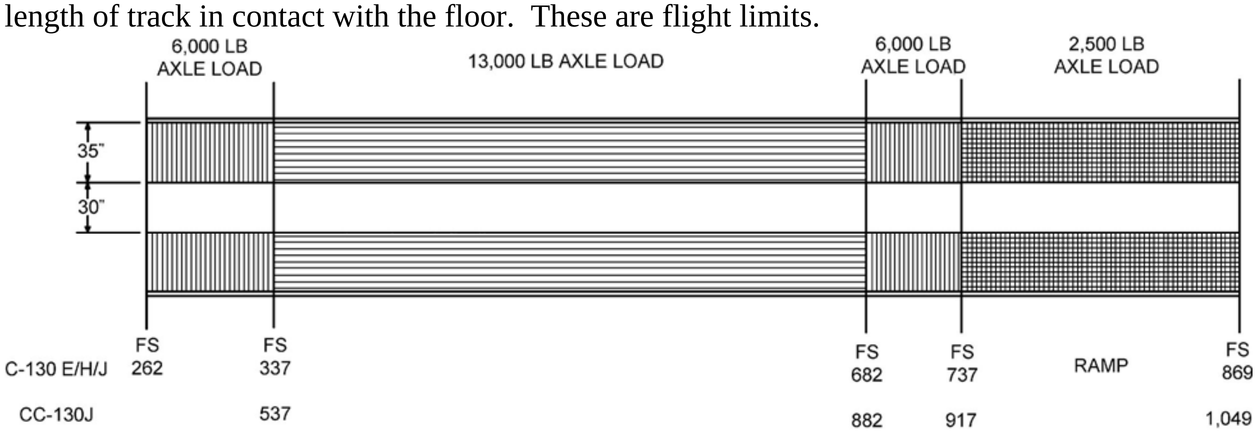
ALL VEHICLES THAT REQUIRE C-130 TRANSPORT MUST BE CAPABLE OF ROLL-ON/ROLL-OFF LOADING AND UNLOADING IN AN OPERATIONAL CONFIGURATION

The maximum concentrated load for bulk cargo on the floor of a C-130 is 50 pounds per square inch (psi). While the maximum payload for a C-130 is 42,000 pounds under ideal conditions, the aircraft range is severely limited at this weight. The heavier the payload, the shorter the distance the aircraft can be flown. Payload is also limited from high altitude airfields or on hot days, when operating into short runways or when refueling at the delivery point is not available. The C-130 must carry sufficient fuel to reach a recovery airfield, so the delivery range is reduced. All of these factors, as well as other operational considerations, may reduce the C-130 payload.

The C-130 has a permanently installed rail system that limits the available floor width. To a height of 5.5 inches, the width is 105 inches. Because of this, the practical maximum floor width for RORO operations of both wheeled and tracked vehicles is 100 inches, although the Air Force would prefer no more than 96 inches.

Wheeled vehicles:
The C-130's 35-inch-wide treadways are rated at 6,000 pounds (axle-load) for pneumatic tires, provided the tire pressure is less than 100 psi. In the central part of the aircraft (fuselage station 337 to 682 for C-130 E/H/J(s), 537 to 882 for C-130J) the treadway axle-load limit increases to 13,000 pounds. The allowable load on each tire (and each treadway) is half the axle-load rating. The maximum axle load on the ramp is 2,500 pounds. If there is one single axle, and nothing else on the ramp, the maximum axle load can be raised to 3,500 pounds. These are flight limits.

Tracked vehicles:
Treadways are rated at 2,800 pounds per linear foot (1,400 pounds per side). In the central part of the aircraft (FS 337 to 682 for C-130 E/H/J(s), 537 to 882 for C-130J) the treadway limit increases to 6,000 pounds per linear foot (3,000 pounds per side). Loading is based on linear length of track in contact with the floor. These are flight limits.



For additional information on the C-130, refer to the 11 September 2002, TEA, White Paper, *C-130E/H/J/J-30 Transportability of Army Vehicles* and the Technical Orders for the C-130.

C-17

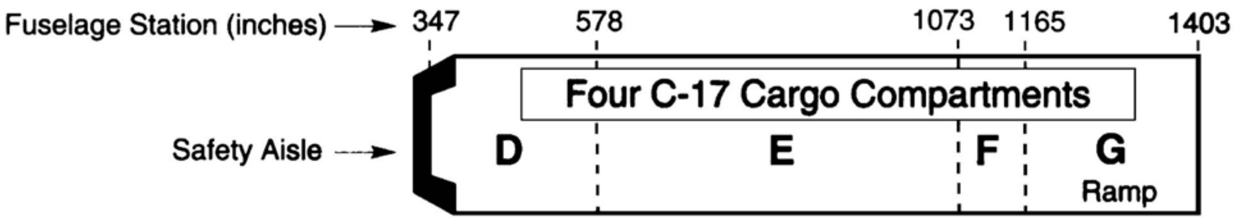
The C-17, a high-speed, high-capacity, long-range jet aircraft, can transport outsize and overweight cargo from origins in the United States to forward airfields overseas. Therefore, the C-17 can function as a strategic, intertheater aircraft and as a tactical intratheater aircraft. The C-17 is loaded through an aft cargo door. The design limits for equipment to be transportable in the C-17 are:

Height:	142 inches
Width:	196 inches
	204 inches if height is less than 136 inches
Length:	784 inches (cargo deck)
	238 inches (ramp)

These design limits allow for 6 inches of clearance between the equipment being loaded and the aircraft ceiling and side walls. The actual C-17 fuselage contours are shown in the following figures. The maximum payload of the C-17, under ideal conditions, is 167,400 pounds; however, the maximum payload for a range of 3,200 nautical miles is 130,000 pounds. The maximum tracked vehicle limit is 135,000 pounds. Other operational considerations may further reduce the C-17 payload capability.

The C-17 cargo compartment width is designed for the side-by-side loading of two 99-inch-wide wheeled vehicles (such as 5-ton vans). Wheeled vehicles should not exceed 99 inches in width, including tire bulge, handles, and so forth, to take full advantage of the capability of the C-17.

The following table gives general floor load limits for the C-17. More detailed limits may apply to specific systems.



C-17 Floor Load Limits

<table>
<tr><th colspan="3">Cargo Compartment</th><th>D</th><th>E</th><th>F</th><th>G
ramp</th></tr>
<tr><td colspan="3">Maximum allowable in each compartment (lb) (total weight not to exceed 167,400 lb)</td><td>72,000</td><td>167,400</td><td>35,000</td><td>40,000</td></tr>
<tr><td colspan="3">Maximum allowable pneumatic tire inflatable pressure (psi)</td><td>100</td><td>100</td><td>100</td><td>100</td></tr>
<tr><td colspan="3">Maximum allowable weight per linear foot (lb)</td><td>6,200</td><td>8,670</td><td>6,200</td><td>6,200</td></tr>
<tr><td rowspan="4">Axle Loads (lb)</td><td rowspan="3">Vehicle center-lines more than 8 inches from air-craft cen-terline (single or double row)</td><td>Single equal-weight axles side-by-side</td><td>13,000</td><td>20,000</td><td>13,000</td><td>13,000</td></tr>
<tr><td>Single axles beside 4,500-lb axles</td><td>22,000</td><td>27,000</td><td>22,000</td><td>22,000</td></tr>
<tr><td>Bogies (tandem) side-by-side 42-inch axle spacing</td><td>23,000</td><td>40,000</td><td>23,000</td><td>23,000</td></tr>
<tr><td colspan="2">Vehicle centerline within 8 inches of aircraft centerline. Vehicle single-axle weight, single-row</td><td>27,000</td><td>36,000</td><td>27,000</td><td>27,000</td></tr>
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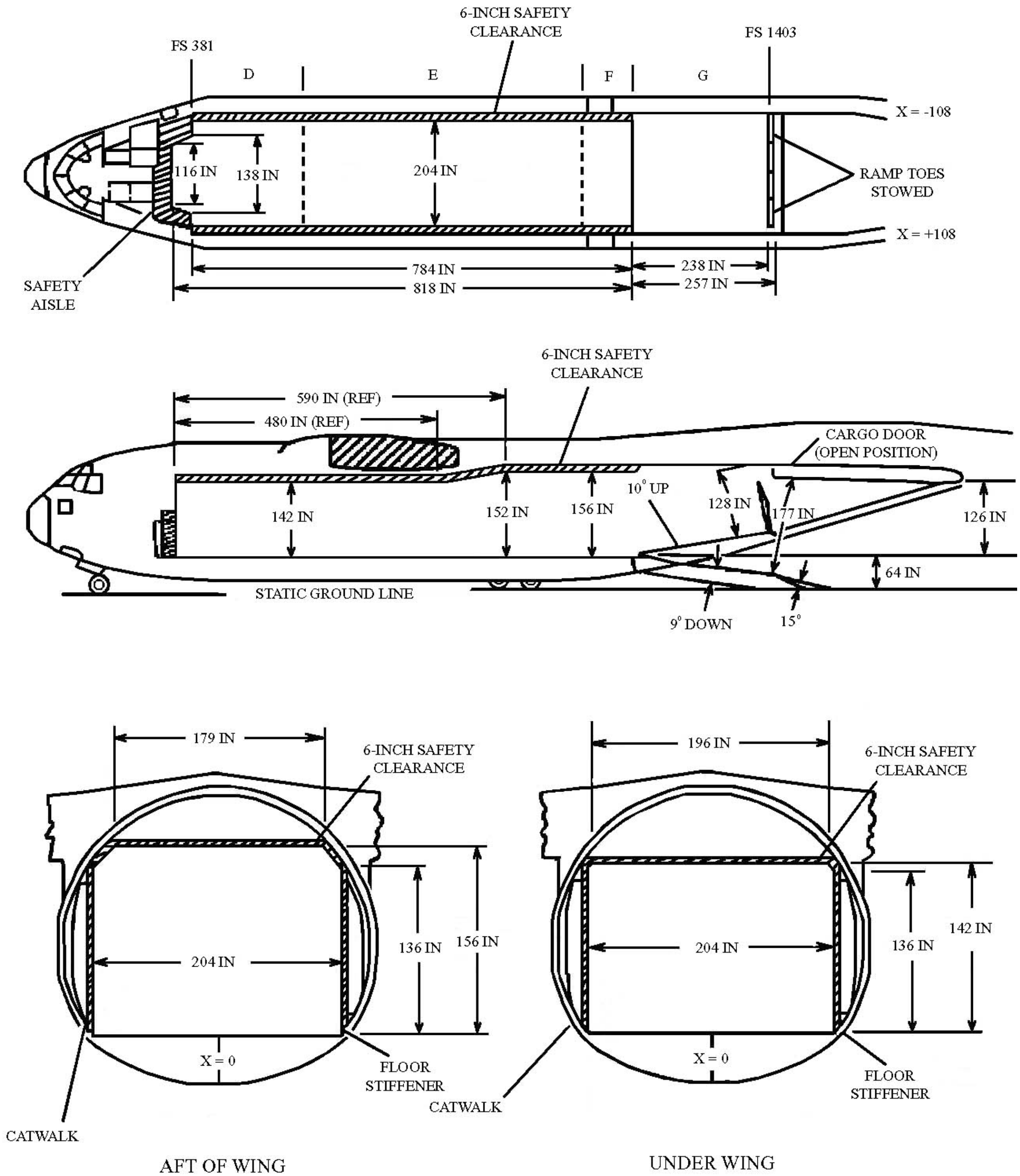


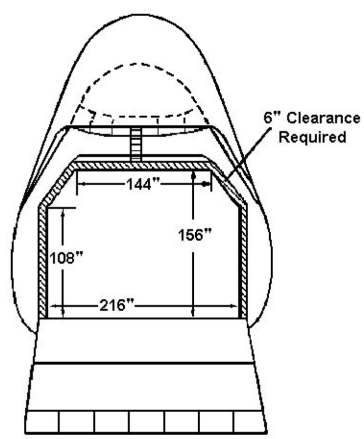
For additional information on the C-17, refer to the 24 May 2002, TEA, White Paper, *C-17 Transportability of Army Vehicles* and the Technical Orders for the C-17.

C-5

The USAF C-5, a high-speed, high-capacity, long-range jet aircraft, is mainly used as a strategic, intertheater aircraft for transporting cargo and troops. The C-5 can be loaded through either a forward visor door or an aft door under the tail. Both doors come equipped with cargo ramps. The dimensional design limits for the cargo compartment in the C-5 are:

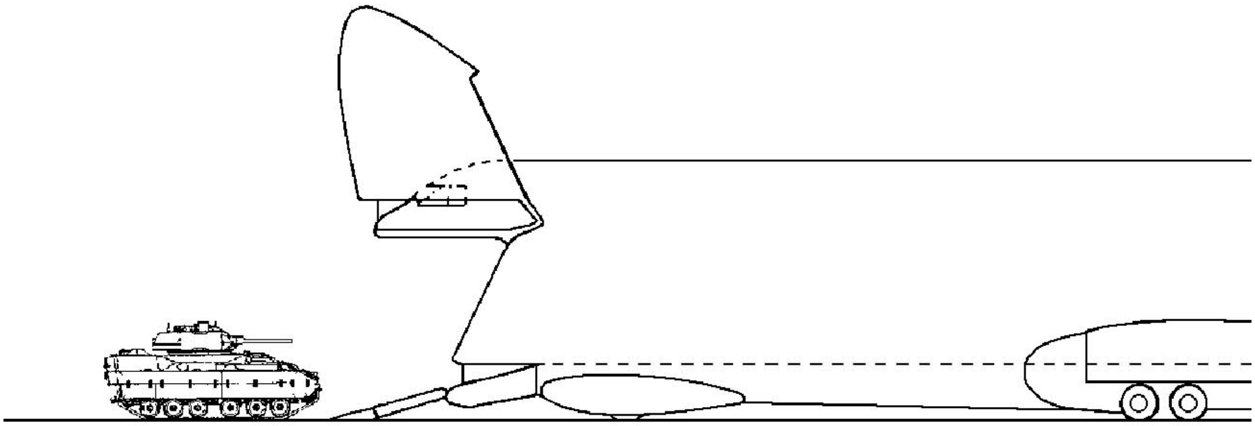
Height:	156 inches
Width:	144 inches
	216 inches if height is less than 108 inches
Length:	1,454 inches

These design limits allow for 6 inches of clearance between the equipment being loaded and the aircraft ceiling and sidewalls.

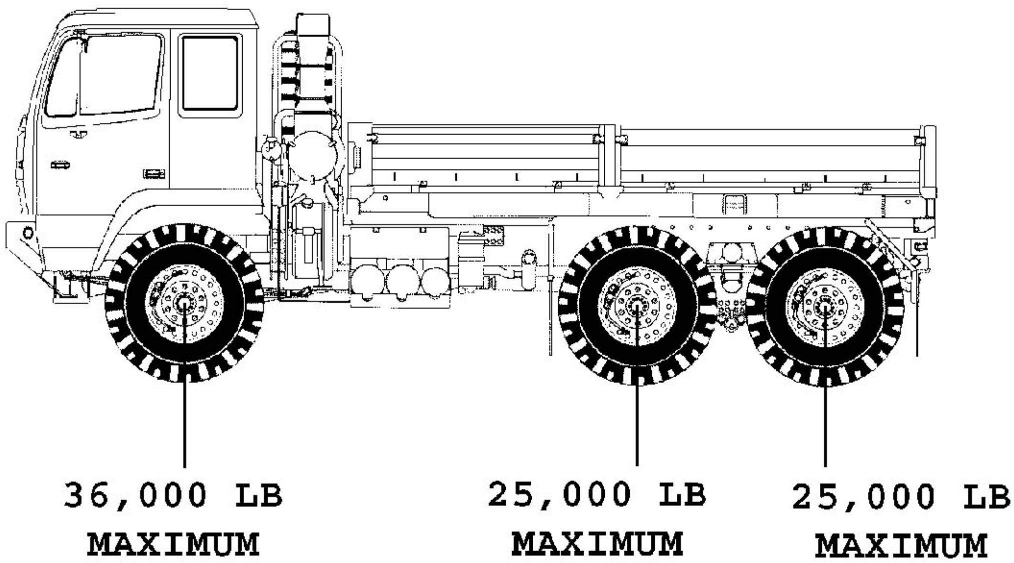


The maximum payload of the C-5, under ideal conditions, is 265,000 pounds (range at this payload is 1,600 nautical miles). A more typical payload, considering fuel weight, is 178,000 pounds (range at this payload is 3,200 nautical miles). The strongest portion of the C-5 floor is capable of supporting loads of 36,000 pounds in any 40-inch longitudinal length of floor. Other operational considerations may further reduce the C-5 payload capability.

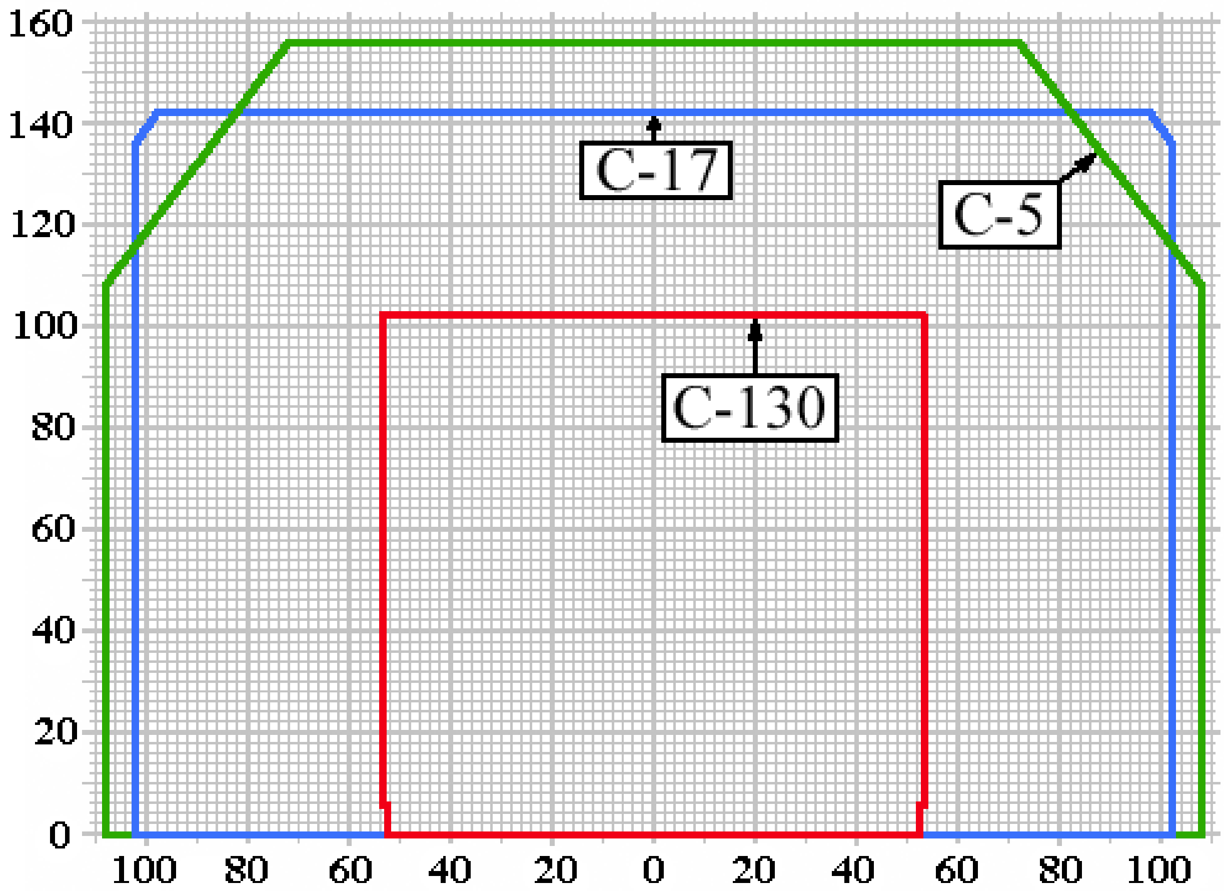
The maximum tracked vehicle weight for the C-5 is 134,200 pounds.



The maximum single axle load allowed on the C-5 is 36,000 pounds and the maximum tandem axle load allowed on the C-5 is 25,000 pounds per axle.

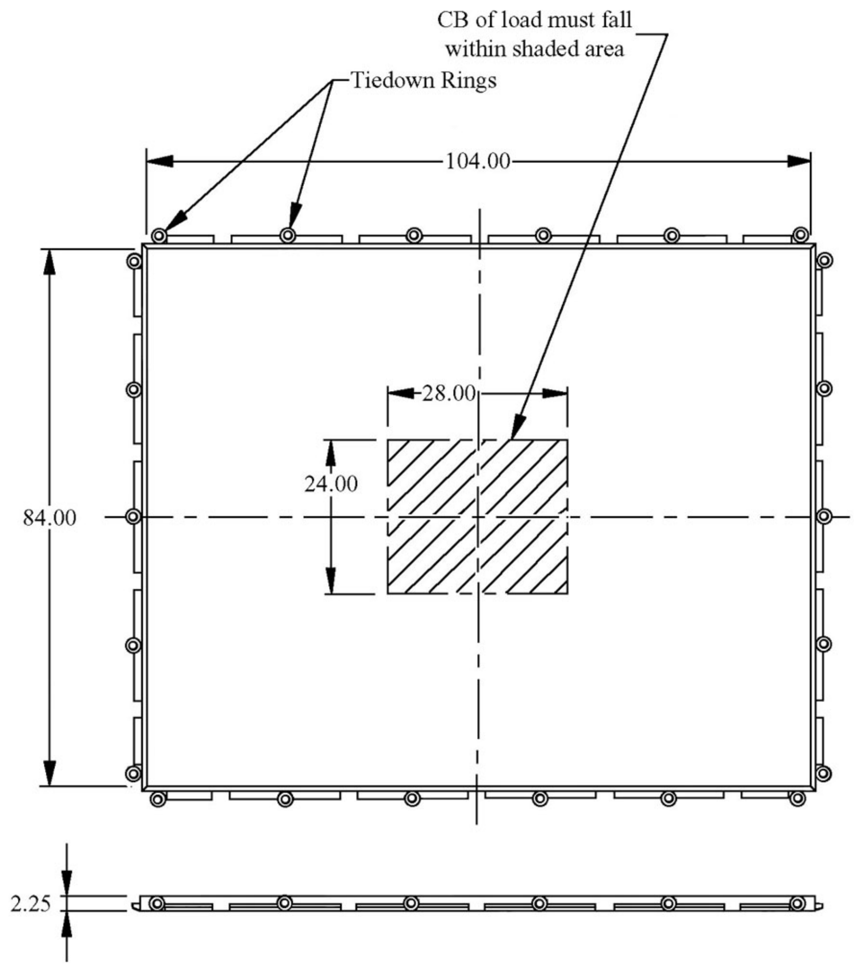


A comparison of USAF aircraft design envelopes is shown below. Dimensions are in inches.



463L Cargo Pallet

The 463L pallet weighs 290 pounds without any cargo loaded onto it and has a maximum usable surface area of 84 inches by 104 inches. The pallet must be loaded such that the Center of Balance (CB) of the pallet lies within a 24-inch by 28-inch rectangle at the center of the pallet. The maximum load that may be placed on a pallet is 10,000 pounds and cargo cannot be stacked higher than 96 inches at this cargo weight. Pallet loads may be restricted to 6,000 pounds or less depending on the aircraft received. There are 22 tiedown rings located around the perimeter of the pallet, each tiedown is rated at 7,500-pound capacity.



Civil Reserve Air Fleet (CRAF)

The Civil Reserve Air Fleet (CRAF) represents about 50 percent of the USAF total strategic wartime airlift capability. It consists of U.S. civil air carriers that have contracted to provide support personnel, equipment, and aircraft to the USAF. This represents 93 percent of air passenger movement and 30 percent of cargo movement (primarily palletized cargo) when stage II CRAF is employed.

For materiel transport, the CRAF aircraft with the greatest utility is the B-747 wide-body aircraft. Aircraft cargo capabilities differ not only between carriers, but also within carrier fleets, according to the specific needs at the time it is ordered from the manufacturer. Many freight aircraft are modified passenger aircraft. The specific carrier is the approving authority for loads. A portion of the B-747 fleet have a nose cargo door, all other cargo aircraft have only a side door.

Because side-door-loaded outsized equipment loads must enter in a lateral aircraft direction and be maneuvered to a longitudinal direction, there is a width-to-length relationship for determining cargo loadability. The longer the item, the narrower it must be. This is driven by the barrel shape of the aircraft fuselage, which causes greater restriction at increased heights. For the B-747, an item 96 inches high and 110 inches wide can be no longer than 232 inches. For the MD-11/DC-10, an item of the same width and length can only be 80 inches high.

