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Ship Systems Integration and Design Department

Technical Memorandum

SMALL CRAFT TRANSPORTABILITY DESIGN AND CERTIFICATION PROCESS GUIDANCE

by

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Combatant Craft Division (23)

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NSWCCD-23-TM-2009/64 Rev B

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14. ABSTRACT
This document identifies the design and certification process, technical data, analyses, and testing that is necessary to ensure that US Navy craft can be effectively and efficiently moved by required transportation assets and modes, according to the user's requirements.

15. SUBJECT TERMS
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Administrative Information

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Summary

This document provides design guidance to assist boat builders, designers and engineers in the design, fabrication, installation, inspection, testing, and certification for safe and efficient means of transporting craft over-the-road (OTR), by sea, and by air. The information is intended to provide a useful tool set, but it should not preclude the use of other good engineering practices or processes that also support delivery of safe and effective capabilities for craft transport. It presents a collection of available information to be updated as new lessons are learned, and as new materials or techniques are developed. The following list is an outline of the transportability design process presented in this guide.

- Transportation Modes
  - Over-the-Road Transport
  - Maritime Transport
  - Internal Air Transport (IAT)
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Introduction

Background

Transportability is the ability of a small boat or craft to be safely and efficiently moved over-the-road, by sea, or by air modes of travel as required. This capability is just as important as the other primary mission capabilities provided by the craft. Requirements documents and procurement contracts specify the intended modes of transportation for a craft as well as the design criteria and verification tests required to ensure safe and efficient means of transport. Training packages and maintenance or repair information related to transport modes must also be prepared and delivered during the acquisition process.

The overall success[1] of a Navy craft acquisition program depends upon the timely exchange of key information and the knowledge of collaborating participants (both private industry and government). Acquisition engineering agents must ensure that craft requirements are clearly delineated. Boat builders must ensure they understand the requirements, apply applicable design standards and fabrication practices, and deliver products that meet the requirements. The government technical point of contact (TPOC) must ensure that proper design reviews and tests are performed to verify that the system design meets the requirements. Before a new craft is accepted and authorized for contract payment, a certification process is performed by the TPOC and an independent team of government subject matter experts to certify the system is safe and effective.

The layout of this guide includes technical information as well as "TIPS" that highlight lessons learned and cautions for avoiding common issues. Typical contract requirements are presented. Best practices for achieving weight allowances and size limitations are summarized, and lessons learned related to detailed design of methods for securing craft in required modes of transportation are reviewed. Acceptance testing methods and boat builder information packages are presented, and design certification processes established to mitigate the risk of unsafe conditions that would prevent or significantly delay transport operations are discussed. Appendix A provides a detailed check off list of all the design elements presented in this guide, and Appendix B provides a design parameter matrix that serves as a useful summary of the key factors to consider when designing restraint systems for each mode of transport. Appendix C provides guidance for development of trailer requirements and specifications. Appendix D illustrates a simplified design example for all transportation modes.

Use of the guide and close communication with the TPOC should result in an adequate design and craft acceptance. The goal of every craft TPOC is to help the builder design, fabricate, and test for the applicable modes of craft transportation.

[1] In the context of this guide, "success" is defined as final delivery of a new craft to an operational squadron with all required transportation modes certified as safe and effective for military use.

TIP: Successful acquisition and delivery of a new craft relies on collaborative teams of knowledgeable individuals. Ask the TPOC immediately if there are questions related to design requirements, applicable standards, or acceptance criteria.

Objective

This document provides design guidance to assist boat builders, designers and engineers in the design, fabrication, installation, inspection, testing, and certification for safe and efficient means of transporting craft over-the-road, by sea, and by air. References for both Department of Defense and civilian federal air and land transportation regulations are provided, and certification processes are summarized so that (1) designers and boat builders understand the importance of information packages required by the contract, and (2) government engineers (in-training) understand the responsibilities of a government Technical Point of Contact (TPOC).