For the B-747s equipped with a nose cargo door, the maximum cargo height through this door is 94 inches, which accounts for a 2-inch-thick pallet. Width varies with item height, with a width of 96 inches for a 94-inch-high item. Length is limited by the cargo loader when equipment is driven into the aircraft. Equipment loaded on pallet trains may also be restricted by the aircraft's roller system.

Airdrop

Airdrop is used to support several types of military operations: mass assault, tactical insertion, and resupply. In a mass assault operation, a large quantity of personnel, supplies, and equipment are airdropped into the opposing forces' territory to establish a position. In a resupply operation, items such as rations, equipment, ammunition, water, fuel, and medical supplies are airdropped into an area held by friendly forces to replenish dwindling stocks. (This procedure takes place when aircraft landing is impossible.) When possible, items should be airdropped in their operational configurations.

The C-130, and C-17 are the primary USAF aircraft used for low-velocity airdrop. The C-5 is available but currently limited to a small number of aircraft.

Before heavy vehicles or equipment are airdropped, each item is secured to an airdrop platform. Energy-dissipating material is placed between the item and the airdrop platform to absorb the shock from impact when the platform strikes the ground.

The dimensional limits of a rigged load (airdrop platform, energy-dissipating material, and the item to be airdropped) include a maximum height of 100 inches and a maximum width of 108 inches. The height is further restricted forward of the rigged item’s center of gravity to allow extraction under a malfunction condition (that is, extraction parachute fails to fully deploy).

The maximum airdrop height for unrigged vehicles with rubber tires and unrigged vehicles with suspension systems is 90 inches. The maximum airdrop height for all other equipment is 84.5 inches.

The maximum airdrop single item gross rigged weight (GRW) is 42,000 pounds. The GRW of an item to be airdropped is estimated based on the following formula:

GRW = 1,600 pounds + (1.18 x item weight for airdrop)

Since 42,000 pounds is the maximum GRW, the maximum item weight for airdrop, which depends on rigging requirements, is currently 34,200 pounds.

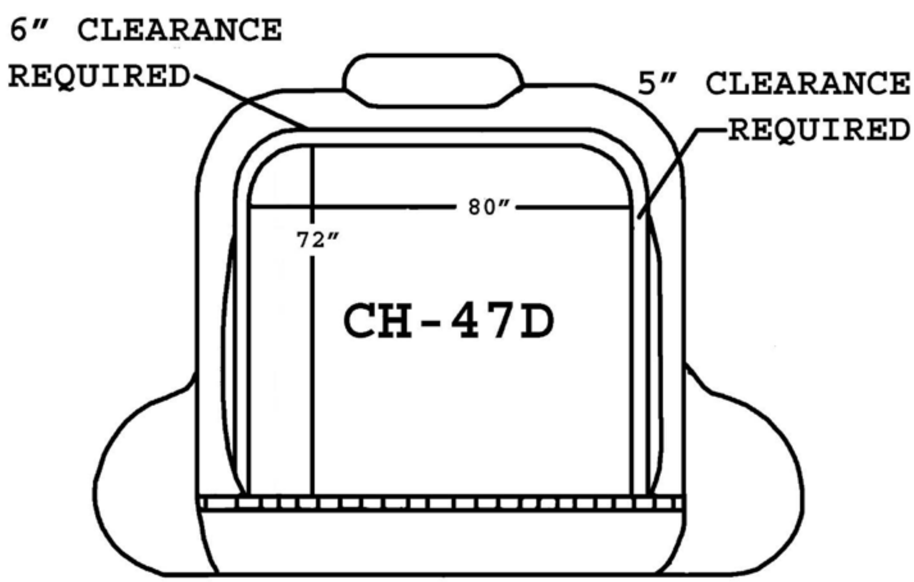
Air (Rotary Wing)

Rotary wing aircraft are used mainly for short-range, tactical transport missions. These aircraft have the ability to transport essential equipment directly to a forward area without having to contend with enroute terrain obstacles or damaged road or railroad systems. The five common types of military helicopters that are used to transport cargo are the UH-1 and UH-60 utility helicopters, the CH-46, CH-47, and CH-53 cargo helicopters. All five aircraft are capable of external lift operations; however, the CH-47 and CH-53 are the only helicopters with cargo compartments large enough to carry a significant amount of internal cargo.

The dimensional design limits for equipment to be internally transported by CH-47 are:

Height:	72 inches
Width:	80 inches
Length:	331 inches

These design limits allow for safety clearances of 6 inches between equipment and the aircraft ceiling and 5 inches at the sidewalls.



Each helicopter has a maximum payload rating; however, the lift capability and range of each helicopter differ for each mission. The temperature, altitude, and fuel carried in a helicopter must be considered for each mission. Helicopters can rarely fly at their maximum payload rating. If a requirement exists for helicopter lift, the mission (weight and distance) requirements must be known. The maximum external loads (pounds) that can be lifted by some common helicopters appear in the following tables. Note the dramatic decrease in helicopter payload capability with increasing temperature and altitude. Also, the CH/MH-53 has wide variations in capability depending on the precise model. The CH-47 and CH-53 have two cargo hooks under the helicopter to lift cargo. These cargo hooks are 160 inches apart on the CH-47 and 121 inches apart on the CH-53.

Maximum External Loads (lbs) for Helicopters

Mission Scenario	UH-1H	UH-60A	UH-60L	CH-46E	CH-47D	CH-47F	CH-53D	CH-53E	MV-22
Sea Level, 60 F, 30 NM	2,585	7,843	9,000	5,915	23,324	18,023	14,700	34,770	13,320
2,000 ft, 70 F, 30 NM	2,624	7,302	9,000	5,480	23,396	18,098	13,900	28,300	9,330
4,000 ft, 95 F, 30 NM	1,169	4,700	6,630	3,780	16,644	15,639	7,860	18,200	7,500

The maximum internal load (pounds) that can be lifted by some common helicopters appear in the table below. Internal helicopter payload capability can decrease significantly with increasing temperature and altitude.

Maximum Internal Loads (lbs) for Helicopters

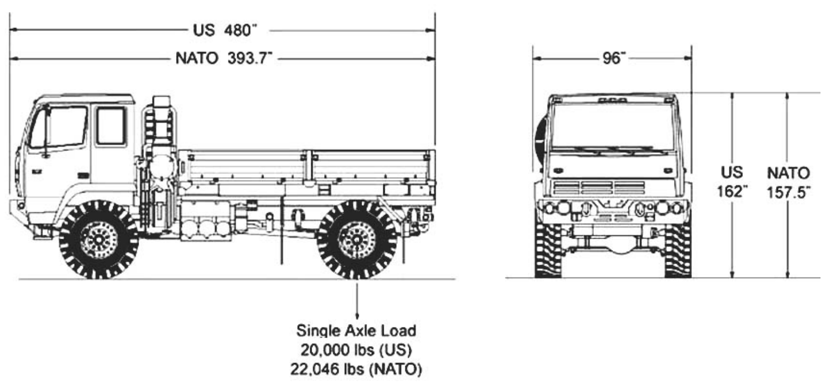
Mission Scenario	CH-46E	CH-47D	CH-47F	CH-53D	CH-53E	MV-22
Sea Level, 60 F, 30 Nautical Miles (NM)	6,000	23,300	18,029	14,770	34,990	13,850
2,000 ft, 70 F, 30 NM	5,600	23,350	18,102	13,970	28,600	9,840
4,000 ft, 95 F, 30 NM	3,890	16,900	16,014	7,910	18,600	8,010

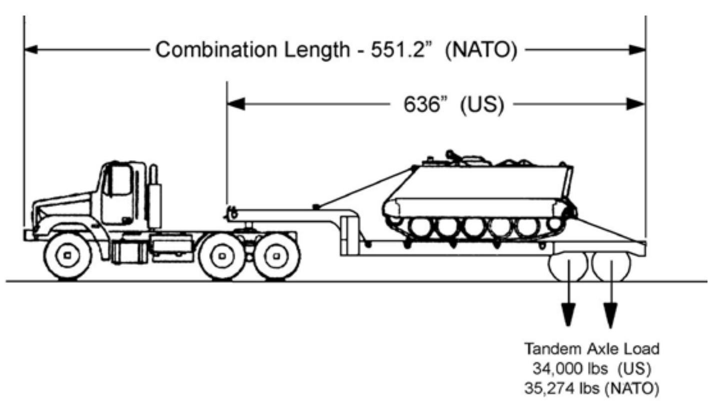
Highway

GENERAL

Highway is the most common transport mode. It is essential for both strategic and tactical deployment, as well as day-to-day operations. Military equipment usually is not located at its strategic deployment port of embarkation, such as ports or airfields. Highway transport can be used to reach these points of embarkation especially if they are less than 400 miles from the origin of the deployment. For tactical deployment, this mode allows the item to be delivered as close as possible to the point where it is needed. This mode is also the most flexible of the surface transport modes. Maximizing the efficiency of the highway network requires that vehicles and vehicular combinations be capable of unrestricted movement. This movement is possible if vehicles or vehicular combinations do not exceed legal size and weight limits imposed by the Federal Government, States, localities, and foreign countries. If the dimensional and weight limits shown in the figures are not exceeded, movement will be generally unrestricted in most States and NATO countries.

There are Federal weight limits on the Dwight D. Eisenhower System of Interstate and Defense Highways, more commonly known as the "Interstate" system, that depend on the number and spacing of axles on the vehicle. The gross vehicle weight limit for the Interstate is 80,000 pounds. More detailed information is available in the *Vehicle Sizes and Weights Chart* by J.J. Keller and Associates, Inc.





Highway Permits

Vehicles and vehicular combinations that exceed the legal highway limits will require permits for highway transport. The difficulty in obtaining these permits depends on the State's policy and the amount by which the legal limit is exceeded. Circuitous routing or time restrictions, resulting in transport delays, may be required as a condition of the permit. Permits for vehicles that exceed the legal width and length limits are not as difficult to obtain as those for vehicles that exceed the legal height and weight limits. In general, States will not issue permits for reducible or divisible loads. However, per 23 CFR 658.5, States may treat military vehicles as nondivisible vehicles or loads. **DOD 4500.9-R**, *Defense Transportation Regulation (DTR), Part III, Appendix V*, explains the procedures for obtaining highway permits.

THE STATES AND LOCAL GOVERNMENTS OWN AND CONTROL ALL PUBLIC ROADS WITHIN THEIR BOUNDARIES, INCLUDING LOCAL, STATE, US, AND INTERSTATE ROUTES. THEY DO NOT HAVE TO GRANT A PERMIT IF THEY FEEL THE VEHICLE OR LOAD IS TOO LARGE OR TOO HEAVY FOR SAFE TRANSPORT

Certification as Essential to National Defense

During an emergency or if State permits are denied, a highway movement may be declared as essential to national defense. The following requirements must be met for an item to be certified as essential to national defense:

- The item must be essential to mission completion or unit readiness.
- The item cannot be reduced or moved by commercial transporters to conform with the limits.
- There is no alternative to highway transport.

Movement for routine training, maintenance, or equipment displays will not be considered essential to national defense. The shipment must be eligible for highway movement in accordance with the provisions of **DOD 4500.9-R**. If all these requirements are met, the commander of the transporting installation will request the major commander of the shipping activity to certify the shipment as essential to national defense. The local installation commander cannot certify a shipment as essential to national defense. The *Directory of Highway Permit and MOBCON Officials*, published by TEA on our website, lists the individuals authorized to determine essentiality to national defense. It also lists military officials authorized to request, and State officials authorized to grant permits for oversize, overweight, or other special military movements on public highways.

Certification as essential to national defense is not a guarantee that State highway officials will allow the shipment. The States have complete authority over their highway network, and their determination is final.

Pavement and structures have a practical load limit. Certification as essential to national defense, followed by the State's permission, does not ensure the load can be transported safely and without damage to the roadway. Pavement and structure analysis may be required at DOD's expense before transporting extremely heavy items. If roadways are damaged, DOD may have to reimburse the State for the cost to repair the damages.

CERTIFICATION AS ESSENTIAL TO NATIONAL DEFENSE IS NOT A GUARANTEE THAT STATE HIGHWAY OFFICIALS WILL ALLOW SHIPMENT

Rail

Rail transport is essential for the shipment and deployment of oversize and overweight equipment. Oversize and overweight equipment is equipment that cannot meet legal highway transport limits. Rail transport is also essential for the land deployment of equipment transported farther than 400 miles. When many items are to be shipped, rail transport is often cheaper than highway transport.

Rail transport of tactical vehicles reduces the time the vehicles must operate during deployment and, thus, places them on the front lines in top operational condition. Rail transport reduces wear and tear on tactical vehicles, minimizes the requirements for en route support, and reduces maintenance requirements.

Although oversize and overweight equipment is routinely transported by rail, there are still maximum limits and restrictions to rail transport. These restrictions are given in clearance diagrams which follow.

Rail transport on standard-gauge rail lines in North America and in Europe is more important than rail transport in other areas of the world to military planners, because rail networks are extensive in these areas. Korea also has an important rail network. The five rail clearance diagrams (see following pages) of greatest interest are:

North America:

Association of American Railroads (AAR) outline diagram for single loads, without end overhang, on open-top cars

DOD clearance profile for the Strategic Rail Corridor Network (STRACNET)

Europe:

Envelope S (formerly Gabarit International de Chargement (GIC))

Envelope M (formerly Envelope B)

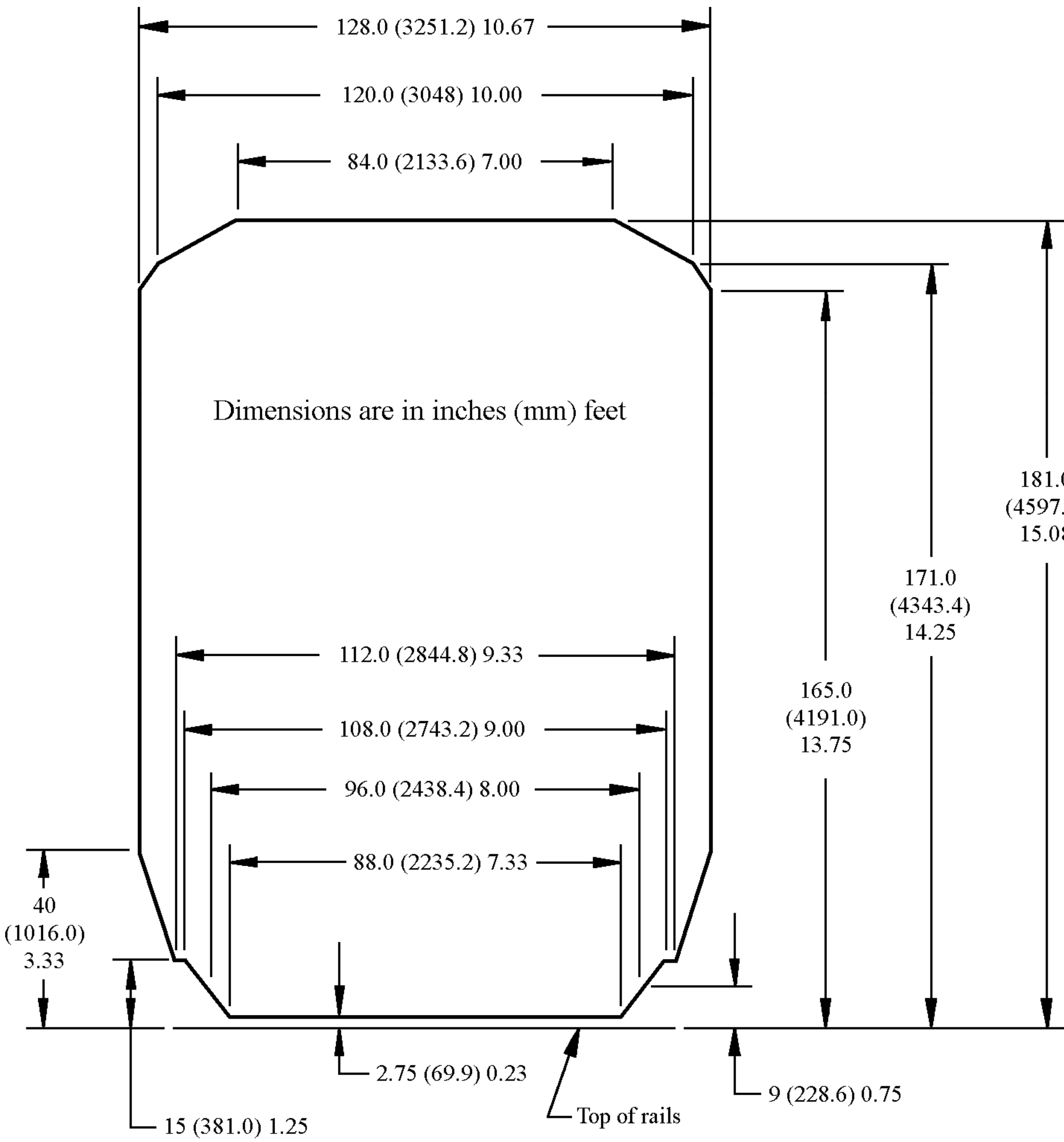
Korea:

Korean clearance diagram

If equipment exceeds the clearance diagrams, it still may be transported by rail; however, special routing and restrictions may be required. This special treatment will add to the transport time, a luxury not available when rapid deployment is essential.

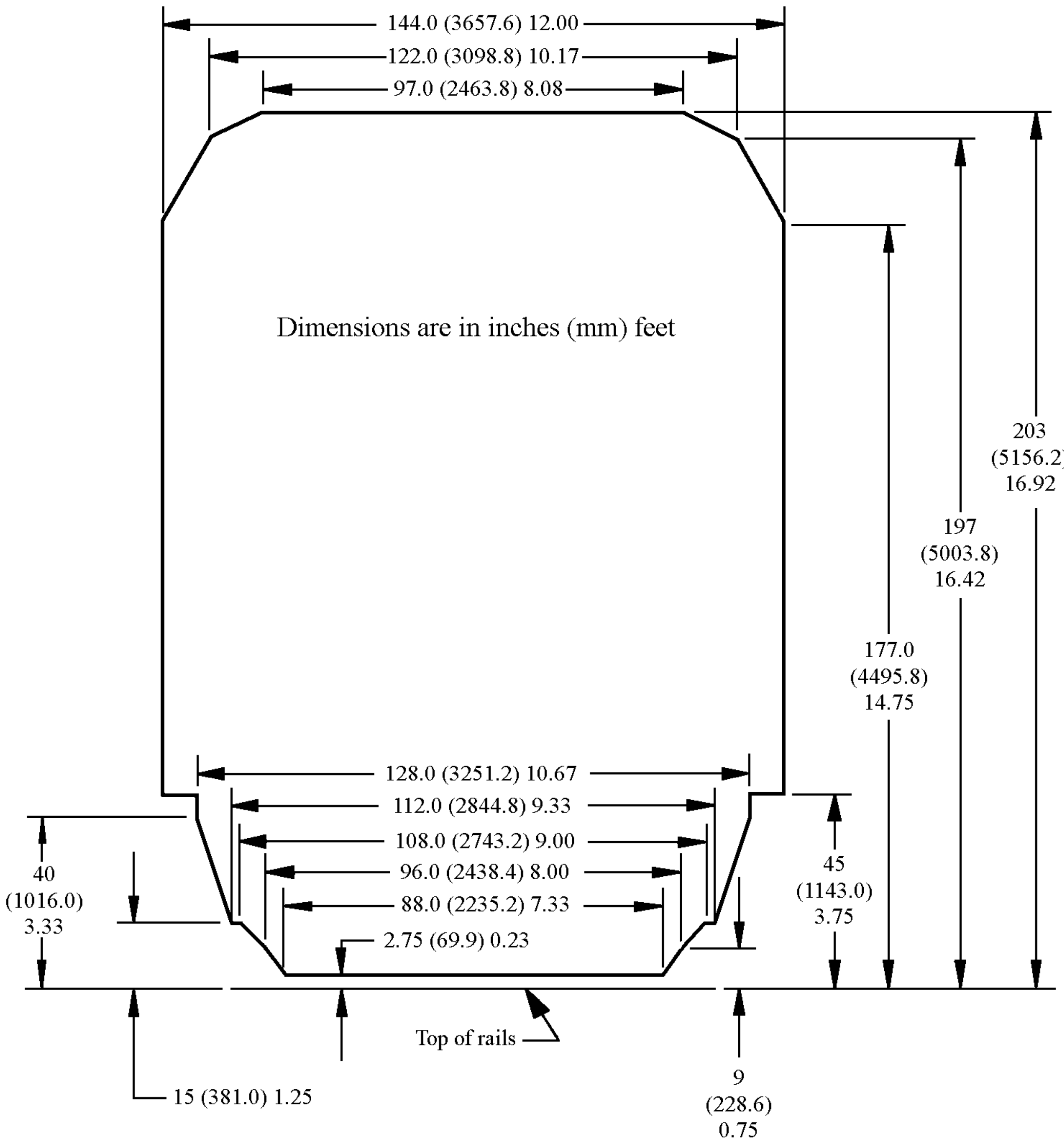
Rail transport, during rail humping and other train handling, can subject equipment to the greatest longitudinal shock loads of any transport mode. Rail humping is a procedure used in rail classification yards to assemble separate railcars into trains. A railcar is pushed over a hump and is allowed to roll into and couple with the train being assembled. During coupling, the normal speed is usually under 4 mph, but speeds can go as high as 8 mph. All items that require rail transport must pass the MIL-STD-810 rail impact test.

The AAR diagram applies to rail lines in North America. Equipment that is mounted on 51-inch-high railcars and falls within the limitations of the AAR diagram will be capable of unrestricted movement on almost all rail lines.



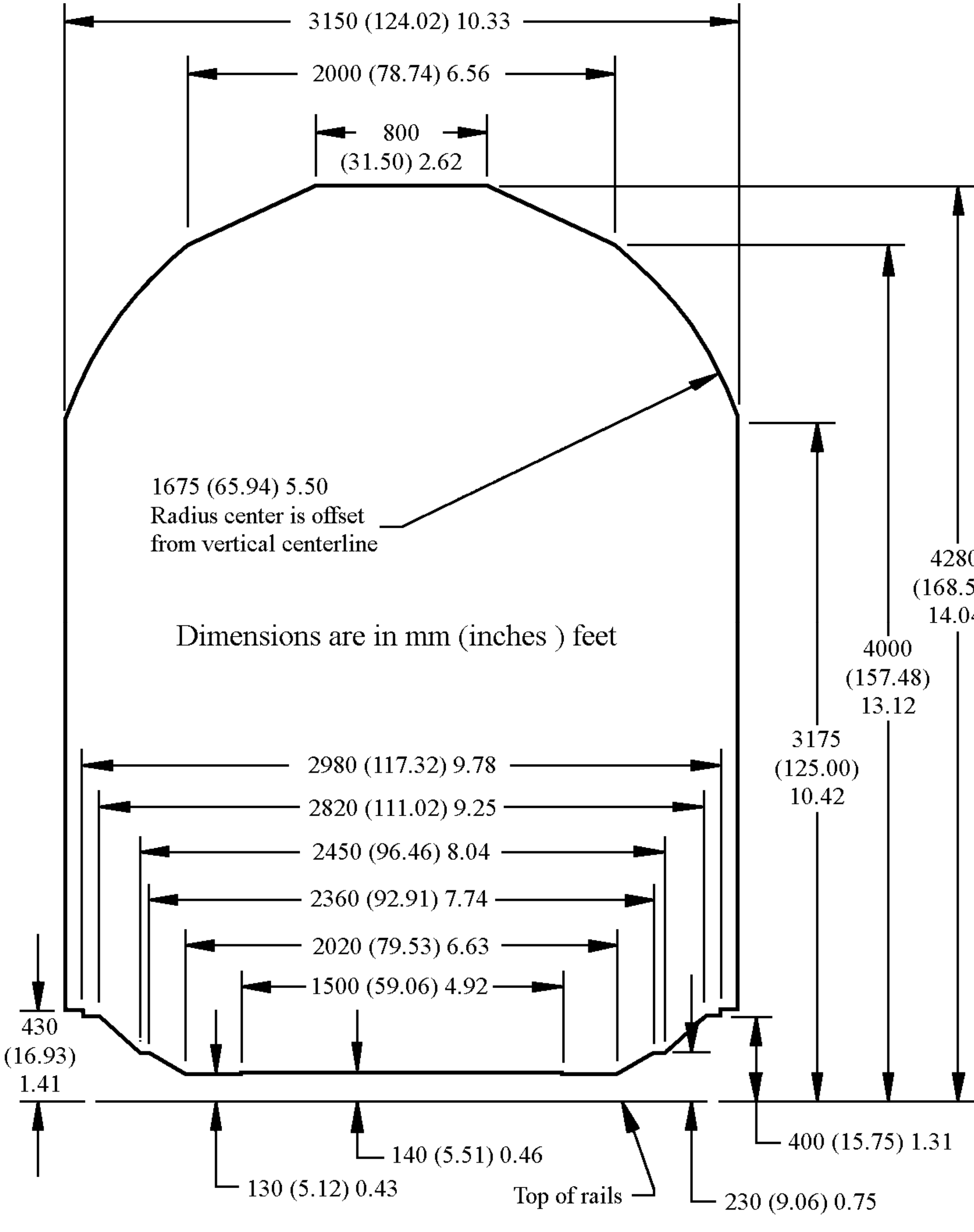
AAR Outline Diagram of Single Loads, Without End Overhang, On Open-Top Cars

The DOD STRACNET clearance profile accommodates 96 percent of DOD equipment types and 99 percent of all equipment in the DOD inventory. However, it is only valid for selected routes and sometimes only at severely restricted speeds. Other special conditions may also apply.