Scope

This guide is generally applicable to the design, fabrication, and certification of safe and effective means for transporting US Navy boats and craft. It conveys typical government preferences and expectations as an educational tool for builders offering boats and craft on the General Services Administration (GSA) Federal Supply Schedule (FSS). The information contained herein is not contractually binding and does not supersede contract requirements.

The design guidance presented in this document is a collection of lessons learned and best practices for consistent application across various platforms to ensure that required modes of transportation can be achieved safely and efficiently. This information provides a useful tool set, but it should not preclude the use of other good engineering practices or processes that can also deliver safe and effective capabilities for craft transport.

Transportation Modes

The following sections provide an introduction to the three primary modes of transporting Navy craft, and how certification is achieved for each mode. Some craft are required to be transported by all over-the-road, sea, and air modes of transportation, while others may only require one or two modes. This section introduces the range of technical information and key design parameters that will be presented in later sections of this guide.

Over-the-Road Transport

Movement by trailers like the one shown in Figure 1 on primary and secondary roads is a requirement for almost all U.S. Navy craft. Craft requiring over-the-road transport may also be moved on shipping cradles like the one shown in Figure 2. The boat builder will typically be expected to address the following topic areas for over-the-road transport requirements:

- Craft and trailer size and weight limits
- Types of road surface conditions
- Interface to the prime mover

- The craft's interface to its trailer or cradle
- Packaging for transport
- Restraint of the craft as cargo
- Physical size and weight validation and testing
- Design documentation including instructions for operation and equipment labeling

Figure 1. Craft Over-the-Road Transport

Figure 2. Craft on a Cradle on a Flatbed Trailer

Maritime Transport

Transportation on maritime shipping is also a requirement for almost all boats and craft. This is primarily accomplished on U.S. Navy ships, but there may be requirements for transport on Landing Craft Air Cushion vehicles or military sealift ships. The boat builder will typically be expected to address the following topic areas for maritime transport requirements:

- Craft and trailer weight
- Dimensions for stowage and movement on ship
- Load planning (access ramp angles, crest clearances, and tolerances)
- Hoisting with pier side or shipboard cranes and davits
- Packaging for transport
- Restraint of the trailer in hoisting
- Restraint of the craft and trailer (or cradle) to the ship
- Physical size and weight validation and testing
- Design documentation including instructions for operation and equipment labeling

Internal Air Transport

When transport in an aircraft is required, the intended mode of transportation is typically by US Air Force cargo plane (C-130, C-17, or C-5) on the trailer using the intended prime mover (or material handling equipment available at the airfield). Figure 3 shows a craft being loaded with its trailer onto a cargo plane. The boat builder will typically be expected to address the following topic areas for air transport requirements:

- Cargo size and weight limitations for each aircraft
- Load planning (access ramp angles, crest clearances, and tolerances)
- Trailer component strength at slow speeds and static loads
- Packaging for transport
- Restraint of the craft and trailer to the aircraft
- Physical size and weight validation and testing
- Design documentation including instructions for operation and equipment labeling

Figure 3. Internal Air Transport

Air transportation is typically the most expensive mode of transport. Before these requirements are imposed the TPOC typically confers with end-users and acquisition program

managers to ensure the air transport requirements are validated by higher naval authority. Table 1 provides historical operational cost information from reference 3 to illustrate the potential impacts on life cycle costs.

Table 1. Comparative Cost to Transport Equivalent Volume of Cargo (US - Kuwait)

Aircraft[2]	Maritime Transport Cost [$K, FY07]	Air Transport Cost [$K, FY07]
C-130	37	295
C-17	205	347
C-5	371	715

Governing Documents

Table 2 lists the governing documents that are applicable to the different transport modes covered in this guide.