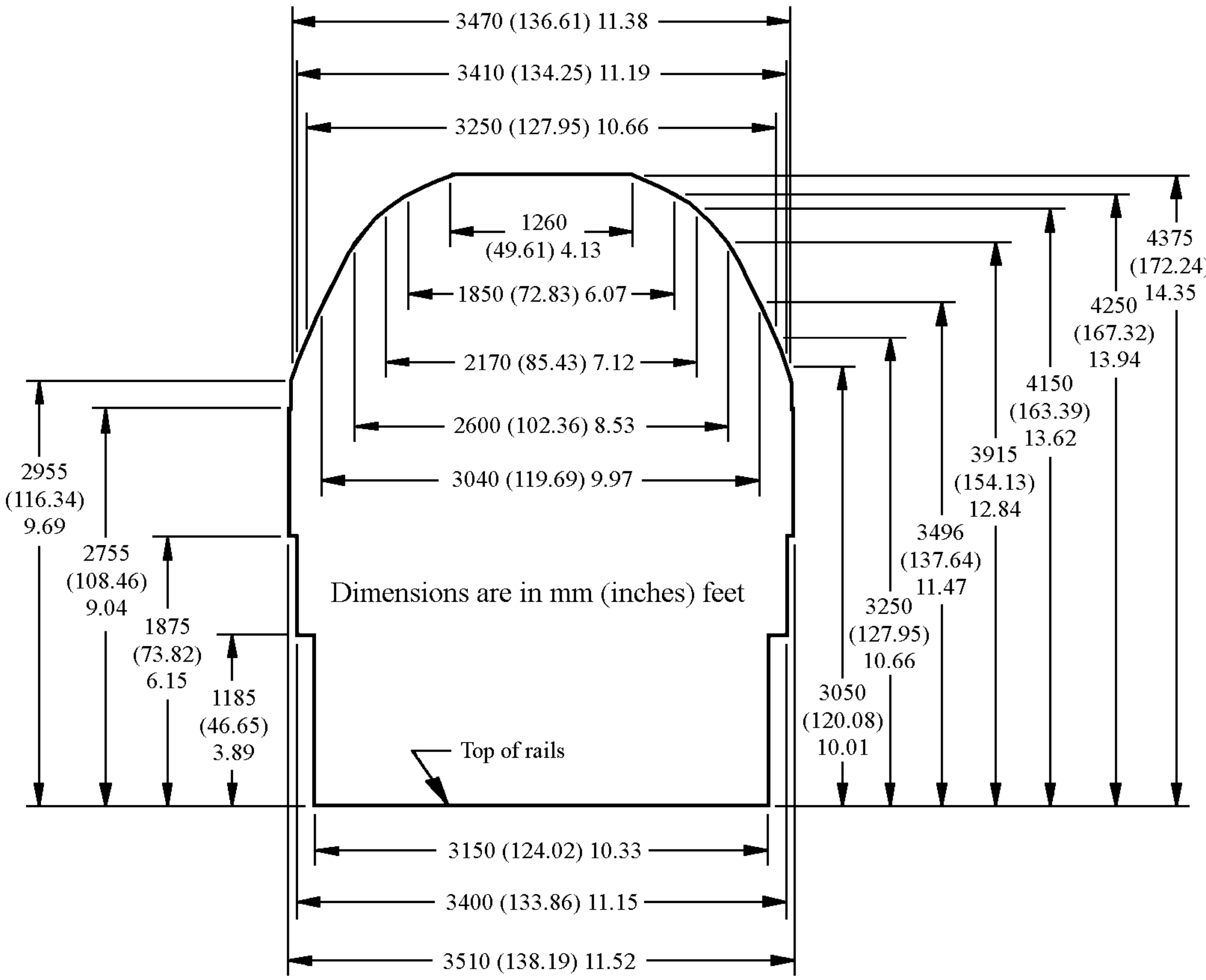
DOD Rail Clearance Diagram

The Envelope S (formerly GIC) applies to rail lines in European countries. Equipment that is mounted on 51.4-inch-high railcars and falls within the limitations of the Envelope S gauge will be capable of essentially unrestricted movement worldwide on standard-gauge rail lines.



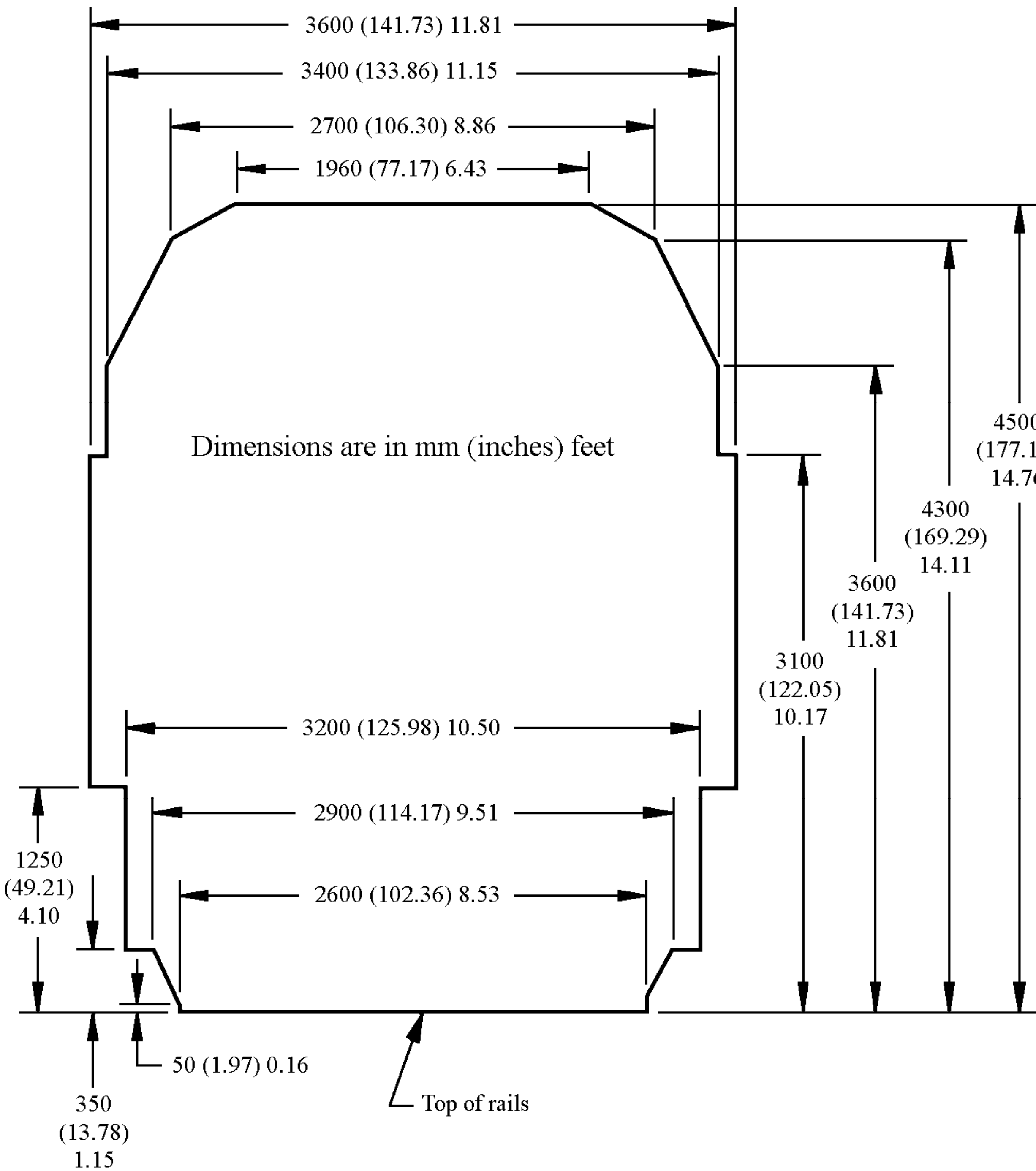
Envelope S (formerly GIC) Rail Clearance Diagram

Equipment Envelope M (formerly Envelope B) applies to rail lines in NATO countries on the European continent. The Envelope M rail network is not as extensive as the Envelope S equipment network, but equipment mounted on 51.4 inch railcars will be capable of unrestricted movement on 85 percent of the rail lines in Europe.

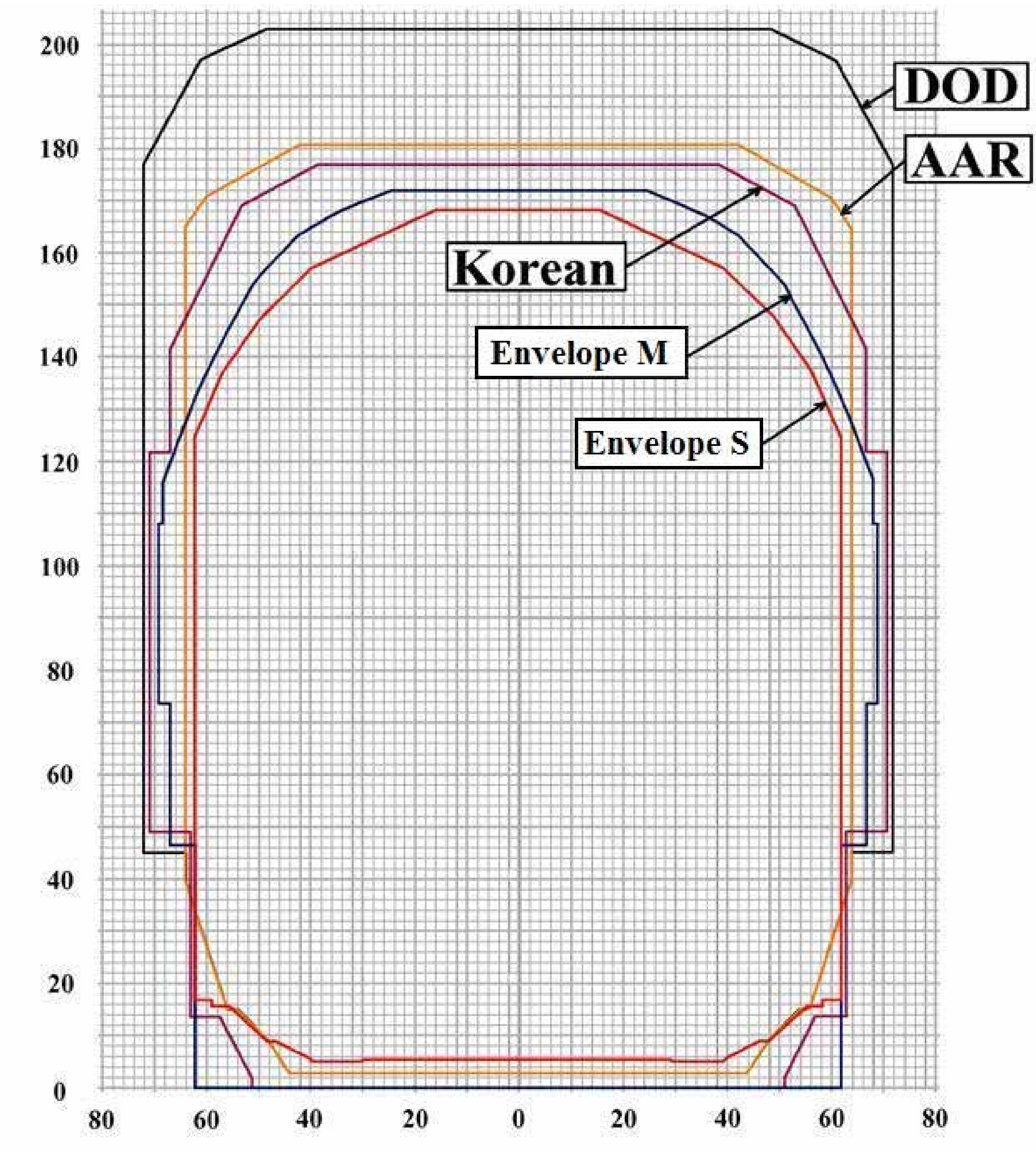


NATO Envelope M (formerly Envelope B) Rail Clearance Diagram

The Korean clearance diagram applies to the major rail lines in Korea for equipment secured to a flatcar. Korean railcars are 47.2 inches high for up to 110,200 pounds or 55.1 inches high for heavier loads such as heavy tracked vehicles.



Korean Rail Clearance Diagram



Comparison of Rail Clearance Envelopes

NOTE: Envelope S was formerly GIC
Envelope M was formerly Envelope B

Marine

Water transport is used for both strategic and tactical deployments. During strategic deployment and joint operations, dry cargo ships transport the equipment and supplies required to conduct and sustain the operation. A dry cargo ship is considered to be usable for military purposes if it has a minimum carrying capability of 2,000 long tons (LT) of cargo and the ability to carry, without significant modification, unit equipment, ammunition or sustaining supplies. The major types of dry cargo ships are breakbulk (general cargo), container, roll-on/roll-off (RORO), barge-carrying, lighter aboard ship (LASH), and sea barge (SEABEE) ships. In general, almost all items of equipment can be transported by ship without major problems or restrictions. The Military Sealift Command (MSC) provides common-user sealift across the range of military operations. Under normal peacetime conditions, the MSC force consists of government-owned ships as well as privately owned ships under charter to MSC. MSC resources available to the Defense Transportation System (DTS) beyond MSC's active peacetime fleet are fast sealift ships (FSS), large medium-speed roll-on/roll-off (LMSR) ships, and prepositioned ships. The Maritime Administration (MARAD) is the Department of Transportation agency responsible for administering federal laws and programs designed to support and maintain a US merchant marine capable of meeting the Nation's needs. It is responsible for managing the National Defense Reserve Fleet (NDRF), which contains the Ready Reserve Fleet (RRF). The RRF consists of commercial or former military vessels of high military use including RORO, SEABEE, LASH, container, tanker, crane, and breakbulk ships. Some of these vessels have had their military capabilities enhanced with the addition of systems such as the modular cargo delivery system and the offshore petroleum discharge system. MARAD maintains these vessels in 4-, 5-, 10-, or 20-day readiness status.

Once in the theater of operations, Army, Navy, and Marine Corps watercraft are used for port, inland waterway, logistics-over-the-shore (LOTS), and intratheater movement operations. These watercraft support operations in and around seaports when port facilities are nonexistent, degraded, or denied. Strategic sealift ships may be required to discharge in the stream, employing complex and time-consuming operations to move cargo and personnel across bare beaches. There is a broad spectrum of operations required to open and reconstitute degraded ports, operate in small, undeveloped ports or fishing villages, or gain access through inland waterways. The term LOTS encompasses the capabilities required to operate across this spectrum of operations, to include the discharge of cargo through major or secondary ports inaccessible or denied to deep draft shipping, small ports, villages, inland waterways, and bare beaches when necessary.

Significant changes are being made to the watercraft fleet. These changes will affect watercraft doctrine, policy, deployment training, technology, and material. Transforming the watercraft fleet into a fully modernized joint enabler is one of the key doctrinal changes that are being made. Shallow-draft and high-speed capabilities are being pursued to reduce the in-theater logistics footprint and provide combatant commanders with the agility and flexibility to quickly move forces. One alternative to provide the watercraft fleet with this agility and flexibility is the Joint High Speed Vessel (JHSV). As envisioned, the JHSV will provide a key capability in support of the US defense strategy. It will enable the services to rapidly project, maneuver, and sustain military forces in distant, anti-access or area-denial environments. The Navy (PMS-325) is the lead DoD service for the JHSV program. An Analysis of Alternatives (AoA) is under way for the services to identify alternative ways to use JHSVs in support of combat forces and assess the costs and benefits of each alternative.

As a precursor to procurement, the Army and Navy partnered in a demonstration that began in fiscal year (FY) 2002 to lease and test the High-Speed Vessel Experiment (HSV-X1) (Joint Venture), a commercial-off-the-shelf (COTS) high-speed vessel with military modifications. The Marine Corps successfully demonstrated the applicability of high-speed shallow-draft technology in Pacific operations, with the leased vessel WestPac Express. In November 2002, the Army leased a fully operational vessel, the TSV-1X (Spearhead) and in 2003, the Military Sealift Command contracted to lease a high speed craft, HSV-2 (Swift), for Naval experimentation, research and development. Characteristics for these leased vessels and other lighters are shown in table 1.

Class	Cargo Deck				Capacity (STON)	Crew	Length	Beam	Draft		Speed (knots)		Troops	Ramp (Width)[1]	Ramp Capacity (STON)
	Length	Width	Height	Area (sq ft)					Light	Full	Light	Full			
Army															
LCM-8	42'9"	14'6"	N/A	620	58.4	6	73'8"	21'0"	3'6"	5'0"	11	9	150[2]	14'6" (Bow)	65
LCM-8 Mod 2	18'6"	14'6"	N/A	269	TBD	6	73'8"	21'0"	-	4'6"	-	9	50	14'6" (Bow)	65
LCU 1600[3]	105'0"	17'0"[3]	N/A	1,785	179.2	14	135'0"	29'9"	4'6"	6'7.5"	12	11	350[2]	15'1" (Bow)	97.5
LCU 2000	100'0"	38'0"	30'0" (Bow)	2,500	392	13	174'0"	42'0"	8'0"	9'0"	12	10	350[2]	16'0" (Bow)	224
LSV	256'0"	60'0"	17'0" (Aft)	10,500	2000	32	273'0"	60'0"	6'0"	12'0"	12.5	11.5	900[2]	19'0" (Bow) 16'0" (Stern)	58.24
HSV-X1	185'0"	78'0"	14'6"	12,114	815[4]	45	313'0"	87'4"	10'0"	13'0"	48	38	325	14'4"	35
TSV-1X	207'0"	78'0"	14'8"	14,000	820[4]	40	318'11"	87'3"	9'0"	11'3"	42	38	292	15'0"	72
Marine Corps															
LCU	121'0"	25'0"[5]	N/A	1,850	143	11	135'0"	29'6"	-	3'6" (fwd) 6'10" (aft)	-	12	400[2]	14'3" (Bow) 18'0" (Stern)	112 (Bow) 97.5 (Stern)
LCM Mark 8															
Steel	42'0"	14'0"	N/A	588	60	5	73'7"	21'1"	-	4'10"	-	12	200[2]	14'9" (Bow)	65
Aluminum	42'0"	17'0"	N/A	714	60	5	74'6"	21'1"	-	4'3"	-	12	200[2]	14'9" (Bow)	65
HSV-X2	207'0"	78'0"	15'4"	14,000	691[4]	41	321'6"	87'3"	9'0"	11'3"	48	38	250	15'5"	75
WestPac Express*	279'0"	78'0"	14'3"	30,912	828[4]	25	331'0"	87'0"	-	15'9"	38	32	970	16'0" (Stern)	36.4
*WestPac Express has two decks. Dimensional data is for the main deck with mezzanine deck raised. Area includes the main deck (20,074 sqft) and upper or mezzanine deck (10,838 sqft). Overhead clearance for main deck with mezzanine lowered is 8'10" and the height of the mezzanine deck is 7'4". Payload is 425 STON with full fuel and no troops (306 STON with full fuel and 970 troops).															
Navy															
LCAC	78'0"	27'0"	N/A	1969	60	7	87'11"	47'0"	0'	3'0"	-	40	23	28'4" (Bow) 14'10" (Stern)	75

[1] Values given are actual dimensions. For design purposes, subtract 12" from the width for ramps and 6" from the height limitations to ensure adequate clearance.

[2] Although landing craft are capable of carrying troops, this should only be done in situations when the distance and time of travel are under 2 hours in sea states less than 2. These craft are not designed to transport troops in high sea states.

[3] The LCU 1600 Class reached the end of its economic useful life in 1996, but a few remain in U.S. Army Reserve units. The LCU 1646 was replaced by the LCU 2000. The cargo deck width of the LCU 1600 Class varies from 17'0" to 28'0" throughout the vessel. For design purposes, use 17'0" as the worst-case value.

[4] This is the total deadweight of these vessels. Minimum fuel must be carried on board for the vessel to perform at maximum payload capacity.

[5] The cargo deck width of the LCU varies from 12'9" to 25'0" throughout the vessel. For design purposes, use 12'9" as the worst-case value.

Vehicles and other equipment must have good, accessible lifting and tiedown provisions to be transported on these strategic sealift ships and watercraft. Equipment too heavy for lift by shipboard cranes requires shoreside cranes. Such equipment is also limited to improved ports where the proper facilities are available. The weight of the equipment to be delivered to unimproved ports or underdeveloped areas should be reviewed to ensure shipboard crane lift. Specific vessel characteristics and crane capacities are in table 2.