Table 2. Governing Documents for Typical Transport Modes

Mode	Document	Applicability
All	MIL-STD-1366	General interface requirements
	MIL-STD-209	Requirements for tie-down fittings
Over-the-Road	23CFR658[3]	Specific design constraints for highways that are part of the National Network (Interstates and US numbered highways) in the continental United States (CONUS)
	49CFR393	Detailed operation and equipment specifications for highway safety, primarily related to the prime mover, trailer, and restraint of the craft as cargo
	49CFR571 (Federal Motor Vehicle Safety Standards)	
Maritime	NSTM Chapter 583	Lifting of craft and trailers with cranes or davits
	Ship's Loading Characteristics Pamphlet (SLCP)	Information particular to amphibious assault ships, published by each ship annually
	Wet Well Manual	Information regarding well deck operations
Air	MIL-HDBK-1791	Detailed guidance to internal air transport

Certification Responsibilities

The Combatant Craft Division (CCD) of Naval Surface Warfare Center, Carderock Division is responsible for verifying that boats and their trailers can be transported in all required modes. The design characteristics, technical data, and testing required to execute this

[2] Estimated costs assume the craft fills the entire payload volume of the aircraft.
[3] References to the Code of Federal Regulations (CFR), reference 2 are typically abbreviated as xxCFRyyy.zzz, where xx is the 'Title' number, yyy is the 'Part' Number, and zzz is a specific section number.

responsibility should be included in the terms of the contract or solicitation. If certifications are required, CCD is responsible for requesting them from the appropriate certification authority.

Over-the-Road

There are typically no formal certifications required for OTR transport beyond those required by the Department of Transportation. The current exception to this applies to the Medium Tactical Vehicle – Replacement (MTVR) as a prime mover, which requires additional testing and formal approval in a naval message from the US Marine Corps Motor Transport program office.

Maritime

There is no formal certification process to carry a boat as deck cargo on most Navy and sealift ships (either on the weather deck or between decks), but documentation of restraint capacities and other shipping information is often required. In some instances the TPOC may be required to coordinate demonstrations or tests with different ships and operational units to ensure that the craft can be transported on the ship successfully. To operate from Landing Craft Air Cushion vehicles (LCACs), a formal certification process is required that leads to addition of the craft and its restraint system to the Safe Engineering and Operations (SEAOPS) Manual for the LCAC.

Internal Air Transport

Internal Air Transport requires a rigorous, formal evaluation and certification process. The US Air Force's Air Transportability Test Loading Activity (ATTLA) is responsible for certifying cargo such as boats for flight in Air Force aircraft. Certification for Navy or Marine Corps aircraft is the responsibility of the Naval Air Systems Command (NAVAIR).

Air Force certification is generally accepted for transport on Navy and Marine Corps aircraft that are common between the services, which currently excludes variants of the C-130T and KC-130 (tanker). These constitute a comparatively small number of aircraft, and are not typically used for air transport. ATTLA is, therefore, the primary certification authority for internal air transport of US Navy boats. Where users require Navy C-130 transport, the TPOC should identify which aircraft variants are available to the operators to determine the certifying authority and the data needed for certification.

Special Modes

Unique transportation requirements primarily involve special mission requirements, such as rail car transport, helicopter sling loading, low velocity air drop, and special storage cradles (e.g. stowage for the admiral's barge). These are not typically employed for craft, and are outside the scope of this guide, however, initial information for these modes is provided in documents listed in Table 3.

Table 3. Reference Documents for Special Transport Modes

Document	Special Mode Guidance
MIL-STD-1366	Rail Transport
MIL-STD-913	Helicopter sling loading
MIL-STD-814	Low velocity air drop
Naval Ships Technical Manual (NSTM), Chapter 583, Volume 2	Special storage cradles

Transport Mode Requirements

Weight Definitions

Designers and builders are responsible for determining weights of craft and trailers for verifying trailer load capacities and tie-down strength calculations. The following items should be included when determining design weights (i.e. total weight) for the different transport modes unless otherwise specified by the TPOC.