Commercial marine transport increasingly relies on container ships for cargo movement. When commercial marine transport is a requirement, compatibility with intermodal containers or flatracks is essential (see page 40 for design guidance)

LMSR - USNS SHUGHART

Table 2. Vessel Characteristics

TYPE/CLASS	FLEET	NAME	LENGTH (FT-IN)	MAX DRAFT (FT-IN)	SERVICE SPEED (KNOTS)	CARGO DEADWEIGHT (LTONS)	TOTAL SQUARE FEET	USABLE SQUARE FEET	MAX BOOM CAPACITY (LTON)	RAMP DOOR OPENING (W X H)	RAMP CAPACITY (LTON)	MAX HATCH OPENING (L X W)
Aviation Maintenance												
C5-S-78a (T-AVB)	RRF	Curtiss/Wright	601-6	33-10	18.7	11,574	77,740	58,305	70	15'0" X 14'6"	56.4	41'11" X 25'8"
Auxiliary Crane Ship												
C6-S-MA1qd (T-ACS 1)	RRF	Keystone State	668-8	33-3	17.0	9,779	16,558	12,419	105	N/A	N/A	43'3" X 26'10"
C6-S-MA1qd (T-ACS 2 & 3)	RRF	Gem State/Grand Canyon State	668-8	33-3	17.0	10,459	16,558	12,419	105	N/A	N/A	43'3" X 26'10"
C6-S-MA73c (T-ACS 4/5/6)	RRF	Gopher State/Flickertail State/ Cornhusker State	610-0	31-7	17.0	8,400	20,531	15,398	120	N/A	N/A	82'0" X 57'0"
C6-S-MA1xb (T-ACS 7 & 8)	RRF	Diamond State/Equality State	668-0	33-4	20.0	9,400	19,857	14,893	120	N/A	N/A	43'2" X 26'11"
C6-S-60d (T-ACS 9 & 10)	RRF	Green Mountain State/Beaver State	665-9	31-7	20.0	9,564	8,112	6,084	120	N/A	N/A	44'0" X 28'0"
						T-ACS total/usable square feet is for area on main deck only.						
Breakbulk												
C4-S-1u	RRF	Capes Jacob	565-0	31-7	17.0	9,875	88,128	66,096	60	N/A	N/A	37'6" X 25'10"
Breakbulk/Container												
C5-S-75a	RRF	Capes Gibson/Girardeau	605-0	35-1	17.9	17,832	94,572	70,929	70	N/A	N/A	42'6" X 25'6"
Container Ship												
C9-M-132b	CPF	LTC John Page/SSG Edward A. Carter	949-10	38-4	19.0	44,653	-	-	36	N/A	N/A	40'9" X 34'6"
Foreign	LPS	A1C Willilam H. Pitsenbarger	621-0	37-6	18.0	23,749	-	-	39	N/A	N/A	42'9" X 26'10"
Foreign	LPS	CAPT Steven L. Bennett	687-0	38-1	18.3	29,833	-	-	40	N/A	N/A	62'10" X 40'10"
Container/LASH												
C8-S-81b	RRF	Capes Fear/Florida	772-4	40-8	21	17,552	-	-	455	N/A	N/A	62'5" X 33'8"
C9-S-81d	RRF	Capes Farewell/Flattery	893-4	38-1	21	27,693	-	-	492	N/A	N/A	62'5" X 33'8"
Heavy Lift												
C8-S-82a	RRF	Capes May/Mohican	873-9	39-1	16.2	23,953	117,786	88,340	N/A	N/A	N/A	N/A

Table 2 (Cont)

TYPE/CLASS	FLEET	NAME	LENGTH (FT-IN)	MAX DRAFT (FT-IN)	SERVICE SPEED (KNOTS)	CARGO DEADWEIGHT (LTONS)	TOTAL SQUARE FEET	USABLE SQUARE FEET	MAX BOOM CAPACITY (LTON)	RAMP DOOR OPENING (W X H)	RAMP CAPACITY (LTON)	MAX HATCH OPENING (L X W)
MPS												
Waterman	SQUADRON 1	SGT Matej Kocak/PFC Eugene A. Obregon/ MAJ Stephen W. Pless	821-0	33-6	20.0	19,069	192,652	144,489	98	44'0" X 18'0"	200	41'0" X 80'11"
Maersk	SQUADRON 2	PFC James Anderson, Jr/PFC William B. Baugh/1LT Alex Bonnyman/CPL Louis J. Hauge, Jr/PVT Franklin J. Phillips	755-5	32-10	16.4	14,488	170,031	127,523	132	21'3" X 15'4"	66	83'7" X 33'5"
Private	SQUADRON 1	1 LT Harry L. Martin	754-0	34-0	17.0	18,874	202,736	152,052	111.6	24'0" X 15'7"	71.4	48'0" X 21'6"
AmSea	SQUADRON 3	2LT John Bobo/SGT William R. Button/1LT Baldomero Lopez/ 1LT Jack Lummus/PFC Dewaye T. Williams	673-2	32-1	17.7	19,278	202,142	151,607	156	44'0" X 15'0"	66	61'8" X 33'4"
LMSR	SQUADRON 2	GYSGT Fred W. Stockham	906-0	34-4	24.0	15,314	299,072	224,304	113	40'0" X 16'0"	71.4	68'0" X 31'6"
Private	SQUADRON 3	LCPL Roy M. Wheat	864-0	35-1	22.0	16,300	113,000	84,750	113	34'5" X 16'0"		49'6" X 29'3"
RORO												
Gas Turbine	RRF	Admiral William M. Callaghan	694-3	29-1	21.3	9,225	153,825	115,369	120	17'0" X 18'0"	55	40'6" X 30'0"
Cape D (G1-Dsl)	RRF	Capes Decision/Diamond/ Domingo/Douglas/Ducato	680-4	31-5	16.2	15,549	167,339	125,504	N/A	23'0" X 17'0"	65	N/A
Cape E (G0-Dsl)	RRF	Cape Edmont	652-11	31-5	15.7	11,476	161,372	121,029	35	34'4" X 18'3"	220	N/A
Cape H (G2-Dsl)	RRF	Capes Henry/Hudson	749-8	35-6	17.4	25,882	214,365	160,774	39	39'4" X 20'8"	63.9	N/A
Cape H (G2-Dsl)	RRF	Cape Horn	749-8	35-6	17.4	25,882	214,365	160,774	39	39'4" X 20'8"	63.9	N/A
Cape I (C7-S-95a)	RRF	Capes Inscription/Intrepid/ Isabel/Island	684-9	34-0	18.7	13,244	149,088	111,816	30	40'0" X 16'0"	100	N/A
Cape K (Dsl)	RRF	Capes Kennedy/Knox	695-10	35-1	16.6	21,599	146,895	110,171	N/A	29'10" X 22'11"	200	N/A
Cape L (Dsl)	RRF	Capes Lambert/Lobos	682-0	30-5	16.2	13,521	75,644	56,733	N/A	12'8" X 14'2"	30	N/A
Cape O (Dsl)	RRF	Cape Orlando	635-3	30-3	16.2	15,896	118,780	89,085	35	24'10" X 22'3"	91.6	N/A
Cape R (Dsl)	RRF	Capes Race/Ray/Rise	647-11	32-8	16.6	20,500	176,313	132,235	N/A	41'0" X 23'6"	200	N/A
Cape T (Dsl)	RRF	Cape Taylor	633-11	29-11	15.7	9,841	116,004	87,003	N/A	36'0" X 26'0"	160	N/A
Cape T (Dsl)	RRF	Capes Texas/Trinity	634-3	28-4	15.7	10,309	117,854	88,391	N/A	36'0" X 26'0"	160	N/A
Cape V (Dsl)	RRF	Capes Victory/Vincent	631-10	28-4	14.0	16,421	133,409	100,057	N/A	23'8" X 20'2"	292	N/A
Cape W (Dsl)	RRF	Capes Washington/Wrath	696-11	38-0	14.9	29,700	295,958	221,969	N/A	26'3" X 19'6"	204	N/A
C3-ST-14	RRF	Comet	499-0	27-5	15.0	8,734	88,357	66,268	60	19'0" X 12'0"	60	42'6" X 30'0"
C4-ST-67	RRF	Meteor	540-0	29-1	17.9	9,460	103,440	77,580	70	18'0" X 13'0"	56	40'0" X 30'0"

Table 2 (Cont)

TYPE/CLASS	FLEET	NAME	LENGTH (FT-IN)	MAX DRAFT (FT-IN)	SERVICE SPEED (KNOTS)	CARGO DEADWEIGHT (LTONS)	TOTAL SQUARE FEET	USABLE SQUARE FEET	MAX BOOM CAPACITY (LTON)	RAMP DOOR OPENING (W X H)	RAMP CAPACITY (LTON)	MAX HATCH OPENING (L X W)
LMSR												
HOPE Class – Avondale New Construction	MSC	USNS Bob Hope/Fisher/Seay/ Mendonca/Pililaau/Brittin/Benavidez	949-3	35-0	24	18,885	387,662	290,747	113	40'0" X 16'0"	71.4	68'0" X 31'6"
WATSON Class – NASSCO New Construction	CPF	USNS Watson/Sisler/Dahl/Red Cloud/Charlton/Watkins/Pomeroy/ Soderman	950-0	33-6	24	19,311	392,584	294,438	113	40'0" X 16'0"	71.4	54'0" X 16'0"
GORDON Class – Newport News Conversion	MSC	USNS Gordon/Gilliland	954-3	36-2	24	15,205	321,831	241,373	113	40'0" X 16'0"	71.4	68'1" X 31'11"
SHUGHART Class – NASSCO Conversion	MSC	USNS Shughart/Yano	906-11	35-4	24	15,205	302,087	226,565	113	40'0" X 16'0"	71.4	68'0" X 31'6"
FSS												
Avondale Conversion	MSC	USNS Altair/Antares/Pollux	946-1	36-8	27	14,266	199,362	149,522	100	30'0" X 13'6"	90	68'0" X 31'6"
NASSCO Conversion	MSC	USNS Algol/Bellatrix/Regulus	946-1	36-8	27	14,210	203,000	152,250	100	30'0" X 13'6"	90	68'0" X 31'6"
Pennship Conversion	MSC	USNS Capella/Denebola	946-1	36-9	27	14,987	206,963	155,222	100	30'0" X 13'6"	90	68'0" X 31'6"
RORO/Container												
C5-S-78a	RRF	Cape Nome	602-0	34-1	18.7	12,450	60,340	45,255	70	15'0" X 14'6"	56.4	41'11" X 25'8"
C6-M	CPS	LTC Calvin P. Titus/MAJ Bernard F. Fisher/SP5 Eric G. Gibson	652-3	36-0	19	30,571	10,987	8,240	36	20'6" X 18'2"	100	40'10" X 34'5"
C4-S-64a	MSC	TSGT John Chapman	669-9	34-6	16	15,477	125,136	93,852	40	23'0" X 15'7"	120	42'7" X 27'5"
RORO/Container/ Breakbulk												
C5-M-PVT118	MSC	Maersk Constellation	598-1	32-0	18	11,077	97,543	73,157	60	23'11" X 15'3"	49	84'4" X 33'5"

[1] with 75% stow factor applied

Legend:

CPF - Combat Prepositioning Force

CPS - Combat Prepositioning Ship

LPS - Logistics Prepositioning Ship

MPS - Maritime Prepositioning Ship

MSC - Military Sealift Command

Containers and Flatracks

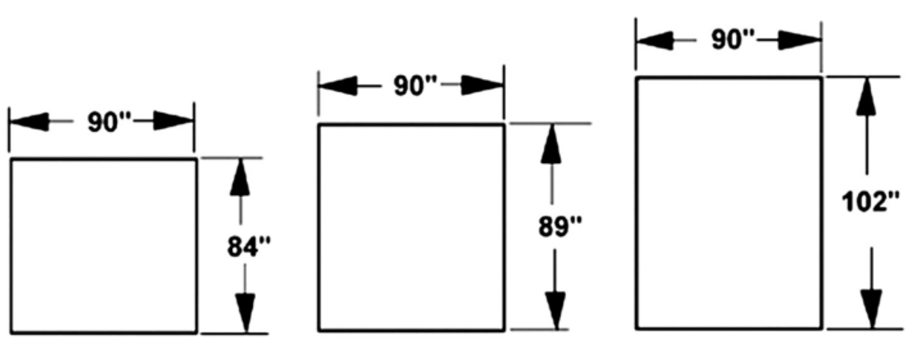
Cargo containers and flatracks are transport equipment designed and constructed to facilitate the international and intermodal exchange of goods. They are designed to be used repeatedly and to provide security during transport. Also, their fittings readily permit handling and transfer from one transport mode to another. A very strong trend exists for commercial ocean carriers to equip their fleets predominantly with ships that have standardized container cells and to withdraw breakbulk ships from service. Thus, force deployability will be improved if many pieces of individual military equipment can be containerized or placed on flatracks for movement in commercial containerships. Designing for container/flatrack transport effectively increases the strategic sealift assets available for deploying the force.

Military materiel should be transportable in 8.5-foot-high by 8-foot-wide by 20-foot-long American National Standards Institute/International Organization for Standardization (ANSI/ ISO) containers or flatracks, where practical, to take full advantage of the intermodal benefits of containerization. Other common containers for military transport are the ANSI/ISO 9-foot-6-inch-tall containers and the ANSI/ISO 40-foot-long containers. When C-130 transport is required the container height is limited to 8 feet.

For rail, truck, and ocean transport, a 20-foot container or flatrack is limited to a gross weight of 52,900 pounds and a 40-foot container to a gross weight of 67,200 pounds. For air transport, lower maximum weights apply. The weight of the containers alone is generally less than 6,000 and 9,000 pounds for 20- and 40-foot containers, respectively.

The door openings of 8-foot-high ANSI/ISO containers are 90 inches wide and 84 inches high. The door openings of 8-1/2-foot-high ANSI/ISO containers are 90 inches wide and 89 inches high. The door openings of 9-1/2-foot-high ANSI/ISO containers are 90 inches wide and 102 inches high. Interior widths and heights are subject to slight variations, but are always larger than the door openings. Items being designed for containerization should be no more than 85 inches wide and no more than 85 inches high (80 inches high if designed for 8-foot-high containers and MILVANs.) Commercial 8-1/2-foot-high ANSI/ISO containers/flatracks are now so common that, if military equipment fits within them, it will be readily container/flatrack transportable, at least on the ocean leg of its journey. The interior lengths of 20- and 40-foot containers are at least 19-feet 3-inches and 39-feet 4-inches, respectively. However, consideration must also be given to restraining the item in the container

ISO Container Door Openings



Shelters

Many communications, support, and weapons systems require the use of shelters. When shelters are used, they should be made the same size and equipped with the same fittings as ANSI/ISO containers, or standard shelters such as the S-250, S-280, S-787 Standardized Integrated Command Post System (SICPS), or S-788 Lightweight Multipurpose Shelter (LMS) should be used. ***The use of nonstandard shelters should be avoided!*** Developers must take care not to overload shelters and their prime movers. As the following chart shows, overloading a system prime mover is possible even if the maximum theoretical shelter payload is not exceeded. When calculating shelter weight, do not forget to include basic issue items (BII), camouflage nets, ladders, manuals, cable reels, and any other items that will be carried on the shelters.

Allowable Shelter Payloads on Different Prime Movers[1]

Shelter	**Shelter Empty Weight/ Gross Weight (lb)**	**HMMWV M1037 (lb)**[2] *(max payload = 3,331 lb)*	**Heavy HMMWV M1097 (max payload) (lb)**[2] *(max payload = 4,401 lb)*	**Expanded Capacity Vehicle M1113 (lb)**[2] *(max payload = 5,120 lb)*	**2.5 Ton Truck (lb)**[3] *(max payload = 5,000 lb)*	**5 Ton Truck (lb)**[3] *(max payload = 10,000 lb)*
S-250[4]	770/3,300	1,783	2,530	2,530	2,530	2,530
S-787[5]	2,750/4,400	N/A[7]	1,650	1,650	1,650	1,650
S-788[5]	630/3,930	1,923	2,993	3,300	3,300	3,300
S-832/G	2,505/3,987	48	1,118	1,482	1,482	1,482
S-832A/G	2,680/3,987	N/A[7]	943	1,307	1,307	1,307
S-842/G	2,861/4,057	N/A[7]	762	1,196	1,196	1,196
S-842A/G	2,941/4,057	N/A[7]	682	1,116	1,116	1,116
S-280/G, A/G, B/G[6]	1,380/6,380	N/A[7]	N/A[7]	N/A[7]	3,620	5,000
S-280C/G	1,400	N/A[7]	N/A[7]	N/A[7]	3,600	7,100

[1] Shaded area are limited by vehicle payload; unshaded areas limited by shelter payload.
[2] Two-man crew and gear at 640 lb and shelter tare weight deducted from allowable payload. If the HMMWV pulls a trailer, the pintle load must be deducted from the above figures.
[3] Shelter tare weight deducted from allowable vehicle payload.
[4] Payloads shown are unshielded; for EMI shielding, deduct 12 lb from these payloads. Tare weight does not include mounting cradle (82 lb).
[5] Tare weight does not include mounting kit (88 lb) and pintle extension (50 lb).
[6] Payloads shown are unshielded; for EMI shielding, deduct 10 lb from these payloads.
[7] Shelter incompatible with vehicle or would overload it empty.

Lifting and Tiedown Provisions

Equipment without adequate provisions is a logistic burden during deployment, especially when time is critical. Inadequate designs create restraint and handling problems during transport, especially transport by rail and marine modes. In addition, inadequate designs can cause damage to equipment and be dangerous to personnel.

All items of military equipment must have adequately designed lifting and tiedown provisions. Vehicles must have provisions designed for the gross vehicle weight (fully loaded vehicle) because vehicles are deployed with unit equipment in their cargo beds. Cargo vehicles shall be equipped with BII tiedown assemblies (chains, load binders, shackles, and so forth) with a working load limit suitable for the design limit load of the cargo provisions and in the quantity necessary to adequately restrain all possible payloads on the vehicle. The design limit load of the cargo tiedown provisions shall meet or exceed the safe working load of the number of anticipated tiedown assemblies to each provision (Title 49 CFR 393.102).

BII tiedown assemblies must also meet tiedown requirements for full vehicle payload for all modes of transport on which the cargo vehicle will be transported. Lifting and tiedown provisions must be integral to the equipment. Shackles and other provisions that can be removed are prohibited. See **MIL-STD-209**, *Interface Standard for Lifting and Tiedown Provisions* for specific requirements.

ADEQUATE LIFTING AND TIEDOWN PROVISIONS ARE ESSENTIAL TO EFFICIENT TRANSPORT

Transportability Vehicle Growth Metrics

The following charts show how the growth of a vehicle in a particular dimension or weight affects its ability to be transported by various transportation assets. The values shown for these transport modes are usually maximums that do not reflect the contour of the transportation asset or envelope. More detailed information on aircraft fuselage design envelopes and rail clearance envelopes is available on pages 17 and 32, respectively.

Over the past 40 years, the Army has developed, fielded, and upgraded several families of combat vehicles; all have experienced significant weight growth. Add-on armor and advances in technology are the two biggest factors in tactical vehicle growth. This has created transportability problems for highway, rail, sea, and air modes of transport. It is critical that the design of new systems allow for sufficient weight growth potential. Developers and contractors should plan for weight growth increase of 25% over the life of their system.

Transportability Design Limits by Width

Width (inches)	Infrastructure/Asset Limitation
53	V-22 tilt rotor aircraft limit for internal air transport (with vehicle crew)
58	V-22 tilt rotor aircraft limit for internal air transport (without vehicle crew)
80	CH-47D limit for internal air transport
85	ANSI/ISO container equipment limit
89	Palletized Load System (PLS) M3 and M3A1 flatrack limit
90.5	PLS M1077 flatrack limit
92	Maximum width for C-17 Dual Row Airdrop System (DRAS)
96	C-130 wheeled and tracked vehicle practical limit (from the floor to a height of 5.5 inches) for passengers to accompany vehicle PLS M1 flatrack equipment limit Highway legal limit in U.S. for unrestricted transport Heavy-Duty 40-foot flatrack limit
97.5	C-130 wheeled and tracked vehicle maximum limit (from the floor to a height of 5.5 inches) for passengers to accompany vehicle (allows 1.0 inch clearance between vehicle and aircraft rail system)
98.4	Highway legal limit in NATO and most other foreign countries
99	C-130 wheeled and tracked vehicle limit (from 5.5 inches to 102.0 inches above the floor) for passengers to accompany vehicle C-17 wheeled and tracked vehicle limit for side-by-side loading
100	C-130 wheeled and tracked vehicle practical limit at the floor (from the floor to a height of 5.5 inches) for a symmetrically loaded vehicle without accompanying passengers B-747 maximum nose door loading limit at a height of 92 inches Type V airdrop platform usable width between the tiedown rails
102	Legal limit for transport on the U.S. Interstate and Defense highway
107	C-130 limit (from 5.5 inches to 102.0 inches above the floor) for a symmetrically loaded vehicle without accompanying passengers
108	Maximum limit for heavy airdrop (low velocity airdrop)

Transportability Design Limits by Width (cont)

110	B-747 practical maximum side door loading limit
118	Landing Craft Mechanized (LCM) Mk. 6 bow ramp limit
120	B-747 nose door loading limit up to a 70 inch limit
124	Gabarit International de Chargement (GIC) rail outline diagram limit (up to 125 inches above the top of the rails, or 73.6 inches above the top of the railcar)
128	Association of American Railroads (AAR) rail outline diagram limit (up to 125 inches above the top of the rails, or 73.6 inches above the top of the railcar)
133.9	NATO Envelope B rail outline diagram limit (up to 120.6 inches above the top of the rails, or 69.2 inches above the top of the railcar)
141.7	Korean rail outline diagram limit (up to 122 inches above the top of the rails, or 74.8 inches above the top of the railcar (66.9 inches for heavy duty railcars))
144	DOD rail outline diagram limit (up to 177 inches above the top of the rails, or 126 inches above the top of the railcar) Maximum highway permit limit in U.S. and Europe C-5 limit at top of clearance envelope (156 inches high)
153	Marine Corps LCU-1646 worst case cargo deck limit (deck width varies up to 300 inches)
162	LCM Mk. 8 ramp limit
173	C-17 limit at 156 inch height (aft of the wing box)
196	C-17 limit for height 136 to 142 inches
204	C-17 limit for height below 136 inches Large Medium Speed Roll-on/Roll-off (LMSR) interior ramp limit Fast Sealift Ship (FSS) maximum interior ramp limit (3 ramps are less than 204 inches wide)
216	C-5 limit for height equal to or below 108 inches

Transportability Design Limits by Height

Height (inches)	Infrastructure/Asset Limitation
47.2	Korean standard flatcar deck height above the top of the rails
51.0	North American standard flatcar deck height above the top of the rails
51.4	NATO countries heavy duty flatcar deck height above the top of the rails
55.1	Korean heavy duty flatcar deck height above the top of the rails
55.7	V-22 limit for internal air transport (for 53 inch width, with crew)
60.0	V-22 limit for internal air transport (for 41.6 inch width)
70.0	Palletized Load System (PLS) M1 flatrack cargo limit for fitting within a container cell
72.0	CH-47D internal height limit
74.0	PLS M3/M3A1 flatrack cargo limit for fitting within an ANSI/ISO container
80.0	ANSI/ISO 8-foot high container cargo limit
84.5	Unrigged vehicle airdrop limit for vehicle with no suspension system
85.0	ANSI/ISO 8-1/2 foot high container cargo limit
86.9	PLS flatrack (M1077, M1, M3 and M3A1) cargo limit for meeting NATO highway transport limits
90.0	Unrigged vehicle airdrop limit for vehicle with suspension system
91.4	PLS flatrack (M1077, M1, M3 and M3A1) cargo limit for meeting U.S. highway transport legal limits
92.0	B-747 maximum nose door loading limit
100.0	Rigged height limit for heavy airdrop (low velocity airdrop)
102.0	C-130 internal transport limit (see page 10)
114.0	B-747 practical maximum side door loading limit
120.0	C-17 coplanar loading limit (straight-in loading from a K-loader)
126.0	Heavy Duty 40-foot flatrack limit (fixed endposts)
142.0	C-17 internal transport limit under and forward of the wing box (see page 14)
150.0	Fast Sealift Ship (FSS) maximum interior ramp limit (3 ramps are less than 150 inches high)
156.0	C-17 internal transport limit aft of wing box C-5 internal transport limit (see page 15) FSS external ramp access door
157.5	Highway legal limit for NATO and most other foreign countries
162.0	Highway legal limit for transport in the U.S.
168.5	Gabarit International de Chargement (GIC) rail outline diagram limit above the top of the rails (width restricted to 31.5 inches at this height) (see page 29) Note: Rail clearance diagrams are contoured outlines. See MIL-STD-1366 for the exact dimensions of the diagram.

Transportability Design Limits by Height (cont)

Height (inches)	Infrastructure/Asset Limitation
172.2	NATO Envelope B rail outline diagram limit above the top of the rails (width restricted to 49.6 inches at this height) (see page 30) Note: Rail clearance diagrams are contoured outlines. See MIL-STD-1366 for the exact dimensions of the diagram.
177.2	Korean rail outline diagram limit above the top of the rails (width restricted to 77.2 inches at this height) (see page 31) Note: Rail clearance diagrams are contoured outlines. See MIL-STD-1366 for the exact dimensions of the diagram.
180.0	Large Medium Speed Roll-on/Roll-off (LMSR) ship maximum interior ramp clearance (6 ramps are less than 180 inches high)
181.0	Association of American Railroads (AAR) rail outline diagram limit above the top of the rails (width restricted to 84 inches at this height) (see page 27) Note: Rail clearance diagrams are contoured outlines. See MIL-STD-1366 for the exact dimensions of the diagram.
186.0	LMSR external ramp access door
203.0	DOD rail outline diagram limit above the top of the rails (width restricted to 97 inches at this height) (see page 28) Note: Rail clearance diagrams are contoured outlines. See MIL-STD-1366 for the exact dimensions of the diagram.

Transportability Design Limits by Length

Length (inches)	Infrastructure/Asset Limitation
179.0	B-747 side door loading, maximum length for maximum practical width (110.0 inches) and height (114.0 inches)
180.0	V-22 tilt rotor aircraft max vehicle length (4 person crew, includes restraint)
200.0	V-22 tilt rotor aircraft max vehicle length (2 person crew, includes restraint)
217.0	Palletized Load System (PLS) M3 and M3A1 flatrack limit
228.0	PLS M1 flatrack limit
230.4	PLS M1077 flatrack limit (cargo other than an ISO container)
231.0	ANSI/ISO 20-foot long container equipment limit
250.0	V-22 tilt rotor aircraft interior cargo compartment limit
264.0	B-747 nose door loading, maximum length for palletized load up to 104 inch width
324.0	B-747 nose door loading, maximum length for palletized load up to 84 inch width
331.0	CH-47D interior cargo compartment limit
393.7	Highway legal limit for a single unit vehicle in NATO and most foreign countries
462.0	Heavy Duty 40-foot flatrack limit
468.0	C-130E/H/J usable flat floor length (not including 130-inch ramp)
472.0	ANSI/ISO 40-foot long container equipment limit
480.0	Highway legal limit for a single unit vehicle in the U.S.
492.0	Rail transport maximum length for ordinary transport in NATO countries C-130E/H/J actual flat floor length (not including 130-inch ramp)
504.0	LCM Mk. 8 Mod. 2 (steel and aluminum) cargo deck length
513.0	LCM-8 cargo deck length
551.0	Highway legal limit for a truck tractor/semitrailer combination in NATO
636.0	Highway legal limit for a semitrailer in the U.S. (no longer any limit on truck tractor/semitrailer combination length)
684.0	CC-130J (C-130J-30) usable flat floor length (not including 130-inch ramp)
784.0	C-17 flat floor length at width of 216 inches (not including usable ramp length of 238 inches)
804.0	Lighter Cushioned Air Cargo (LCAC) cargo deck length (Navy)
818.0	C-17 flat floor length at width of 116 inches (not including usable ramp length of 238 inches)
906.0	Landing Craft Utility (LCU)-1466 cargo deck length
1,200.0	LCU-1646 cargo deck length (USMC)
1,296.0	LCU-2000 cargo deck length
1,320.0	LCU-1646 cargo deck length (Army)

Transportability Design Limits by Weight

Weight (pounds)	Infrastructure /Asset Limitation
3,600	V-22 tilt rotor aircraft maximum two axle vehicle weight over ramp
4,700	UH-60A external limit for 4,000 feet, 95 F, 30 NM radius mission scenario
4,900	V-22 tilt rotor aircraft maximum two axle vehicle weight in cabin
5,000	C-130 ramp flight limit V-22 tilt rotor aircraft pallet cargo capacity
6,630	UH-60L external limit for 4,000 feet, 95 F, 30 NM radius mission scenario
7,500	V-22 external limit for 4,000 feet, 95 F, 30 NM radius mission scenario
7,843	UH-60A external limit for sea level, 60 F, 30 NM radius mission scenario
9,000	UH-60L external limit for sea level, 60 F, 30 NM radius mission scenario
10,000	Air Force 463L pallet cargo capacity
13,320	V-22 external limit for sea level, 60 F, 30 NM radius mission scenario
15,000	C-5 ramp flight limit
15,639	CH-47F external limit for 4,000 feet, 95 F, 30 NM radius mission scenario
16,014	CH-47F internal limit for 4,000 feet, 95 F, 30 NM radius mission scenario
16,644	CH-47D external limit for 4,000 feet, 95 F, 30 NM radius mission scenario
16,900	CH-47D internal limit for 4,000 feet, 95 F, 30 NM radius mission scenario
18,023	CH-47F external limit for sea level, 60 F, 30 NM radius mission scenario
18,029	CH-47F internal limit for sea level, 60 F, 30 NM radius mission scenario
23,300	CH-47D internal limit for sea level, 60 F, 30 NM radius mission scenario
23,324	CH-47D external limit for sea level, 60 F, 30 NM radius mission scenario
25,000	B-747 maximum practical vehicle weight
27,500	Armored C-130E/H payload limit under ideal conditions for an assault landing (3,000 foot runway) with no fuel available for the aircraft at the destination airfield and the recovery airfield for the aircraft to refuel being 250 nautical miles away.
30,500	Armored C-130E/H payload limit under ideal conditions for an assault landing (3,000 foot runway) with no fuel available for the aircraft at the destination airfield and the recovery airfield for the aircraft to refuel being 100 nautical miles away.
33,000	Palletized Load System (PLS) flatrack payload limit
34,200	Airdrop equipment limit (using current 42,000-pound airdrop system hardware)
35,000	Armored C-130E/H payload limit under ideal conditions for an assault landing (3,000 foot runway) with fuel available for the aircraft at the destination airfield
36,500	Armored C-130E/H payload limit for a range of 1,000 nautical miles under ideal conditions for a normal landing (5,000 foot runway) with fuel available for the aircraft at the destination airfield
38,000	Armored C-130E/H payload limit for a range of 860 nautical miles under ideal conditions for a normal landing (5,000 foot runway) with fuel available for the aircraft at the destination airfield

Transportability Design Limits by Weight (cont)

Weight (pounds)	Infrastructure /Asset Limitation
40,000	C-17 ramp flight limit Armored C-130E/H payload limit for a range of 500 nautical miles under ideal conditions for a normal landing (5,000 foot runway) with fuel available for the aircraft at the destination airfield
42,000	Armored C-130E/H payload limit for a range of 60 nautical miles under ideal conditions for a normal landing (5,000 foot runway) with fuel available for the aircraft at the destination airfield
43,333	C-17 three-vehicle limit (per vehicle) at a range of 3,200 NM
44,092	Unrestricted rail transport in NATO countries
45,000	M871 semitrailer payload limit
52,900	20-foot ANSI/ISO container gross weight limit
54,000	Lighter Cushioned Air Cargo (LCAC) cargo capacity
59,333	C-5 three-vehicle limit (per vehicle) at a range of 3,200 NM
59,500	Ks Deutsche Bundesbahn (DB) flatcar load limit (light duty, 2 axle)
65,000	C-17 two-vehicle limit (per vehicle) at a range of 3,200 NM
67,200	40-foot ANSI/ISO container gross weight limit
68,000	M872 semitrailer payload limit Landing Craft Mechanized (LCM) Mk. 6 cargo capacity
80,000	U.S. highway legal limit on the Interstate system M870 semitrailer payload limit
89,000	C-5 two-vehicle limit (per vehicle) at a range of 3,200 NM
110,200	Korean 50Ton flatcar load limit
111,300	Rs Deutsche Bundesbahn (DB) flatcar load limit (heavy duty, four axles)
120,000	LCM-8 cargo capacity
130,000	C-17 payload capacity at a range of 3,200 NM
134,200	C-5 maximum limit for tracked vehicles with suspension systems
135,000	C-17 maximum limit for tracked vehicles with suspension systems
140,000	M1000 payload limit TTDX and ITTX railcar load limit Armored Vehicle Launched Bridge (AVLB) (modified) limit Wolverine heavy assault bridge limit
143,300	Samms Deutsche Bundesbahn (DB) flatcar load limit (heavy duty, 6 axle)
144,000	Heavy Duty 40-foot flatrack limit
146,000	HTTX railcar load limit
154,000	Korean 70Ton flatcar load limit
156,800	Fast Sealift Ship (FSS) maximum crane lift capacity
160,000	Large Medium Speed Roll-on/Roll-off (LMSR) ship external ramp limit for one vehicle (the ramps can carry one M1 tank (weighing 160,000 pounds) towing another M1 tank (weighing 160,000 pounds). The two tanks must be 48 inches apart.
164,000	DODX 42000-series railcar load limit
167,400	C-17 payload up to a range of 2,250 NM
178,000	C-5 payload at a range of 3,200 NM
180,000	DODX 41000-series railcar load limit

Transportability Design Limits by Weight (cont)

Weight (pounds)	Infrastructure /Asset Limitation
201,600	FSS external ramp limit for one vehicle
253,120	LMSR maximum crane lift capacity (20 to 95 foot operating radius, twin crane mode)
298,000	DODX 40000-series railcar load limit
320,000	LMSR and FSS external ramp limit for two vehicles (the ramps can carry one M1 tank (weighing 160,000 pounds) towing another M1 tank (weighing 160,000 pounds). The two tanks must be 48 inches apart.

Transportability Design Limits by Axle Load

Axle Load (pounds)	Infrastructure/Asset Limitation
1,800	V-22 tilt rotor aircraft limit up ramp
2,450	V-22 tilt rotor aircraft limit in cabin
2,500	C-130 ramp in-flight axle load limit
3,500	C-130 ramp in-flight axle load limit if there is nothing else on the ramp
5,000	CH-47D axle load limit on treadways
6,000	C-130 limit for pneumatic tires at a pressure of 100 psi or less (outside of 28.75 foot long high strength treadways, Fuselage Station (FS) 337 to 682)
7,470	B-747 limit, nose door loading
11,000	B-747 practical limit, side door loading for movement of multiple vehicles
13,000	C-130 limit for pneumatic tires at a pressure of 100 psi or less (limited to the 28.75 foot long high strength treadways (FS 337 to 682)) C-17 limit for single equal-weight axles side-by-side (compartments "D," "F" and "G")
17,000	B-747 tandem axle limit, side door loading for movement of multiple vehicles
20,000	C-17 limit for single equal-weight axles side-by-side (compartment "E") U.S. Highway legal limit for single axles
22,000	C-17 limit for single axles beside 4,500 lb axles (compartments "D," "F" and "G")
22,046	NATO countries' highway legal limit for single axles
23,000	C-17 limit for tandem axles side-by-side (compartments "D," "F" and "G")
27,000	C-17 limit for single axles beside 4,500 lb axles (compartment "E") C-17 limit for single axles with the vehicle centerline within 8 inches of the aircraft centerline (compartments "D," "F" and "G")
34,000	U.S. highway legal limit for tandem axles
35,274	NATO countries' highway legal limit for tandem axles
36,000	C-5 single axle load limit C-17 limit for single axles with the vehicle centerline within 8 inches of the aircraft centerline (compartment "E")
40,000	C-17 limit for tandem axles side-by-side (compartment "E")
50,000	C-5 tandem axle load limit (25,000 lb per axle)

3 Transportability Problem Item

What is a Transportability Problem Item?

All items that qualify as a transportability problem item are required to have transportability approval prior to each major milestone decision.

A piece of equipment is considered a transportability problem item when any of the following conditions apply:

a. The item is wheeled or tracked, and is to be towed, hauled, or self-propelled on or off highway.

b. The item increases the physical characteristics of the designated transport medium.

c. The item requires special handling or specialized loading procedures.

d. The item has inadequate ramp clearance for ramp inclines of 15 degrees.

e. The item exceeds any of the following conditions:

(1) Length - 20 feet

(2) Width - 8 feet

(3) Height - 8 feet

(4) Weight - 10,000 pounds

(5) Weight per linear foot - 1,600 pounds/foot

(6) Floor contact pressure - 50 psi

Note: Items that are not on military units' tables of organization and/or equipment (TOE or T/E) and do not have a strategic or Homeland Security deployment requirement are not considered transportability problem items and do not need transportability approval.

What is a Non-problem Item?

When an item does not qualify as a transportability problem item, it is termed as a "non-problem item." Non-problem items are not required to have transportability approval at major milestones and TEA's involvement throughout the acquisition cycle is not required. It is the program manager's responsibility to determine if an item qualifies as a transportability problem item. If desired, TEA will provide a nonproblem item statement; however, it is not necessary and this type of request is usually handled through email only and not through official correspondence. Sometimes a program manager has the desire to subject a system that does not qualify as a transportability problem item to transportability testing. In this case, the program manager may coordinate directly with the testers. TEA involvement is not required.

4 Acquisition Process

General

Transportability and Deployability must be a design consideration for all systems that meet the definition of a transportability problem item. This is regardless of the acquisition category or acquisition strategy, including modifications to existing equipment. Equipment being reprocured must be updated to reflect changes to the Defense Transportation System (DTS) and to correct past deficiencies. The Defense Transportation System is the portion of the global transportation infrastructure that supports DOD common-user transportation needs across the range of military operations. Transportability and deployability must be addressed throughout the acquisition process to ensure maximum benefit for the fielded system. This chapter provides a discussion of how and where transportability fits into the acquisition process.

While transportability and deployability may be thought of as an integral part of system design in preparation for fielding, it is never too early to consider these issues as potential materiel solutions are being conceived. Both are an important part of the process of translating operational needs into stable, affordable programs. Size and weight constraints for transport should be a part of the earliest analyses of equipment alternatives. Delaying consideration will result in lost time and increased costs for later design changes.

Concept Studies and Concept Refinement

In today's environment of limited procurement budgets and changing threats, there is an increased emphasis on concept refinement prior to the decision to initiate an acquisition program. Concept studies at this time should include the potential for meeting transportability and deployability mission needs, and how alternatives can best improve the utilization of transportation resources to improve force transport and deployment. These improvements should be a part of the decision supporting initiation of a new acquisition program.

With this in mind, TEA has developed modeling and simulation tools that provide the capability to address transportability and deployability throughout the acquisition process. These analysis tools result in improved up-front analyses and give concept developers the ability to conduct multiple analyses on different concepts and technologies in a timely manner. See Chapter 7, *Modeling and Simulation,* and Chapter 9, *Deployability,* for information on these analysis tools.

Equipment Acquisition

With the decision to initiate a new acquisition program, the transportability and deployability lessons from concept refinement provide the basis to produce a system enhancing equipment transport and force deployment. Transportability and deployability actions take place throughout the acquisition cycle. Each input and action is important to assure that the equipment being procured, as well as the associated support items of equipment, is capable of efficient transport and deployment. The omission of transportability and deployability at any time in the acquisition process, or tradeoff decisions that do not consider the full implications on transportability and deployability, can negate all previous efforts and advances made during the early stages of procurement.

While applicable throughout acquisition, the transportability and deployability status of an item should be updated prior to each milestone decision. However, this is too late to correct shortcomings prior to the milestone. This will determine corrections that must be made during the next acquisition phase. Considering transportability and deployability throughout the process will prevent shortcomings from being identified at the milestone decision, and assure they are identified and corrected as a part of the development process.

Transportability approval establishes that the item of equipment meets transportability requirements established in the system's capabilities documents. Approval is required prior to the production decision for an item. Concurrence is also required in support of materiel release. This release ensures any modifications incorporated into the produced item have not adversely affected item transport and deployment.

Design Considerations

Historically, combat systems have increased in weight by 25 percent over the life of the system. This has created transportability problems for highway, rail, marine, and air modes of transport. Consideration of potential improvements and allowing for them in the initial design can mitigate future transport degradation. For additional information on system weight growth, refer to TEA's 27 August 2002 White Paper, *Historic Weight Growth of U.S. Combat Vehicle Systems.* Acceptance of equipment sectionalization for transport should be closely considered. While it may be expedient to accept sectionalization as a means of accomplishing difficult design requirements and promoting a program, it adversely affects the receiving units when the required equipment preparation significantly increases their deployment and employment preparation. An item of equipment that can deploy in the configuration in which it will be employed should always be the goal in designing equipment for transport and deployment.

5 Requirements

General

Transportability requirements must be provided in all capability documents for transportability problem items. Determining and documenting these requirements are essential to achieving the level of transport required of the item to perform its mission. The meaning of different transportability requirements and the limitations associated with each requirement are explained in this chapter.

Transportability Requirements

AR 71-9, *Materiel Requirements*, states that transportability must be included in all capability documents. Simply including transportability, however, is not enough. The transportability requirements of an item to be procured must reflect the mission requirements of that item. For example, if an item has a rapid-deployment-type mission, it must be air transportable by C-130 in an operational configuration. The mission requirements must be known when the original need for the item is developed. Once these requirements have been developed, the determination of transportability requirements is simple. The options available for each mode when a transportability requirements statement is needed are explained in detail in this chapter.

Highway

Almost every item of military equipment, be it a self-propelled vehicle, a trailer, or cargo, uses the highway mode. All equipment (with the possible exception of aircraft and large marine craft) must be capable of highway transport. This is especially true of equipment with a rapid-deployment-type mission, since highway transport is essential to the delivery of equipment to the port of embarkation for deployment as well as within the theater of operations.

The optional statements for the highway portion of the transportability requirements statement for wheeled vehicles follow. Tracked vehicles and skid-mounted (or other) equipment must be included in the prime mover combination when highway transport restrictions are discussed.

The item must:

1. Meet U.S. and NATO countries' highway legal limits

The choice of this option means that highway transport would be almost unrestricted. This is the most restrictive, practical highway transport statement. The vehicle or loaded prime mover combination would have to be within both the U.S. and NATO size and weight limits listed on page 23.

2. Meet U.S. highway legal limits

The choice of this statement means that the vehicle or loaded prime mover combination could have the maximum dimensional and weight characteristics listed under the U.S. highway limits on page 23. Highway transport in the United States would be almost unrestricted.

3. Be within the maximum permit limits established by the individual States

The choice of this statement means that vehicles or loaded vehicle combinations could exceed the legal limits for highway transport by obtaining permits for each move but could not exceed the maximum permit limits established by the States. This statement should be used only when the available prime movers already exceed the legal limits and only when there are no alternatives. The use of this statement will put an added logistic burden on the user.

4. Be highway transportable

This requirement provides no dimensional or weight restrictions for design as almost anything can be highway transported, given enough time and money. The choice of this statement means that a contractor could design a vehicle or have a loaded prime mover combination that exceeds established permits limits, and require certification as essential to national defense (pg 24). Highway transport that requires certification as essential to national defense at best severely limits highway transport, and does not ensure highway transport will be allowed. This statement should be used only when highway transport is desired but is not critical to mission accomplishments. Instead, requirements that place specific limits on design based on past experience and knowledge of planned operating areas should be used, as in the following statement.

5. Be highway transportable, with a turning radius of [50 feet], a maximum gross weight of [130,000 pounds], a maximum single axle load of [25,000 pounds], and a maximum tandem axle load of [45,000 pounds]

Note: Example of tailored to meet specific operating restrictions.

The choice of this statement means that a contractor could design a vehicle or have a loaded prime mover combination that exceeds established permit limits and may require certification as essential to national defense (pg 25). However, the design is more constrained than if statement 4 were used. This statement should be used only when other requirements make it impossible to design equipment that meets highway permit limits and it is known that the equipment will be based at a specific installation and deployed through a specific port. Then the equipment can be designed to meet the constraints of a specific highway route. However, it may not be readily transportable on other highways if future operational plans change.

6. Be transportable on/by *(specify)* transport vehicle

The choice of this statement means that the size and weight of the item of equipment would be limited to the dimensional and weight capabilities of a specific transport vehicle.

7. Highway transport not required

This statement should be used only when the item of equipment will never require highway transport. This statement should apply only to extremely large items, such as barges or locomotives.

Rail

The rail mode, like the highway mode, is used to transport almost every item of military equipment (except aircraft). During deployment, military equipment will be transported by rail from installations to ports of embarkation and from ports to inland areas once in the theater of operations, if rail facilities are available. Therefore, rail transport is essential to deployment. The optional statements for the rail portion of the transportability requirements statement are provided below and the diagrams of each rail envelope are provided in Chapter 2. Only standard-gauge rail transport is covered by this example. Verification of suitability for rail transport requires passing a MIL-STD-810 rail impact test. The item must:

1. Meet the Envelope S (formerly GIC) outline diagram

The choice of this statement means that rail transport on standard-gauge rail lines will be almost unrestricted worldwide.

2. Meet the Envelope M (formerly Envelope B) outline diagram

The choice of this statement means that rail transport in Europe will be possible, but with limitations. These rail lines generally connect major population centers and most locations important for DOD use.

3. Meet the AAR (Association of American Railroads) outline diagram

The choice of this statement means that rail transport in North America will be almost unrestricted.

4. Meet the DOD clearance profile

The choice of this statement means that rail transport in the United States will be limited to the STRACNET and a limited number of other rail lines. STRACNET provides rail service to all U.S. locations important for DOD use. Even on these rail lines, surcharges, operations at restricted speeds, and other limitations may be necessary. Transportation over foreign rail lines may not be possible.

5. Be rail transportable

The choice of this statement means that a contractor could design an item of equipment that would always require special routing or special provisions for rail transport. Rail transport might not even be possible over the rail lines that would actually have to be used in a contingency. Therefore, this statement should not be used, because it provides no limits for rail transport. Rail transport is very likely to be impractical for items that do not meet the DOD clearance profile.

6. Rail transport not required

This statement should be used only when the item of equipment will never require rail transport. This should apply only to extremely large items, such as watercraft, or to very sensitive or delicate equipment, such as aircraft.

Marine

All military equipment (except self-deploying aircraft) must be capable of water transport because most equipment in a strategic deployment will be transported by ship. Equipment should be capable of transport on barges and tactical watercraft, to ensure the equipment can be deployed in JLOTS operations. The optional statements for the water portion of the transportability requirements statement are as follows:

The item must:

1. Be marine transportable on *(choose the smallest lighterage required to transport the item: LCM-8, LCU-1646, or LCU-2000)* **and larger vessels/ships.**

Requirements documents should require items to be marine transportable on the LCM-8 and larger vessels. The choice of this statement specifies the smallest watercraft on which the item of equipment must be capable of being transported and covers all larger vessels/ships.

2.   Marine transport not required.

This statement can only be used if marine transport will never be required. Since all military equipment must be capable of marine transport, the only equipment that would not require marine transport would be self-deploying aircraft and marine vessels or towed barges/vessels.

Air (Rotary Wing)

Rotary-wing aircraft are used primarily for short-range tactical transport missions. The rotary wing mission requirements and estimated weight of the equipment should be known before specifying rotary wing transport. This is because the lift capability of helicopters depends on several factors, including temperature, altitude, and amount of fuel in the aircraft.

The optional statement for the rotary wing portion of the transportability requirements statement is provided below.

1. The item must be transportable in/by the:

- **a. UH-1** *(externally)*
- **b. UH-60** *(externally)*
- **c. CH-47** *(specify internally, externally, or both; if externally, specify by single-point or dual-point lift or both)*

.... and meet MIL-STD-913 ***(when external air transport is a requirement).***

These are the only rotary-wing aircraft in the active Army that can routinely transport equipment. Other rotary wing aircraft in the DOD inventory that can transport equipment are the CH-46 and CH-53 cargo helicopters and the MV-22 tilt-rotor aircraft.

2. Transport must be accomplished in the: *(specify scenario, see pg 22).*

The "high-hot" scenario (4,000 ft altitude and 95º F) provides the greatest flexibility in operations and should be selected unless the operational mission of the equipment limits its use only to areas meeting either of the other scenarios.

Air (Fixed Wing)

Fixed-wing aircraft transport is the most important mode in terms of rapid strategic mobility. The four U.S. Air Force (USAF) prime mission cargo aircraft are the C-130, C-17, and C-5. The C-130 is a tactical (intratheater) aircraft; the C-5 are strategic (intertheater) aircraft, and the C-17 is both a tactical and strategic aircraft. Equipment with a rapid-deployment-type mission must be air transportable in an operational configuration in the C-130 aircraft. The optional statements for the fixed-wing air portion of the transportability requirements statement are provided below.

The item must:

1. Be air transportable in *(as many as required)*

a. C-130
b. C-5
c. C-17
d. CRAF (Civil Reserve Air Fleet)
(choose the aircraft required to transport the vehicle: B-747, DC-8, DC-10, MD-11, L-1011)

AND meet the requirements of MIL-STD-1791

This statement specifies which aircraft are required and states the requirements for air transport in USAF cargo aircraft. It is essential that the aircraft required are listed in the requirements document (see chap 2 for aircraft limitations).

2. Be air droppable from *(choose the required aircraft: C-130, C-5, C-17)* **aircraft and meet MIL-HDBK-669 and MIL-STD-814**

This statement should be used when airdrop from USAF aircraft is required (see chap 2 for limitations).

3. Be air transportable without the need for load spreading or approach shoring

This statement should be used when vehicles must be loaded and unloaded in a roll-on/roll-off operational configuration for quick-reaction-type forces. Load spreading and approach shoring add both time and logistic burdens to air transport requirements, reduce air payload availability, and should be avoided whenever possible.

4. At least *(specify number of items)* **shall be capable of worldwide strategic transport in one** *(specify model of aircraft)*

5. (If equipment is a system): **Be capable of worldwide strategic transport by no more than** *(specify number and model of aircraft)* **sorties**

This statement means that a limitation is set on a number of sorties required to transport a system, thereby restricting the total size of the system.

6. Be reduced to transport configuration in *(specify)* **minutes by** *(specify)* **personnel**

7. Be reassembled to operational configuration in *(specify)* **minutes by** *(specify)* **personnel**

These two statements set maximum times and personnel requirements for assembly and disassembly required for transport. Setting these maximums limits the amount of disassembly required for transport, thereby ensuring that the equipment will be capable of transport and be capable of operation shortly after disassembly or assembly begins. This eases the logistic burden on the deploying unit as well as decreases the time required to deploy. The desire to reduce or reassemble a piece of equipment with or without Material Handling Equipment (MHE) should also be noted when using these statements. (Disassembly, however, introduces the possibility that parts may be lost during transport, thus preventing reassembly at the final destination.)

8. Be reduced/reassembled from/to operational configuration without disconnecting flight control surfaces or requiring a maintenance test flight

This statement minimizes helicopter assembly and disassembly required for air transport. It eliminates the requirement for a maintenance test pilot at the port of debarkation, easing the logistic burden on the deploying unit as well as decreasing the time required to deploy.

9. Air transport is not required

This statement should be used only when the item of equipment will never require air transport. This should apply only to extremely large or heavy items that could be deployed only by ship.

Containers

Military equipment should be transportable in ANSI/ISO containers or flatracks where practical so that the intermodal benefits of containerization can be realized and container ships can be more effectively used to support deployments. The following would be the container portion of the transportability requirements statement.