Craft Weight:

Over-the-Road Transport

- Completed craft weight
- Full fuel & operating fluids
- Deduct water in jets, strainers, etc (free flood volumes)
- Maximum combat load-out including mission equipment (fittings, weapons, ammo, etc.) and personnel at 285 lbs each
- Deduct personnel (at 220 lbs each) for resultant personnel gear weight
- 5-10% margin

Maritime Transport

- Completed craft weight
- Full fuel & operating fluids
- Deduct water in jets, strainers, etc (free flood volumes)
- Mission equipment and personnel gear identified by TPOC (typically may include weapons and ammo)
- 10% margin (for hoisting)

Air Transport[4]

- Completed craft weight
- 5% fuel
- Deduct water in jets, strainers, etc (free flood volumes)
- Additional cargo weight identified by TPOC (typically may include equivalent weight of additional fuel)

[4] For air transport the weights of the craft and trailer should be each rounded up to the nearest 1000 pounds unless otherwise specified by the TPOC.

Trailer Weight:

- Full operating fluids
- Tools/Stowages
- Tie-down straps
- Miscellaneous Material required for over-the-road transport (e.g. boat covers, etc)
- 5-10% margin (10%, minimum for hoisting in maritime transport)

Dimension and Weight Requirements

The total weights and dimensions of the craft and its trailer (and/or cradle) are the most important parameters for transport design. The following sections provide design criteria, including weight, height, length, and width limits for each transportation mode.

Over-the-Road Transport.

Most craft are typically required to be capable of road transport on U.S. and allied highways. The exception to this general requirement is limited to very large craft that are not transported to their mission area over-the-road (e.g. coastal patrol vessels). Table 4 provides height, length, width, and weight criteria for approved travel on CONUS and NATO highways. The prime mover will be allowed unrestricted travel (movement) if the parameters listed in the first row of Table 4 are achieved.

> *TIP: Typically, the designer and builder should design for unrestricted travel in CONUS. If this is not possible, design for travel with minimal restrictions is preferred.*

The allowable limits on height, length, width, and weight will typically be identified in the terms of the solicitation or contract when restricted road transport is the intended mode of OTR transport.

> *TIP: Consult with the TPOC as soon as possible for additional information if restricted road transport is specified or is determined by design to be most practical.*

If operators require a “rough terrain” capability, specific testing by the government over a range of terrain types is required. General guidance concerning testing of on-road and off-road trailers is included in Appendix C.

Table 4. General Limits for Over-the-Road Movement [5]

	Height [in]	**Length [in]**	**Width [in]**	**Weight, Combined: Applies to Craft, Trailer, and Prime Mover**
CONUS Unrestricted	162 (13'-6")	480[6] (~40'-0")	102 (8'-6")	- Satisfies Federal Bridge Gross Weight Formula - 80,000 lbs. Combined Gross Vehicle Weight (incl. Prime Mover) - Single Axle load: 20,000 lbs - Tandem Axle Load: 34,000 lbs - Triple Axle Load: 42,000 lbs
CONUS Minimal Restrictions	162 (13'-6")	480 (~40'-0")	120 (10'-0")	Same as CONUS Unrestricted
CONUS with Restrictions	180 (15'-0")	720 (60'-0")	144 (12'-0")	- Single Axle load: 20,000 lbs - Tandem Axle Load: 34,000 lbs - Triple Axle Load: 42,000 lbs
NATO Highways Unrestricted	4.00 meters	10.00 meters	2.50 meters	- Single axle load: 10,000 kg - Tandem axle load: 16,000 kg
Korea Highways Unrestricted	4.00 meters	17.00 meters	3.00 meters	- Single axle load: 10,000 kg - Tandem axle load: 16,000 kg - Triple Axle Load: 40,000 kg

"Minimal restrictions" as cited in Table 4 (row 2) reflect a typical threshold where permits are required, but are relatively easy to obtain, and the travel does not require significant logistical support, such as escort vehicles or specified schedules and routes that are characteristic of travel (movement) "with restrictions" (shown in row 3).

TIP: Boat builders should ensure trailer designers use axle spacing identified in reference 7 for final estimates of maximum axle loads.

Maritime Transport.

All craft that can be transported over-the-road are typically required to be capable of maritime transport as deck cargo (unless specifically stated otherwise in the terms of the solicitation or contract). Height and weight restrictions may be more limiting on ships than for over-the-road transport (depending upon the intended transport ships and stowage location on open weather decks or below decks via access ramps). MIL-STD 1366E provides height, width, and weight restrictions for military sealift ships.