- The item must be transportable in ANSI/ISO containers/flatracks *(specify size, see pg 40).*

Lifting and Tiedown Provisions

All equipment must have adequate lifting and tiedown provisions since these provisions are essential to efficient transport. Vehicles must have provisions designed for the gross vehicle weight (fully loaded vehicle). All transportability requirements statements must contain the following lifting and tiedown statement.

- The item must have lifting and tiedown provisions (and cargo tiedown provisions if applicable) that meet the requirements of MIL-STD-209.

If helicopter sling lift (HSL) is required, the item's lifting provisions must also comply with MIL-STD-913.

General Requirements

Other general transport requirement statements that could be included in the transportability requirements statement are listed below.

The item must:

1. Reduce/not increase deployment transport requirements of the receiving military unit(s).

The choice of this statement dictates that an item (or system) must not be larger or heavier than the item (or system) it replaces.

2. Be transportable at its maximum gross vehicle weight (GVW) during *(choose mode(s))* **- highway, air, rail, marine, or all-mode transport.**

The choice of this statement ensures that the equipment can be transported at its maximum operational weight by all or by specific modes. All equipment should be capable of all-mode transport at its GVW.

In certain situations, other statements may be specified to ensure transportability.

6 Transportability Approval

General

Transportability approval is required by **AR 70-1,** *Army Acquisition Policy* and **AR 70-47,** *Engineering for Transportability*. This chapter provides a discussion on which items need transportability approval, how approval is requested and obtained, and what data are required for approval.

Transportability Approval

Developing efficiently and economically transportable equipment and combat resources will be an integral part of the acquisition process. Transportability is a critical element of strategic and tactical deployment. When strategic and tactical deployment is a system requirement, transportability will be a primary system selection and design factor.

The required type of transportability (worldwide highway, rail, air, marine) together with any special requirements for contingency forces, airdrop, helicopter lift, and tactical transport will be explicitly stated in the capability documents, purchase descriptions, and specifications. TEA will review capability documents for systems classified as transportability problem items (chap 3).

Throughout the acquisition process, TEA monitors equipment that qualifies as a transportability problem item and concurs at major milestone decisions if the equipment meets its transportability requirements.

AR 70-47 requires transportability approval before major milestone decisions. The procedures and requirements for this approval are explained in **AR 70-47**. This chapter briefly explains how approval is requested and obtained, and what data are required for TEA to conduct a transportability engineering analysis.

How is Transportability Approval Requested and Obtained?

The materiel developer requests transportability approval from the service transportability agent (TEA for Army systems). A transportability report containing the characteristic data required by **AR 70-47** should be sent to TEA at least 90 days before approval is needed. TEA then will perform a transportability engineering analysis of the item to determine if the requirements have been met. If they have been met, approval will be granted.

Transportability Report

What is a Transportability Report?

The transportability report is a report listing all the characteristic data for a transportability problem item. The transportability report provides all information necessary to perform a comprehensive transportability engineering analysis of problem items. This report is submitted to TEA by the materiel developer (or a field unit). The following information and format (taken from **DI-PACK-80880C**) is required in a transportability report. This information may be obtained by invoking data item description **DI-PACK-80880C**, *Transportability Report*, in contracts.

Format for Transportability Report

(1) Title. TRANSPORTABILITY REPORT.

(2) Points of contact: State contractor name, location, phone number, and email address. State the name, title, organization, and department of individual preparing the transportability report.

(3) Date of transportability report.

(4) Official nomenclature.

(5) National stock number (if known).

(6) Line Item Number (if known).

(7) Brief description.

(a) Intended use.

(b) List whether commercial, modified commercial, non-developmental, developmental, reprocurement, or modified equipment.

(c) Specify type of military units that will use or transport the item.

(d) State whether for worldwide use or for specific theater of operations. List specific theater of operations in priority order.

(e) Planned quantity. State item acquisition quantity by fiscal year.

(8) Transportation Data.

(a) Hazardous materials. For each item classified as hazardous material, state:

1. The class of hazardous material as specified in: *Title 49*, *Code of Federal Regulations* (49 CFR), Parts 100-179, *Transportation;* **AFJMAN 240-204**, *Preparing Hazardous Materials for Military Air Shipments;* International Maritime Organization (IMO), *International Maritime Dangerous Good (IMDG) Code*; or the United Nation's *Recommendation on the Transportation of Dangerous Goods.*

2. DOT proper shipping name.

3. Net explosive weight (DOT class A or B explosives only).

4. Venting requirements.

5. Grounding requirements.

6. Any other than above.

(b) Sectionalization and Reduction. State if the item can be sectionalized, folded, or reduced for transport and provide the following information:

1. Time and personnel required to disassemble at departure site and reassemble at destination (Time: in work and clock hours).

2. Special equipment, tools or software required for sectionalization or reduction (for example, cranes, forklifts, wrecker trucks, pallets, nitrogen, hand tools, calibration equipment, fixtures, or height management system software). All of the data that is required by this Data Item Description (DID) for the operational equipment, must also be provided for each component(s) or subassembly that exceeds the criteria for a "transportability problem item" (see para 4.4 of **MIL-STD-1366D** or equivalent paragraph in later versions of this standard). For each component(s) or subassembly not exceeding the criteria for a "transportability problem item," provide only the length, width, height, and weight of each sectionalized component.

(c) Modeling and simulation (when available). Provide computer-aided design (CAD) models of the equipment to support structural, kinematic, and dynamic analyses of the transportation environment, or provide results of CAD transportation analyses performed by the contractor.

(d) Transportability tests. A copy of test report(s) (or test plan and scheduled date(s) if not completed) shall be included as a part of this report, when available.

(e) Speed requirements. State self-propelled or towed speed limits.

(f) Shipping data. A paper copy of shipping data plate that will be secured to the vehicle shall be included with this report, when available (see **MIL-STD-209**).

(g) Crew Size. State number of soldiers required for a crew.

(h) Photographs. Provide electronic or hardcopy photographs of equipment, when available.

(i) Dimensional and Weight Data sets. A data set shall be provided for all configurations of the equipment. As a minimum, one set of data shall be provided for the fully operational configuration (including gross weight, fuel, lubricants, water, crew, BII equipment, and so forth), and one set of data shall be provided for the shipping (reduced or sectionalized) configuration. If there are different reduced shipping configurations for various transportation assets and modes, a different set of data shall be provided for each different shipping configuration.

1. Weight. State curb weight and maximum gross weight, and any other intermediate weights for special configurations required to meet specific transport requirements (that is, fixed-wing air transport or helicopter transport).

2. Drawings (required if CAD models are not provided (see para (c))). Indicate top, plan, side, and end view configurations on each drawing. Hardcopy or electronic files are acceptable. Drawings must include all data as shown in figures 1, 2, or 3.

(j) Lifting and tiedown provisions.

1. State the number and strength (yield and ultimate) of lifting (including aerial recovery), equipment tiedown, multipurpose, cargo tiedown, and supplemental air transport tiedown provisions for the item and major components removed for transport.

2. Provide the dimensional location of the lifting, equipment tiedown, multipurpose, and supplemental air transport tiedown provisions (with respect to the CG) as shown in figure 4.

3. Provide the dimensional location of the cargo tiedown provisions with respect to the center of the cargo area, as shown in figure 5.

4. Provide the dimensions A, B, D, E, C_L, and C_s for each lifting, equipment tiedown, multipurpose, and higher strength cargo tiedown provisions, as shown in figure 6.

5. Provide the dimensions A and B for the cargo tiedown provisions, as shown in figure 7.

6. Identify the location of hardpoint lifting provisions provided for aerial recovery (if required).

(k) Projections. State the dimensions and locations of any significant projections (for example, environmental control units, ladders, antennas, shelters, and so forth). See figures 1, 2, and 3.

(l) Additional information required for **wheeled** vehicles.

1. Weight ratings. Specify the gross vehicle weight rating (GVWR)

2. Tires. State the number, size(s), load rating(s), locations, and inflation pressure of tires.

3. Axle loads. State the axle load, for each axle, for the following configurations:

a. Empty vehicle.

b. Fully loaded vehicle. (For cargo vehicles, assume a uniform load on the cargo bed).

4. Maximum axle load ratings. State maximum axle load ratings for each axle.

5. Pintle, kingpin, and lunette loads. As applicable, state the pintle, kingpin, or lunette loads.

6. Landing legs. As applicable, state axle loads and landing leg load, when trailer is resting on landing legs. Provide dimensions of landing legs as shown in figure 8.

7. Suspension type and ratings. State type and load ratings for each suspension.

8. Crest angle. State the angle (in degrees) connecting two horizontal surfaces that the vehicle can pass (crest) without interference (see fig 9). Assume the ramp length is equal to or greater than the wheel base of the vehicle.

9. Tire footprint area. State the locations and dimensions of all tire footprint areas actually in contact with the ground in the fully loaded condition, and at the tire inflation pressure specified in paragraph 3.(l).2. (see fig 10).

10. Axle tracking width. State the tracking width of each axle (see fig 11).

11. Vehicle turning diameter. State the vehicle turning diameter for the following:

a. Wall-to-wall.

b. Curb-to-curb.

(m) Additional information required for **tracked** vehicles.

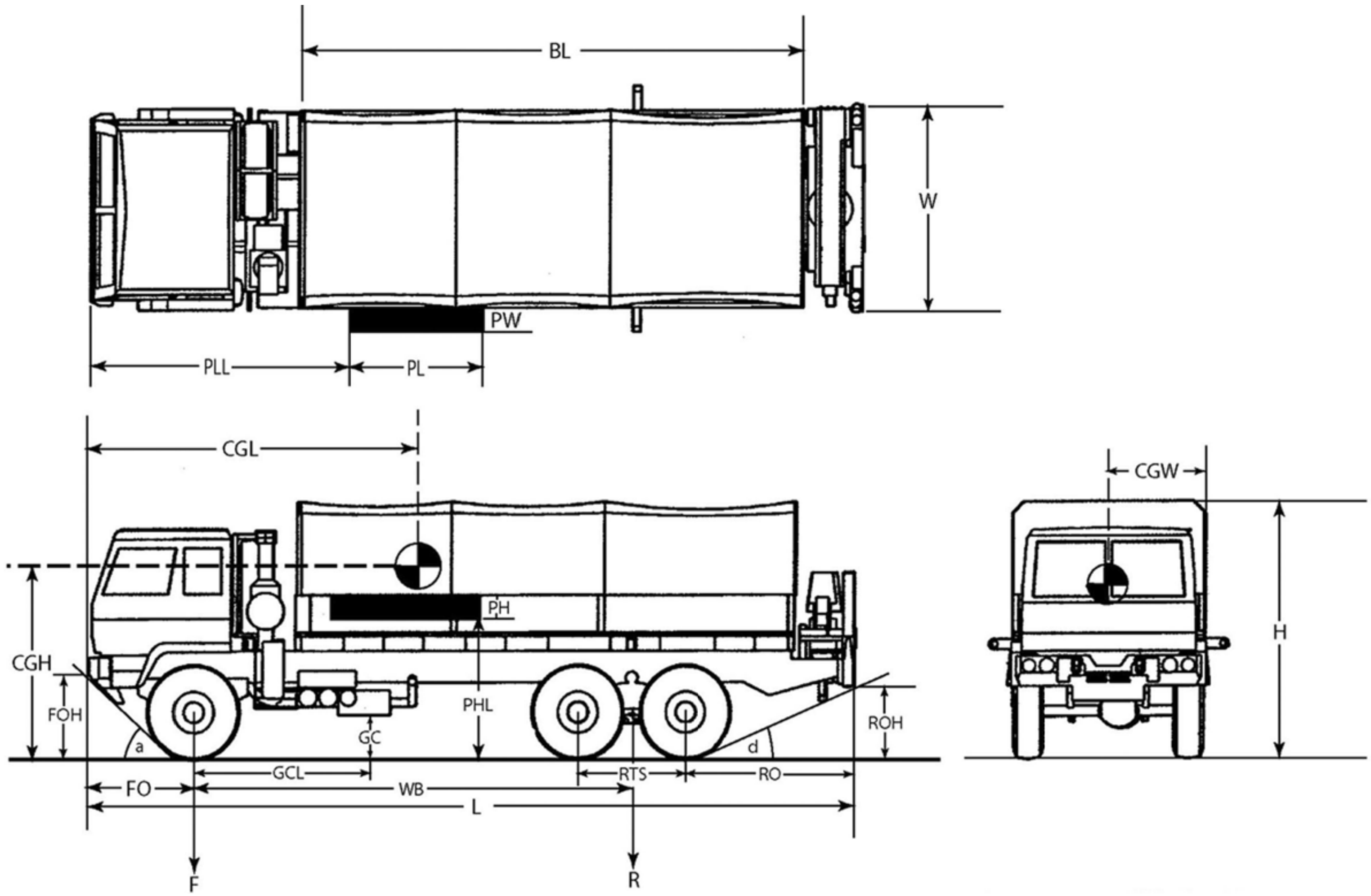
1. Track pads. State the area and number of track shoe pads actually in contact with the ground (see fig 12).

2. Ground pressure. Specify the ground pressure created by the heaviest pad (pounds per square inch). State the weight supported by each road wheel.

(r) Additional information required for **skid-mounted** equipment.

1. Number of skids.

2. Dimensions of all skid areas actually in contact with the ground.

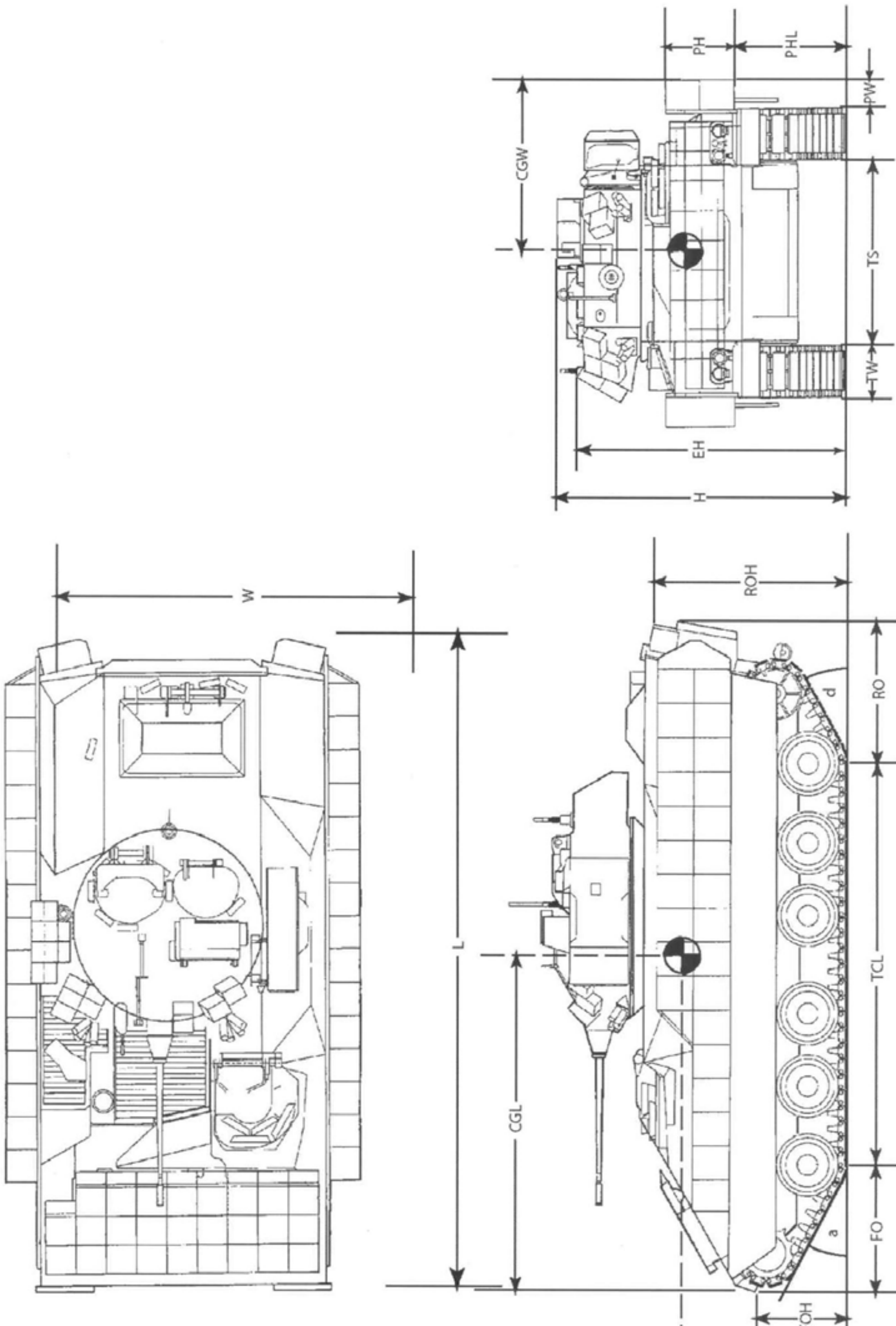


a - Angle of Approach
BL - Body Length
CGH - Center of Gravity Height
CGL - Center of Gravity Length
CGW - Center of Gravity Width
d - Angle of Departure
F- Front Axle Load
RTS - Rear Tire Separation

FO - Front Overhang
FOH - Front Overhang Height
H - Height
GC - Ground Clearance
GCL - Ground Clearance Location
L - Length
PH - Projection Height
W - Overall Width

PHL - Projection Height Location
PL - Projection Length
PLL - Projection Length Location
PW - Projection Width
R - Rear Axle Load
RO - Rear Overhang
ROH - Rear Overhang Height
WB - Wheel Base

Figure 1. Wheeled Vehicle Dimensions

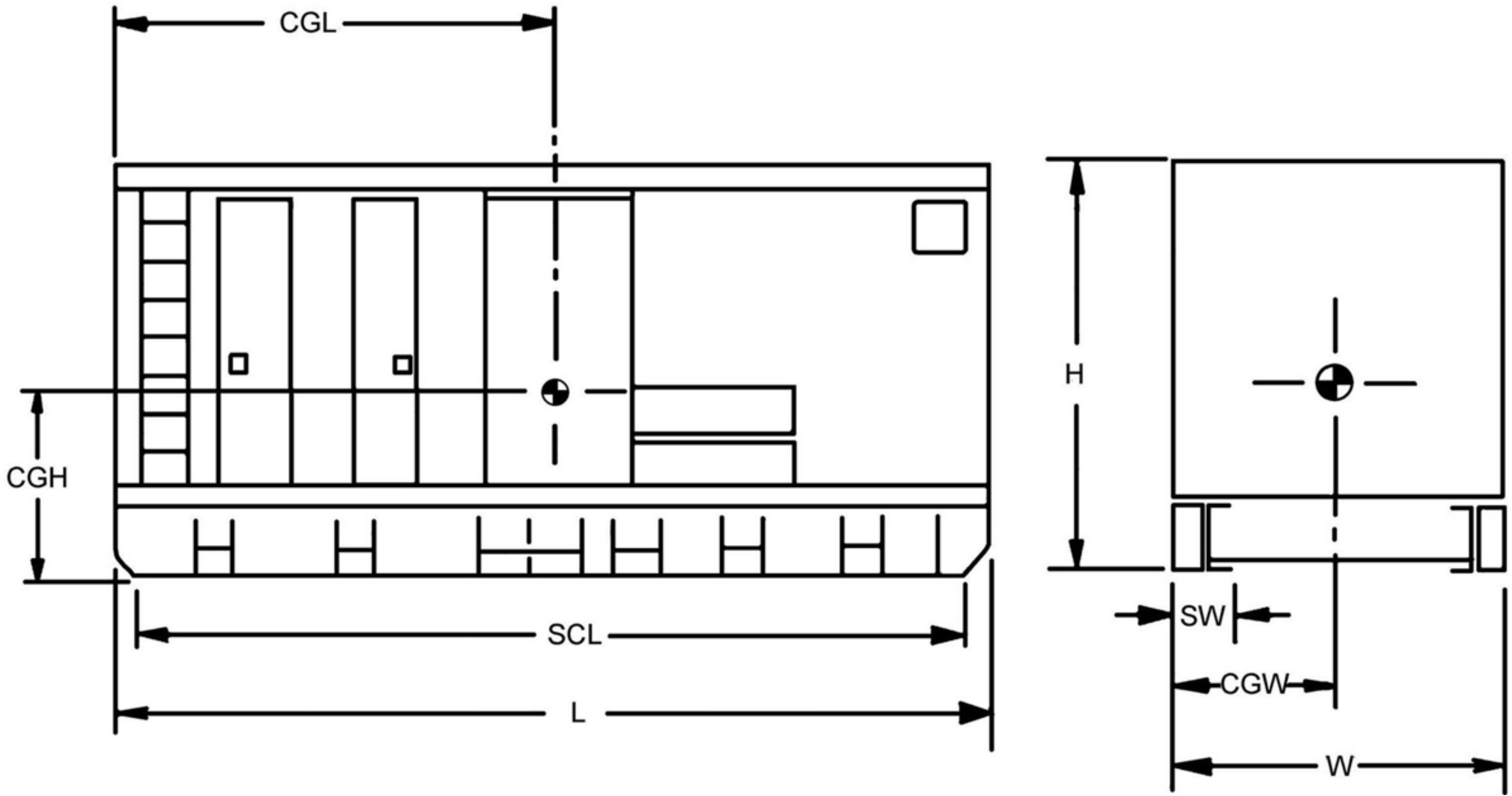


a - Angle of Approach
CGH - Center of Gravity Height
CGL - Center of Gravity Length
CGW - Center of Gravity Width
d - Angle of Departure
EH - Edge Height

FO - Front Overhang
FOH - Front Overhang Height
H - Height
L - Length
PH - Projection Height
PHL - Projection Height Location

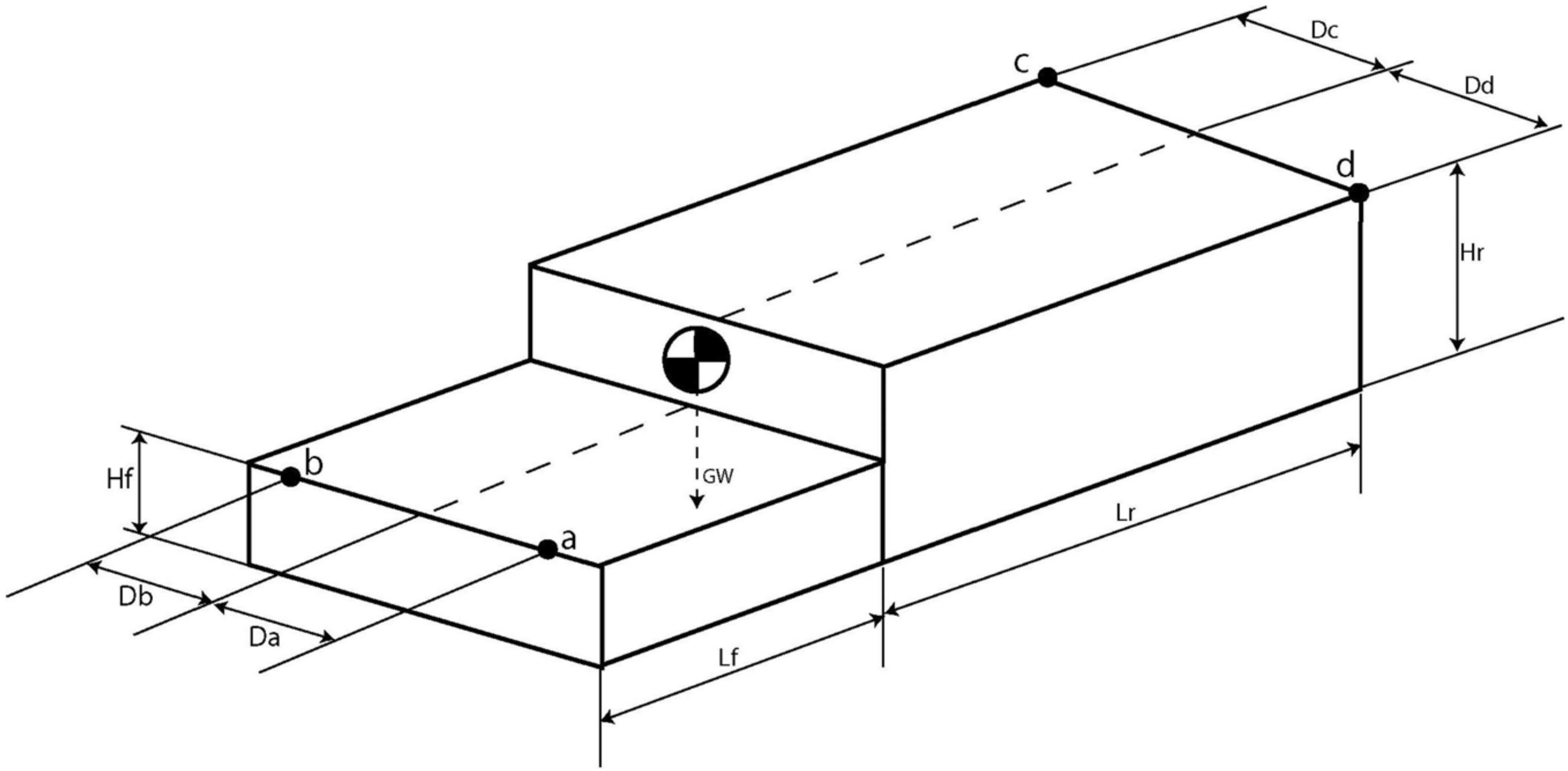
PW - Projection Width
RO - Rear Overhang
ROH - Rear Overhang Height
TCL - Track Center Line
TS - Track Separation
TW - Track Width
W - Width