[5] Applicable permitting limits vary from state to state, but generally do not exceed the dimensions and weights identified in this table

[6] Federal length limits in 23CFR658.13 apply only to semitrailers and combination semitrailer-trailer configurations. For craft OTR design, trailered length should be limited to approximately 40 feet, if possible, and boats carried on semitrailers should conform to the length limit of 48 feet whenever possible.

Tables 5, 6, and 7 provide deck height limits, weight limits, access ramp slope, and ramp width limits for Navy ships typically used to transport small boats and craft. Unless otherwise specified, trailers hauling a craft should be able to pass over a ramp with a slope equal to no less than 15 degrees.

The uniform distributed load (UDL) limits for decks in ships is an equivalent deck pressure calculated using the total weight (craft and trailer) and the trailer contact areas to the deck. Experience has shown that small boats and craft on trailers seldom come close to these limits.

TIP: For a conservative design approach, subtract 6 inches from the deck heights and ramp widths provided in Tables 5 and 7.

Table 5. US Navy Ship Deck Heights for Vehicle Stowage (Ref 8)

Ship Class	Vehicle Handling & Stowage Location	Clear Deck Height [in]	Remarks
LCM 8	Main Deck	N/A	Open Deck
LCU 1610	Main Deck	N/A	Open Deck
LCAC	Main Deck	N/A	Open Deck
LSD 41	Main Deck	156	Height at opening between the fixed ramp and aft end of main deck
	01 Level	180	
LSD 49	2nd Deck	180	
	Main Deck	156	Height at opening between the fixed ramp and aft end of main deck
	01 Level	180	
LPD 4/7	2nd Deck	190/114	114 inches to bottom monorail train
LHA 1	2nd Deck	168/109.5	109.5 inches to bottom monorail train
LHD 1	2nd Deck	168/109.5	109.5 inches to bottom monorail train
LPD 17	1st Platform (Main-V)	191	150 inches in forward vehicle area
	2nd Deck (Upper-V)	133	143.5 inches ramp to flight deck

Table 6. US Navy Ship Deck Strengths (Ref 8)

Ship Class	Well Deck		Upper Vehicle Deck		Main Vehicle Deck		01 Level		02 Level		03 Level	
	UDL (psf)	Wheeled Vehicle	UDL (psf)	Wheeled Vehicle	UDL (psf)	Wheeled Vehicle	UDL (psf)	Wheeled Vehicle	UDL (psf)	Wheeled Vehicle	UDL (psf)	Wheeled Vehicle
LSD 41	300	M1A1	300	M55	N/A	N/A	300	M55	N/A	N/A	N/A	N/A
LSD 49	300	M1A1	300	M55	N/A	N/A	300	M55	N/A	N/A	N/A	N/A
LHA 1	550	M1A1	550	M55	N/A	N/A	N/A	N/A	550	M55	550	M55
LHD 1	500	M1A1	500	M55	N/A	N/A	N/A	N/A	500	M55	500	M55
LPD 4/7	300	M60	300	M62	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
LPD 17	627	M1A1	627	M923	627	M923	N/A	N/A	N/A	N/A	N/A	N/A

Table 7. US Navy Ship Vehicle Ramps and Stern Gates (Ref 8)

Ship Class	Slopes (Degrees)	Clear Width (Inches)	Ramp	Location	Capacity (lbs)	Remarks
LCM 8	20	168	Bow Ramp	Well Deck	120,000	Hinged
LCU 1610	20	178	Bow Ramp	Main Deck	140,000	Hinged
	12	178	Stern Gate	Main Deck	140,000	Hinged
LCAC	14	340	Bow Ramp	Main Deck	140,000	Hinged
	14	178	Stern Ramp	Main Deck	140,000	Hinged
LSD 41	N/A	600	Stern Gate	Well Deck	140,000	Hinged
	14.5	120	Portable Ramp	Well Deck/2nd Deck	34,000	
	14.5	120	Fixed Ramp	2nd/Main Deck	34,064	
	15	138	Fixed Ramp	Main Deck/01 Level	34,064	
	15	150	Fixed Ramp	01 Level/Helo Deck	34,064	
LSD 49	N/A	600	Stern Gate	Well Deck	140,000	Hinged
	16/12	600	Well Deck	Well Deck/2nd Deck	140,000	Fixed, Double Knuckle
	15	138	Fixed Ramp	2nd Deck/Main Deck	34,064	
	15	138	Fixed Ramp	Main Deck/01 Level	34,064	
	15	138	Fixed Ramp	2nd Deck/Helo Deck	34,064	
	15	150	Fixed Ramp	01 Level/Helo Deck	34,064	
LPD 4/7	N/A	600	Stern Gate	Well Deck	140,000	Hinged
	12	600	Well Deck	Well Deck/3rd Deck	90,000	Fixed
	25	214	Upper Ramp	3rd Deck/Main Deck	41,000	
LHA 1	N/A	600	Stern Closure	Well Deck	N/A	
	15/11	380	Well Deck	Well Deck/3rd Deck	140,000	Fixed, Double Knuckle
	15	180	Hangar	3rd/Hangar Deck	43,000	
	15	114	Side port Ramp	Pier/3rd Deck	43,000	Portable
LHD 1	N/A	600	Stern Gate	Well Deck	140,000	Hinged
	15/11	600	Well Deck	Well Deck/3rd Deck	140,000	Fixed Double Knuckle
	15	180	Hangar	3rd /Hangar Deck	43,000	47,000 for LHD2 and Up
	15	114	Side port Ramp	Pier/3rd Deck	43,000	Portable
LPD 17	N/A	600	Stern Gate	Well Deck	140,000	Hinged
	15/11	283	Well Deck	Well Deck/1st Plat	140,000	Fixed, Double Knuckle
	15	138	Bridge Ramp	1st Plat/2nd Deck	47,000	
	15	138	Fixed Ramp	1st Plat/2nd Deck	47,000	
	15/11	138	Fixed Ramp	2nd/Main Deck	47,000	Fixed, Double Knuckle
	15	114	Side port Ramp	Pier/3rd Deck	47,000	Portable (P), Hinged (S)

Internal Air Transport

Figure 3 illustrates the close tolerances associated with loading a large craft into an aircraft. The allowable cargo dimensions in the cargo compartments of Air Force C-5, C-17, and C-130 aircraft from reference 7 are shown in Figure 4.

TIP: If the C-130 is the specified air transport mode, the craft must allow for a safety aisle for the aircrew and is subject to maximum axle and tongue loads, depending on its position in the aircraft. These constraints are outlined in MIL-STD-1366 and MIL-HDBK-1791.

The maximum cargo weight (based on optimum flight conditions) is limited to 24,000 lbs for the C-130, 130,000 lbs for the C-17, and 178,000 lbs for the C-5 [Reference 7]. Typically, a craft and trailer will not approach the limits of the larger C-17 and C-5 aircraft, but they may require consideration if it is intended to be transported with the prime mover, or a second craft, or other gear.