Figure 2. Tracked Vehicle Dimensions



CGH - Center of Gravity Height
CGL - Center of Gravity Length
CGW - Center of Gravity Width
H - Height
L - Length
SCL - Skid Chamber Length
SW - Skid Width
W-Width

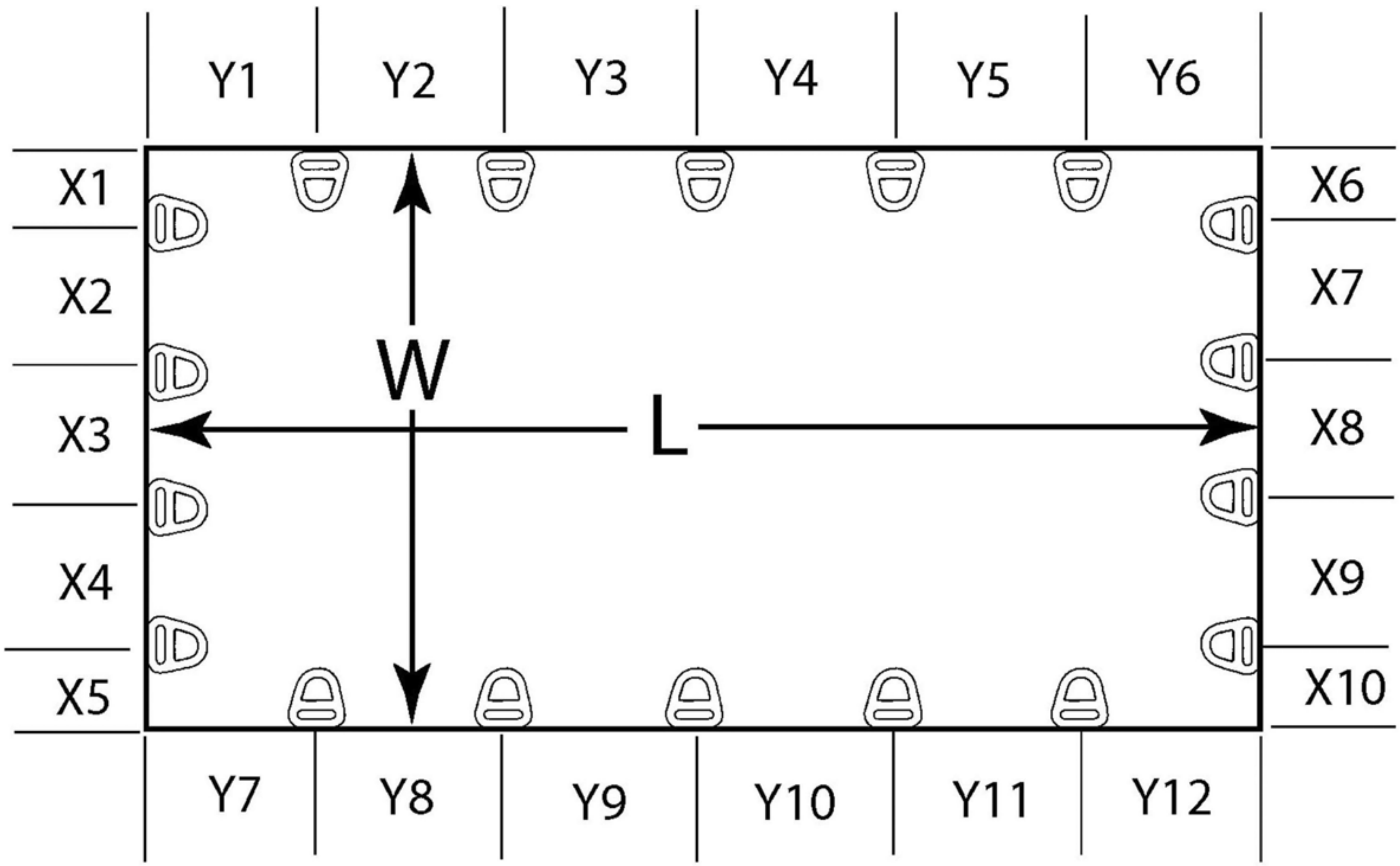
Figure 3. Skid-Mounted Item Dimensions



Da - Lateral distance from provision a to the CG
Db - Lateral distance from provision b to the CG
Dc - Lateral distance from provision c to the CG
Dd - Lateral distance from provision d to the CG
GW - Gross Weight

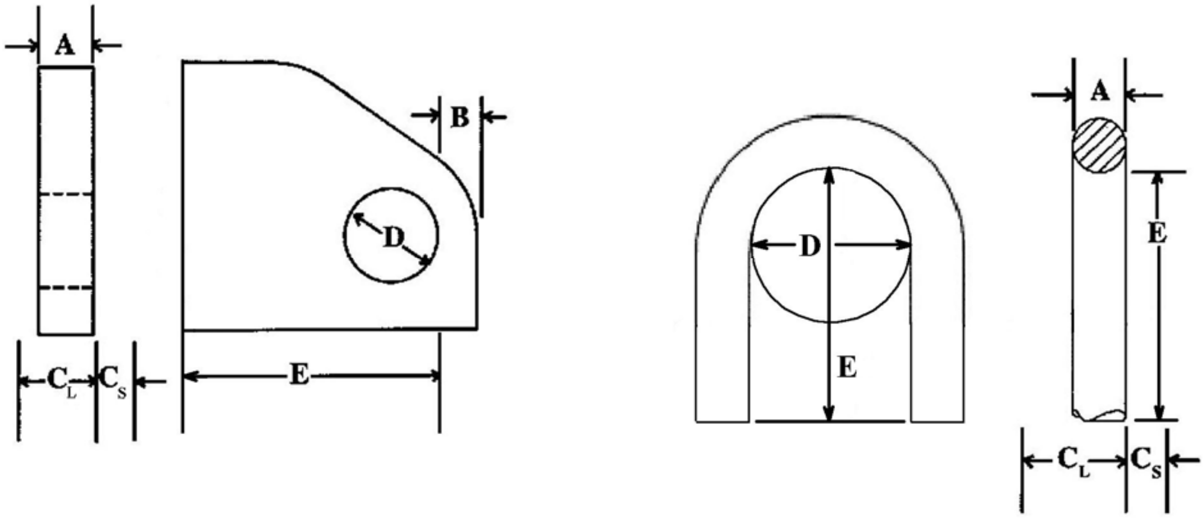
Hf - Height of front provisions
Hr - Height of rear provisions
Lf - Longitudinal distance between front provisions and the CG
Lr - Longitudinal distance between rear provisions and the CG

Figure 4. Dimensions Defining the Location of the Lifting and Tiedown Provisions



X1-10 - Distance between provisions on front and rear of cargo bed
Y1-12 - Distance between provisions on left and right side of cargo bed
W- Width of cargo bed
L - Length of cargo bed

Figure 5. Dimensions to Determine Location of Cargo Tiedown Provisions



C_L and C_S are the dimensions between one side of the provision and the nearest interference or obstruction. Either side of the provision may be used as the datum from which to measure C_L and C_S.

E is the dimension between the outer edge of D and the nearest interference or obstruction.

Figure 6. Lifting and Tiedown Dimensions

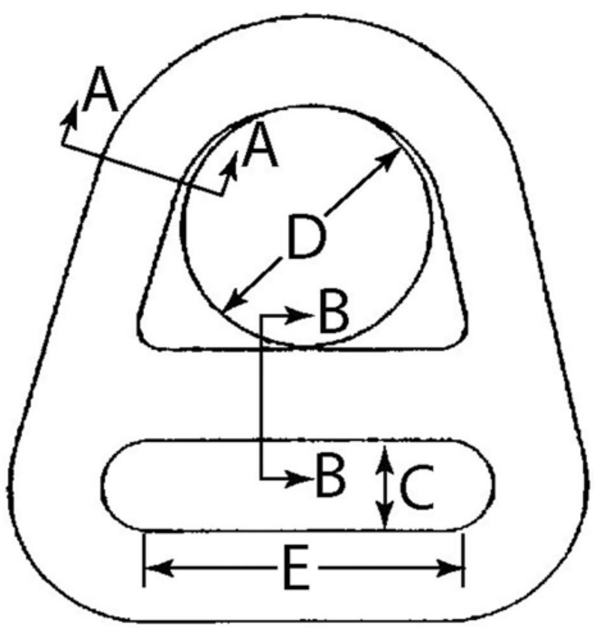
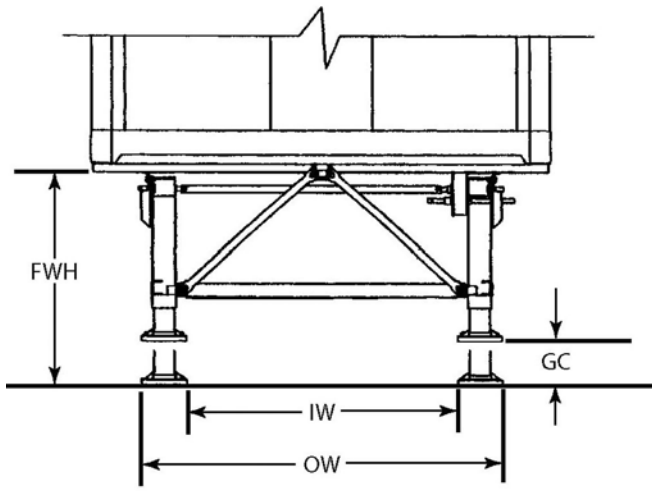


Figure 7. Cargo Tiedown Dimensions



FWH - Fifth wheel height
GC - Ground Clearance
IW - Inside Width
OW - Outside Width
L - Length of landing leg pad (not shown in drawing)
W - Width of landing leg pad (not shown in drawing)

Figure 8. Landing Leg Dimensions

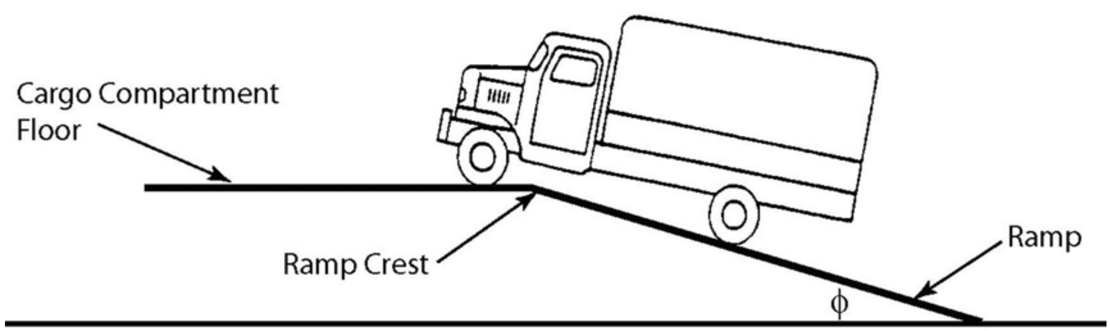
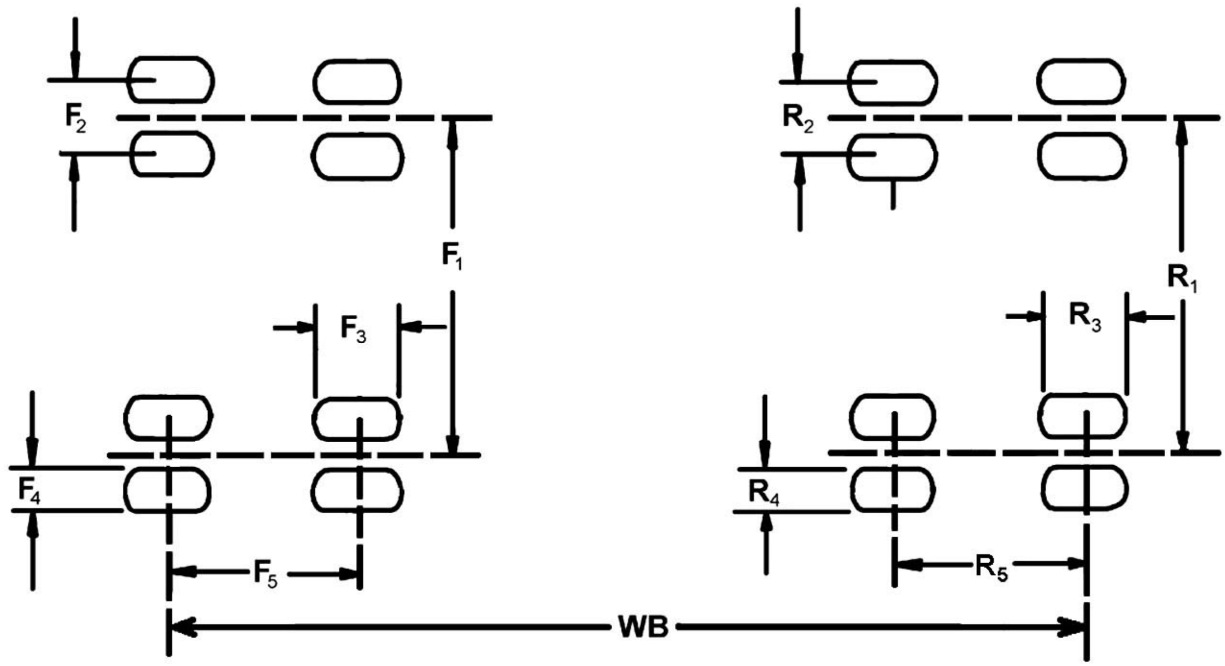
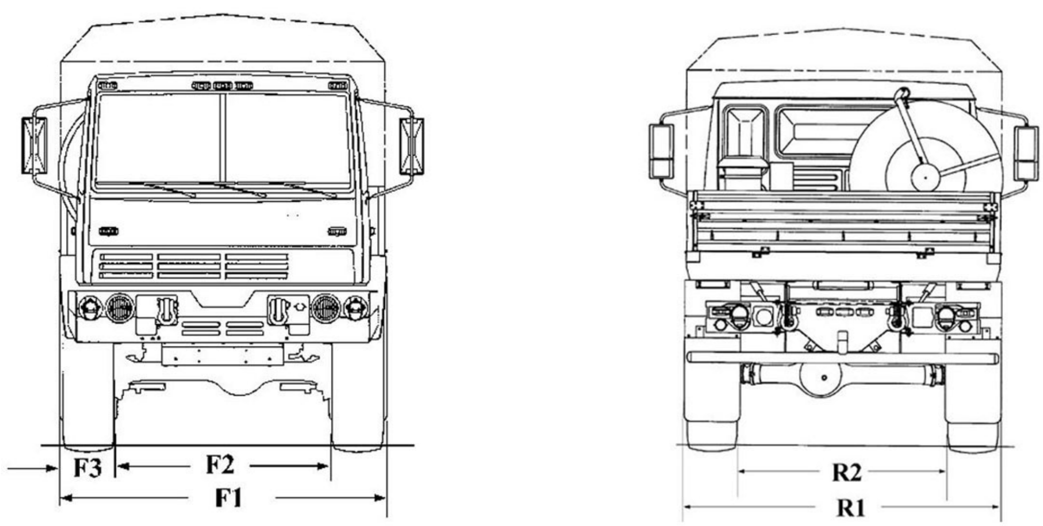


Figure 9. Ramp Crest Angle



WB - Wheel Base

Figure 10. Tire Footprint Area



F1 - Outside distance between tires
F2 - Inside distance between tires
F3 - Front tire width (to include tire bulge in transport configuration)
R1 - Outside distance between tires
R2 - Inside distance between tires
R3 - Rear tire width (to include tire bulge in transport configuration)

Figure 11. Axle Tracking Width

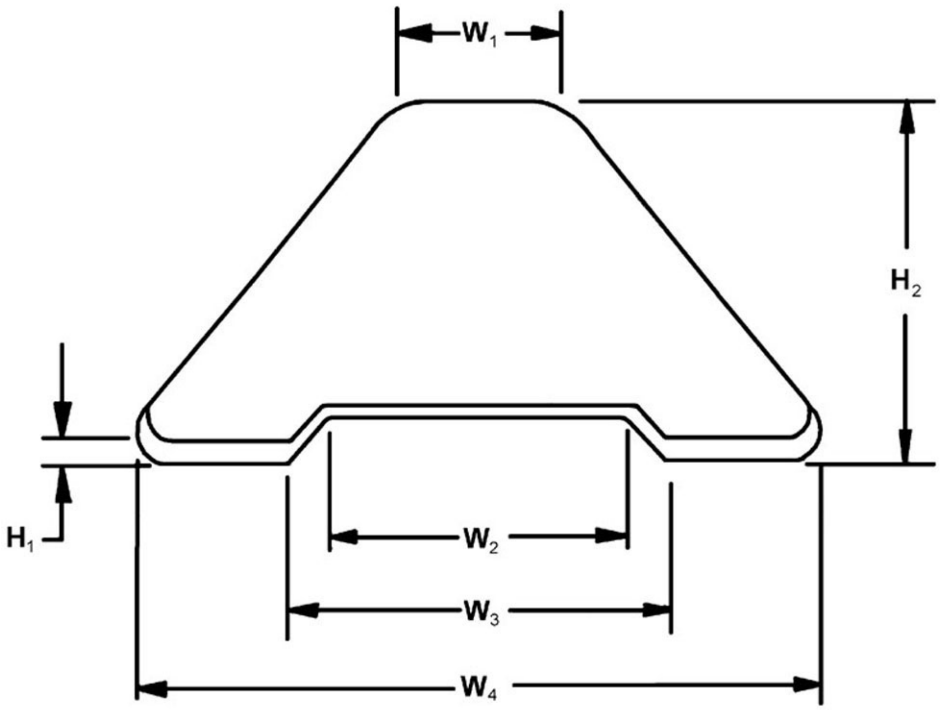


Figure 12. Track Shoe Pad Dimensions (footprint data)

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7 Modeling and Simulation

Due to the rapid growth in computer technology and decreasing DOD resources, modeling and simulation (M&S) is becoming more prevalent. To provide better transportability engineering support, TEA engineers use a combination of Computer-Aided Engineering (CAE) modeling tools implemented by commercial software to simulate and analyze military equipment in various transportation scenarios and test environments. Conducting transportability testing and analysis in software early in the acquisition process facilitates successful design for transport, thus reducing costly test failures and redesign cycles. The result is better equipment design at reduced costs, risks and schedules. Three functional areas of the program are described in the following sections.

Three-Dimensional (3D) Modeling

Engineers use 3D modeling software to model transportation configurations of military equipment (for example, cargo aircraft density loadings, rail tiedown configuration, lift configurations, and so forth.) The engineers can quickly and accurately determine cargo-transporter incompatibilities and provide design guidance and alternatives. Advanced visualization and video capabilities provide an informative means of illustrating results, such as transport procedures and interference issues.

Multibody Dynamic Analysis

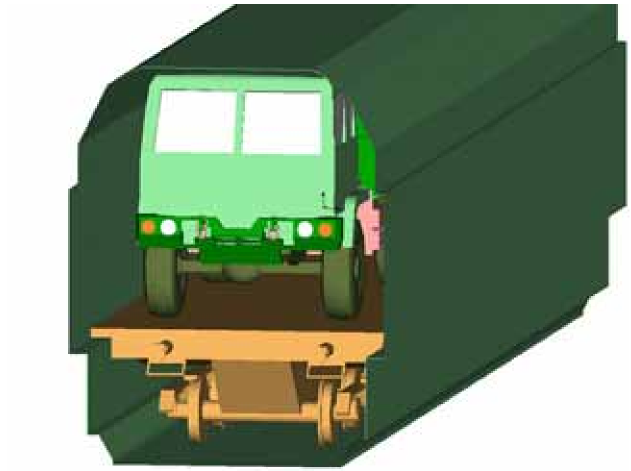
Engineers use multibody dynamics to simulate the forces experienced by mechanical systems in load-intense transportation environments. Available models include crane lifting and aircraft clearance analysis. Predicted forces and accelerations from crane lift simulations provide design criteria, and can be applied to vehicle structural models to assess strength compatibility. Aircraft loading simulations apply motion to 3D equipment and cargo hold models to provide detailed analysis of clearances.

Structural Analysis

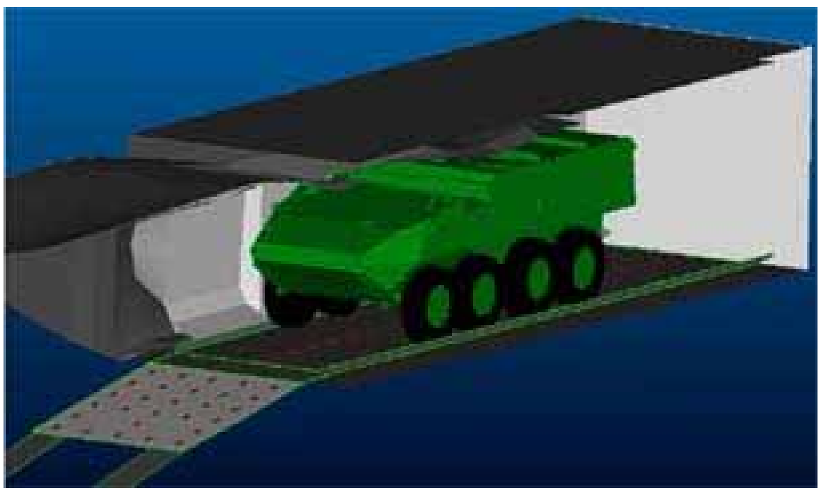
Engineers create detailed models of equipment and parts to analyze their structural integrity under various loading scenarios using commercial Finite Element Analysis (FEA) software. Our focus has primarily been on lifting and tiedown provisions but includes all aspects of the equipment, as well as feasibility studies. This capability provides a means to identify potential problem areas and provide corresponding workable solutions. By analyzing transport loading scenarios, TEA is able to facilitate successful equipment and part design very early in the process, reducing the number of failed field tests and actually eliminating the need to test in certain cases.

Typical Applications

Rail Clearance Analysis - Use of 3D Modeling to compare a vehicle's dimensional characteristics to various rail envelope profiles and railcars for strategic rail lines used in deployment.



Aircraft Loading Analysis - Use of 3D modeling and kinematic simulation to evaluate clearance and suitability of loads and loading procedures. High-precision models of each aircraft (C-130, C-5, and C-17) are used for aircraft loading analyses. These aircraft models were created from digitized data of the interior of each type of aircraft. Since these models represent the true interior of the aircraft, we are able to conduct highly precise analyses of aircraft loadings.



Lifting and Tiedown Analysis - Use of 3D modeling and dynamic simulation to evaluate for interference and determine actual sling and contact loads of lifted items. Structural analysis is used to evaluate the ability of equipment to withstand actual lift or contact loads, as well as the **MIL-STD-209** test requirements for lifting and tiedown provisions.

Other - 3D modeling and structural analysis is also used to resolve field transport issues, such as the design and evaluation of a platform container, rail ramp or container ramp for loading and transporting military equipment.

Model Requirements for a Simulation Analysis

The following paragraphs describe the system models required for conducting typical simulations. Files can be transferred to TEA via file-transfer-protocol (ftp), CD, or ZIP.

3D Modeling

To conduct transportability clearance and transporter compatibility analyses for a vehicle or other items of equipment we require 3D CAD models. Preferred format is the current commercial version of Pro-Engineer from Parametric Technology, Inc. (PTC). We also accept Initial Graphic Exchange Specification (IGES) translations. In absence of 3D CAD models we can build models from engineering drawings of the equipment.

Structural Analysis

To conduct a structural analysis of **MIL-STD-209** provision pull testing loading we require detailed design information (3D CAD model or engineering drawings) of the tiedown and lifting hardware and supporting structures. We also require material property data including Poisson's ratio, minimum yield strength, and tensile strength. Structural analyses performed by outside sources must be submitted for review to verify loading and constraint validity to meet the requirements of **MIL-STD-209**.

Multibody Dynamics

To conduct dynamic simulations we require a multibody dynamic vehicle/system model, appropriate mass and inertial properties of related components, and locations of vehicle tiedown and lifting provisions. Preferred format is in the Wildfire version of ProEngineer (ProE) software from PTC, Inc. using the "INCHES" system of units. In the absence of a ProE model, we can build a model from IGES (.igs) files or engineering drawings and specifications. Data required to build the dynamic model include masses, CGs, inertial properties, locations and dimensions of rigid bodies, and joint locations.

3D Model Database

TEA maintains a 3D Model Database that contains detailed models of military and commercial equipment used for transportability and deployability simulations and analyses. These can be downloaded from our web page at www.tea.army.mil/DEP/TRANSPORT/vpgt/3d.htm. The files available for downloading have an extension of .prt or .igs. The .prt file is a Pro/Engineer CAD part file of the model. The .igs file is an IGES file for importation into other CAD packages.

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8 Transportability Testing

General

Transportability testing may be required during the acquisition cycle as a part of Developmental Testing (DT). Simulated testing, as described in Chapter 7, may be substituted for some physical testing. However, if the simulated test results indicate that the equipment will fail or marginally pass the test, a physical test will be required. If physical testing is required, test procedures should be coordinated with TEA at least 30 days before the test date. TEA should be notified of the exact test time and location at least 5 days before the tests. Transportability tests should be witnessed by TEA or other approved Government personnel. The ability of an item to withstand the rigors of transport may be demonstrated by:

- Lifting and tiedown provision strength test
  - Helicopter lift test (internal and/or external)
  - Air Force aircraft test loading
  - Airdrop test
  - Rail impact test

Lifting and Tiedown Provision Strength Test

The lifting and tiedown provisions on all items of equipment must be tested to the limits specified in **MIL-STD-209**. The provision must be tested after it has been installed on the equipment. A dynamometer pull test on each provision, to include the provision's connection to the structural frame of the item, is the simplest way to test the strength of each provision. Equipment with a requirement for airdrop must also be tested to the requirements of **MIL-STD-814** for suspension, tiedown, and extraction provisions. Equipment with a requirement for external air transport must also be tested in accordance with **MIL-STD-913.**

Helicopter Lift Test (Internal and External)

The helicopter internal transport test determines fit and the feasibility of tiedown procedures. This test usually is required only when the fit is expected to be close. The helicopter external lift test (in accordance with **MIL-STD-913**) determines the ability of the item to be lifted, the stability of the item in flight, the speed at which the item can be flown, and the rigging procedures for lifting the item. All items with a helicopter external lift requirement must pass a helicopter flight test.

Air Force Aircraft Test Loading

An aircraft test loading determines the fit, and loading and tiedown procedures. Also, it ensures that none of the aircraft design limitations (axle loads and ramp hinge loads) are exceeded. This test loading is conducted only when required by the Air Force. Failure to pass an aircraft test loading will negate air transport. Validation loadings are less expensive than test loadings and may be required when mathematical calculations indicate that fit will be tight.

Airdrop

The airdrop test determines the adequacy of rigging procedures and the ability of the item to survive the landing impact. This test shall be performed in accordance with **MIL-STD-814** and **MIL-HDBK-669.** After this test, the item must be undamaged and operable.

Rail Impact Test

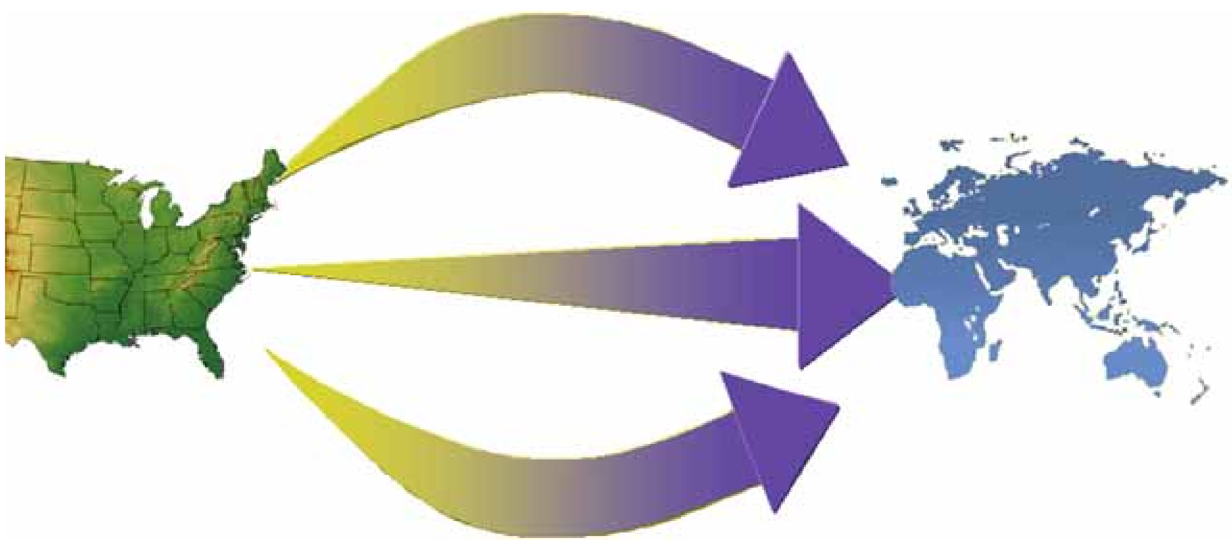
Rail transport subjects the item to the most severe longitudinal impacts of any transport mode. The rail impact test, therefore, is the most severe transportability test. The rail impact test in **MIL-STD-810** tests the integrity of the item and the adequacy of the rail tiedowns and tiedown procedures. Any item that passes the **MIL-STD-810** rail impact test should be capable of rail transport without damage to the item or the tiedowns. **MIL-STD-209** provision lift and pull testing should be successfully completed prior to **MIL-STD-810** testing. After this test, the item must be undamaged and operable.

9 Deployability

Introduction

Deployability is the ability to move forces and materiel anywhere in the world in support of military operations. The national military strategy requires a flexible power projection force. U.S. Armed Forces must be capable of rapidly deploying to any area of the world and generating decisive force across the full range of military operations.

To successfully meet the requirements of deploying forces, the deployment scenario must be evaluated at an early stage to accurately assess whether or not a new piece of equipment enhances or encumbers deployment. It is possible that from a transportability standpoint, the equipment is sufficient, but from a deployability standpoint (for example, a substantial logistics tail) could be a hindrance to force closure. A determination of the impact from both the transportability and deployability standpoints must be made to field a system that will enhance both.



Products of the Deployability Analysis

A deployability analysis typically consists of several key elements: sortie count, transportation asset requirements, throughput analysis, closure profile, and infrastructure assessment. These elements help determine the overall transportation feasibility of a plan. A plan is considered transportation feasible when the capability exists to move forces, equipment, and supplies from origin to destination according to the plan.

Sortie/Voyage Count: Given the gross dimensions and weight characteristics, along with the assumed force structure, a sortie assessment can be made for the C-130, C-17, and C-5, and also mixtures of each of the aircraft can be determined at a very high-level of confidence. Likewise, a ship voyage count can be made for various strategic vessels and watercraft. This information can then be used to compare current force size to the projected force size with the new system.

Throughput Analysis: Given specific contingency scenarios, the capability of a particular airfield, and/or port can be assessed with the known force size. Typically, the throughput assessment is based on the physical structure of the airfield or port. The short tons per day figure that is inherent in each airfield/port is the direct determinant for the throughput capabilities of the force.

Infrastructure Assessment: The CONUS and OCONUS-based scenarios and the movement of equipment through the contingency areas are dependent on successful maneuvering through the roads and bridges. This analysis is performed using a geographic information system (GIS)-backed desktop software package, such as the Enhanced Logistics Intratheater Support Tool (ELIST), that analyzes the force size and weight along with the imposed roadway limits.

Closure Times: The capability of a force to close in a certain amount of time is directly dependent on the sortie/voyage count, throughput analysis, and the infrastructure assessment. Using the data from these analyses, the closure profile for the force can be determined and compared with that of a current force. In many instances, there is a time requirement for the force to close within and these limits can be used to analyze what assets would be required to close in that timeframe. Ultimately, this is the gauge by which the deployment scenario is measured.

Example #1

There is a proposal to replace an existing 68-ton tracked vehicle with a 72-ton tracked vehicle. Since most military vehicles are not deployed singly but as part of a military unit, we would perform an analysis of two separate unit deployments, one with the existing vehicles and one with the proposed replacement vehicles. Based on the differences in aircraft missions, heavy equipment transporters (HETs), railcars, and closure time, we can draw conclusions about the proposed replacement vehicle's deployability.

For instances where we have information on the combat support and combat service support force structure required for the replacement vehicle, the differences between the two scenarios for this type of equipment would be accounted for in our analysis also. However, in this example, only the replacement of the primary vehicles is considered.

First, we would determine the notional unit standard requirement code (SRC) as well as the existing vehicle's line item number (LIN). Depending on the proposed fielding plan (1 new vehicle for 1 old vehicle, 1 new vehicle for 2 old vehicles, 2 new vehicles for 1 old vehicle, and so forth), we would develop a notional unit SRC reflecting the new vehicles.

Air: In this example, total aircraft missions would increase despite the fact that you can only load one of each type of vehicle in the airlifter. Aircraft payload limits require that sustainment and support equipment will be reduced when transporting a heavier vehicle, therefore, increasing total aircraft missions. Increased aircraft sorties will result in an increased closure time.

Marine: Increasing the vehicle weight will not significantly impact existing strategic marine transport vessels; however, it would reduce the available lighterage for in-stream discharge. The new vehicle will reduce the unit's ability to perform LOTS operations.

Rail: Increasing the vehicle weight will reduce the number of vehicles that can be loaded on DODX railcars. Whereas some railcars can be loaded with two 68-ton vehicles, they can only be loaded with one 72-ton vehicle. This will increase the railcar requirement as well as the time required to move the unit from the fort to the port; therefore, increasing unit closure time.

Highway: Since both vehicles are tracked, they cannot self-deploy via the existing highway system and will require HETs. Increasing the vehicle weight from 68 tons to 72 tons, however, will eliminate the unit's ability to use current HETs. This will increase the unit's requirement for newer and/or commercial HETS.

As we can see from this example, increasing the weight from 68 tons to 72 tons degraded both the vehicle’s transportability and deployability.

Example #2

There is a proposal to replace existing S-280 shelter/2.5-ton M35 prime mover combinations with S-788 shelter/M1097A2 HMMWV combinations. The fielding plan calls for each existing S-280/M35 combination to be replaced by three S-788/M1097A2 combinations.

Again, we need to remember that HMMWV/shelter combinations are usually deployed as part of a unit, not singly. Therefore, we will base our deployability analysis on a notional unit deployment. The differences in combat support and combat service support force structure required for the primary vehicle combinations being analyzed is not considered in this example.

Air: Both combinations can be transported on C-17s and C-5s; however, only the S-788/M1097A2 combination can be transported on the C-130. Based on this fact, the proposed equipment replacement is more transportable than the existing equipment. However, the total length for the three M1097A2 combinations is over twice as much as a single M35A2 combination. This will increase the C-130/C-17/C-5 missions required to deploy the unit and increase unit closure time.

Marine: The M1097A2 combination is able to be moved by more ship/lighterage types than the M35 combination; therefore, it is more transportable. However, again the total square footage for the three M1097A2 combinations is more than twice the amount for the original M35 combination. This may increase the shipping/lighterage required to deploy a unit, increase ship load/unload time and increase unit closure time.

Rail: Both the M1097A2 and M35 combinations are transportable by rail without significant restrictions. However, more railcars may be required to deploy the new unit with three S-788/ M1097A2s from the fort to the port.

Highway: Both combinations are self-deployable by highway without significant restrictions.

As we can see from this example, although the HMMWV/shelter combination is undoubtedly more transportable than the original M35/shelter, the vehicle replacement ratio decreases the unit's deployability.

10 Lessons Learned

When the military is developing or buying a system, one of the key considerations for combat and materiel developers should be transportability. If the ability to move the system is not carefully considered while the system is being designed or purchased, the result may be transportation problems that reduce the system's operational effectiveness. Strategic deployability and tactical mobility are based on good transportability engineering. Developers must understand the impact of deployment, payload, and mobility requirements on the systems they intend to field.

Efficient transport is not something that evolves by itself. The equipment designer must make a conscious effort to ensure that the equipment has design features that will allow it to be efficiently transported. Developers must consider what types of units will receive the system, and what their deployment and operating requirements are. They must also consider whether a system will operate in a combat, combat support, or combat service support role. Transportability by helicopter, good off-road mobility, and airdrop capability are generally most important for systems that are primarily oriented toward a combat or combat support role. Compliance with CONUS and host nation legal limits, while always important, becomes particularly important for combat service support vehicles at the corps and echelons-above-corps levels.

Infantry brigade combat teams have mission requirements that dictate that their equipment be highly deployable to and within the theater of operations. Recent operations have shown a need for these units to have equipment that is transportable by helicopter and airdrop.

Overall, a CONUS-based force requires equipment that is more easily transported. For most, if not all, future weapons systems, transportability will be a critical design element.

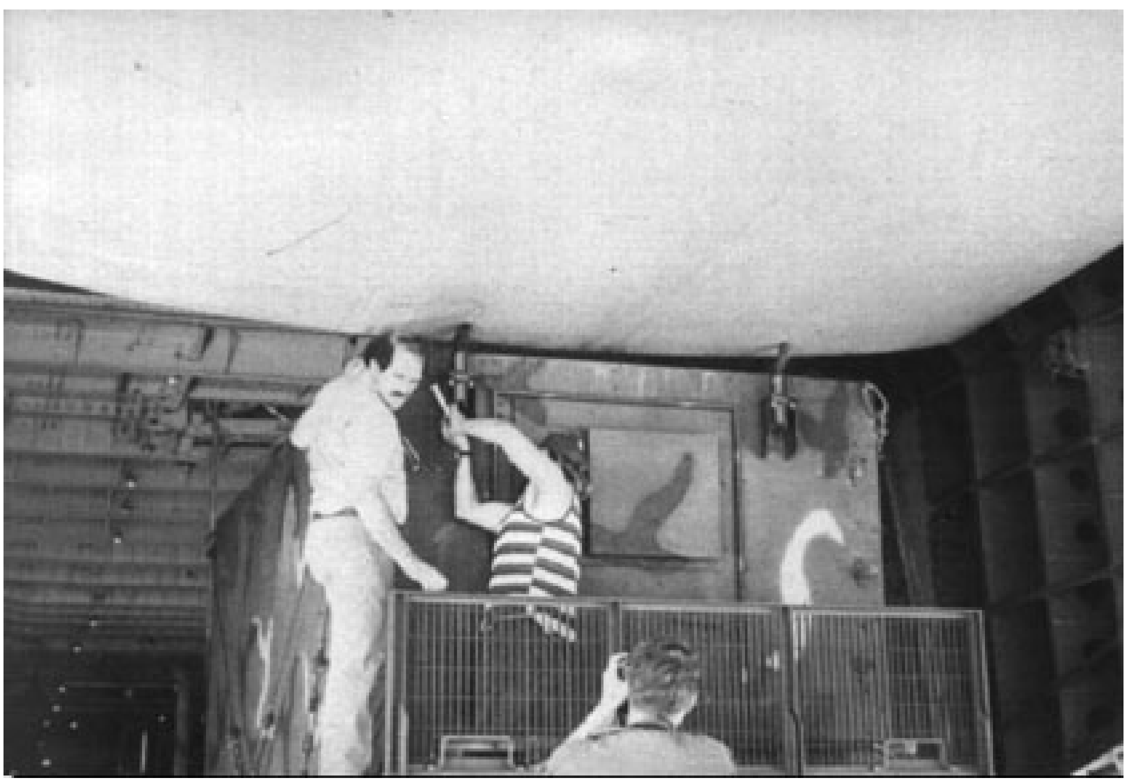
Why Transportability Matters

On the following pages are some examples as to why transportability matters in equipment design. Although not all examples are military equipment, each example could have been prevented if the infrastructure and transportation asset limitations had been taken into account during equipment design and transport.

Rail transport overhead clearance accident

Bradley falls off semitrailer

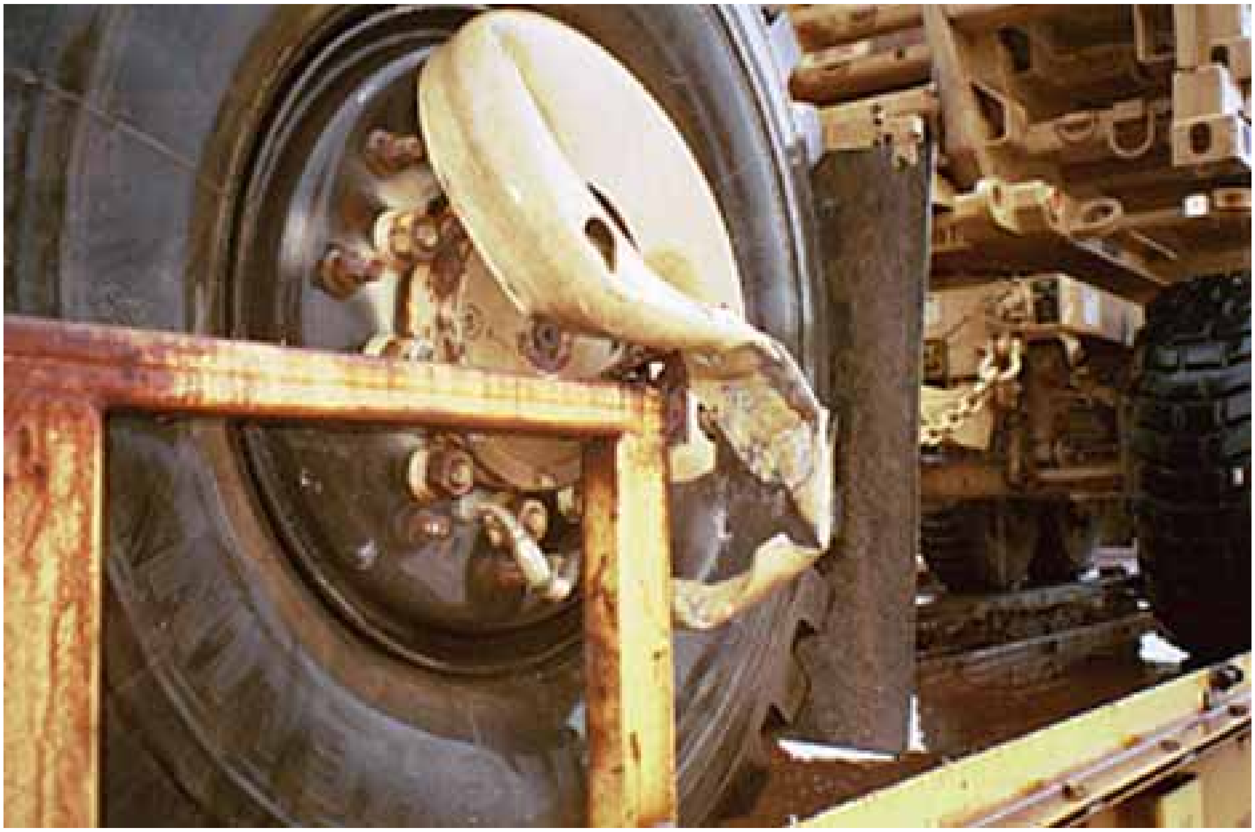
Road damage from overweight vehicles



Antenna mounts strike the door of a C-5

Ship ramp too short

Fatal accident when load was too high



Vehicles wider than railcar railing

Chains breaking during rail transport

Tractor trailer that overloaded a bridge

Tight fit on a ship...little room for error

Locomotive struck by a combat engineer vehicle

Combat engineer vehicle that struck locomotive

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References

Department of Defense Directives/Instructions/Regulations

DOD 4500.9-R	*Defense Transportation Regulation, Part III, Mobility*
DOD 4510.11	*DOD Transportation Engineering*
DOD 4540.7	*Operation of the DOD Engineering for Transportability and Deployability Program*

Army Regulations

AR 70-1	*Army Acquisition Policy*
AR 70-47	*Engineering for Transportability (1985)*
AR 71-9	*Materiel Requirements*

Military Standards

MIL-STD-209	*Interface Standard for Lifting and Tiedown Provisions*
MIL-STD-810	*Test Method Standard for Environmental Engineering Considerations and Laboratory Tests*
MIL-STD-814	*Requirements for Tiedown, Suspension, and Extraction Provisions on Military Materiel for Airdrop*
MIL-STD-913	*Requirements for the Certification of Sling Loaded Military Equipment for External Transportation by Department of Defense Helicopters*
MIL-STD-1366	*Interface Standard for Transportability Criteria*
MIL-STD-1472	*Human Engineering*
MIL-STD-1791	*Designing for Internal Aerial Delivery in Fixed Wing Aircraft*

Military Handbooks

MIL-HDBK-669	*Loading Environment and Related Requirements for Platform Rigged Airdrop Materiel*
MIL-HDBK-759	*Handbook for Human Engineering Design Guidelines*

Military Specifications

MIL-DTL-31000	*Technical Data Packages*

DOD 4000.25-13R DEPARTMENT OF DEFENSE LOGISTICS DATA ELEMENT STANDARDIZATION AND MANAGEMENT PROGRAM (DOD LOGDESMAP) PROCEDURES

DOD 5010.12-M PROCEDURES FOR THE ACQUISITION AND MANAGEMENT OF TECHNICAL DATA

MIL-DTL-32108	*Spreader Bars and Lifting Slings*

Army Manuals

FM 5-170	*Engineer Reconnaissance*
TM 5-312	*Military Fixed Bridges*

Air Force Pamphlets and Manuals

AF PAM 10-1403	*Air Mobility Planning Factors*
AFJMAN 24-204/ TM 38-250/NAVSUP PUB 505/ MCO P 4030.19/DLAI 4145.3	*Preparing Hazardous Materials for Military Air Shipments*

Standardization Agreements

STANAG 2021 ENGR	*Computation of Bridge, Ferry, Raft, and Vehicle Classifications*
STANAG 2175	*Classification and Designation of Flat Wagons Suitable for Transporting Military Equipment*
STANAG 2832	*Restrictions for the Transport of Military Equipment by Rail on European Railways*

Other Publications

C-130E/H/J/J-30 Transportability of Army Vehicles, Military Traffic Management Command Transportation Engineering Agency

C-17 Transportability of Army Vehicles, Military Traffic Management Command Transportation Engineering Agency

DI-PACK-80880C, Military Surface Deployment and Distribution Command Transportation Engineering Agency

The Impact of Weight and Dimensional Changes on the Transportability of Military Equipment, Military Traffic Management Command Transportation Engineering Agency

Directory of Highway Permit Officials and Mobilization Movement Control (MOBCON) Coordinators, Military Surface Deployment and Distribution Command Transportation Engineering Agency

Summary of Size and Weight Limits, American Trucking Association

Limits of Motor Vehicle Sizes and Weights, International Road Federation

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International Maritime Dangerous Goods Code, International Maritime Organization

Recommendation on the Transportation of Dangerous Goods, United Nations

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Contact Information

Please contact us directly or visit our web site if you need transportability assistance of any kind.

Director
Military Surface Deployment and Distribution Command
Transportation Engineering Agency
ATTN: SDDCTEA - DPE
Building 1990, 709 Ward Drive
Scott AFB, IL 62225

Telephone: 1-800-722-0727
FAX: DSN 770-5551 or (618) 220-5551
http://www.tea.army.mil/

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Handbooks for Military Movements

PAM 55-19 ***Tiedown Handbook for Rail Movements***
PAM 55-20 ***Tiedown Handbook for Truck Movements***
PAM 55-21 ***Lifting and Tiedown Handbook for Helicopter Movements***
PAM 55-22 ***Marine Lifting and Lashing Handbook***
PAM 55-23 ***Tiedown Handbook for Containerization Movements***
PAM 55-24 ***Vehicle and Equipment Preparation Handbook for Fixed Wing Air Movements***

Planning and User's Guide

PAM 70-1 ***Transportability for Better Deployability***
PAM 700-2 ***Logistics Handbook for Strategic Mobility Planning***
PAM 700-4 ***Vessel Characteristics for Shiploading***
PAM 700-5 ***Deployment Planning Guide***
PAM 700-6 ***Large, Medium Speed, Roll-On/Roll-Off Ships Users' Manual***
PAM 700-7 ***Fast Sealift Ships Users' Manual***