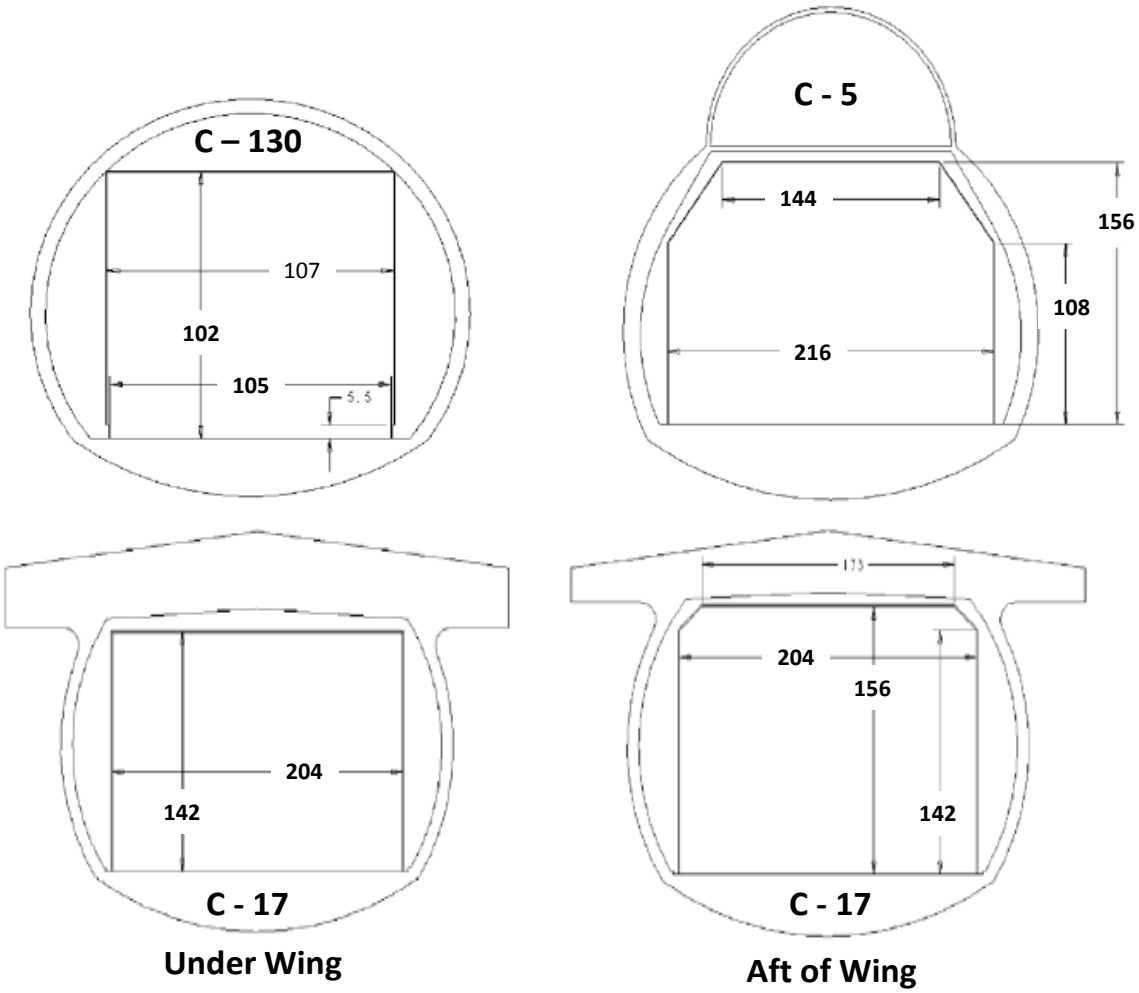


Figure 4. Aircraft Cargo Compartment Dimensions

Over-the-Road Transport Specific Requirements

Operational Area

The intended operational environment imposes constraints on the boat and trailer package. These constraints primarily include the dimension and weight limits identified earlier, terrain types, and launch and recovery site conditions.

Terrain. Transportation over-the-road requires traversing various types of terrain. Categories and descriptions of these terrain types are described below. More detail for each type, including roughness measurements, is included in Appendix C.

Primary Roads - (*high quality paved, secondary pavement, and rough pavement*) - All may consist of two or more lanes, all weather, maintained, hard surface (paved) roads with good driving visibility used for heavy and high density traffic. These roads have lanes with a minimum width of 108 inches, road crown less than 2 degrees and the legal maximum gross vehicle weight/gross combined weight (GVW/GCW) for the county and state is assured for all bridges.

Secondary Roads - (*loose surface, loose surface with washboard and potholes, and Belgian block*) - These roads are one or more lanes, all weather, occasionally maintained, varying surface (e.g., large rock, crushed rock and gravel) intended for medium-weight, low-density traffic. These roads have no guarantee that the legal maximum GVW/GCW for the county and state is assured for all bridges.

Trails - One lane, unimproved, seldom maintained loose surface roads, intended for low density traffic. Trails have no defined road width and can include large obstacles (boulder, logs, and stumps) and no bridging.

Cross-Country Terrain - Vehicle operations over terrain not subject to repeated traffic. No roads, routes, well-worn trails, or man-made improvements exist. In addition, cross-country terrain can consist of tank trails with crushed rock or having large exposed obstacles (rocks, boulders, etc).

Most Navy craft typically require transport over primary and secondary roads. For craft not normally trailered (i.e. moved using a shipping cradle on a flat-bed truck), only transportation over primary roads is typically required. If operators require a "rough terrain" capability, specific testing over the range of all terrain types is required. General guidance for development of a "rough terrain" trailer is included in Appendix C. The TPOC can address any questions regarding specific terrain requirements that are not included in the terms of the contract or solicitation.

Launch and Recovery Site. Launch and recovery from a ramp with primary or secondary road surface characteristics is typically required for a trailered craft. Defining the requirement for other methods of launch and recovery is the shared responsibility of the TPOC and the end-users.

In defining this requirement, three fundamental methods of launching a boat are typically considered: ramp launching, launching over an embankment, or by hoisting the boat directly into the water. The applicable requirements for hoisting the boat directly into the water are covered in detail in reference 1. For ramp launching, or for launching over an embankment, accessibility, approach slope (and potential need for additional braking), terrain type, and water depth, are factors that should be considered. Figure 5 and Figure 6 show extreme examples of difficulty that may be encountered in launch and recovery operations in unimproved rough-terrain areas.

Figure 5. Soft Soils at Launch Site

Figure 6. Water Depth at Launch Site

Prime Mover Interface

Dimensions and Capacities. Table 8 provides typical dimensions and tow capacities for prime movers often used to transport craft. This table should be used to establish gross vehicle weight ratings, critical dimensions for trailer hitch types, height ranges, cresting angles, and aircraft load plans.

TIP: The trailer hitch height and distance to rear axle shown in Figure 7 are key parameters for determining the ability of trailers to clear the crest of a ship or aircraft loading ramp.

Electrical Connections**.** All trailers should have both 7-pin and 12-pin connectors designed to interface directly with the intended prime mover's electrical system. Commercially-available prime movers, including militarized variants like the Light Service Support Vehicle (LSSV) have standard 12-volt systems with a 7-pin (flat terminal) commercial round connector shown in Figure 8. Tactical vehicles (e.g., MTVR, High Mobility Multi-Wheeled Vehicle (HMMWV), or Mine Resistant Ambush Protected (MRAP)) have standard NATO 24-volt systems with a 12-pin connector, NSN5995-01-544-5774 (also shown in Figure 8).

Table 8. Typical Prime Movers

Prime Mover	Hitch Height [in]	Distance to Rear Axle [in]	Rated Tow Capacity [lbs]	Wheelbase [in]	Notes
LSSV	18.5	64	13,000	167	1, 3, 5, 8, 10
LSSV (EMP)	26.5	62	13,000	167	1, 2, 3, 6, 10
Ford F-550 (Crew Cab)	27	68	16,000	176.2	3, 6, 10
FL-80	23	77	36,500	252	4, 9, 10
MTVR MK23	39	56	22,400	184	4, 6, 10
MTVR MK31 (pintle)	34	36	22,400	184	4, 7, 10
MTVR MK31 (fifth wheel)	57.5	28.3 (forward of rear axle)	94,000	184	
HMMWV	24.5	40	4,200	Varies	4, 10
MRAP	31	35	Not Available	Varies	4

Notes:

(1) LSSV: Chevrolet Silverado 2500HD variant with diesel engine.
(2) Enhanced Mobility Package (EMP): LSSV Suspension Option
(3) Typically Ball Hitch / 2-inch Receiver
(4) Pintle Hitch
(5) Measurement taken with trailer loaded
(6) Measurement taken with no trailer hooked up
(7) Measurement taken with fifth wheel loaded (~12,000 lbs), suspension raised (~50%)
(8) LSSV axle ratings are 4500/6084 lbs (front/rear), when evaluating Federal Bridge Gross Weight formula
(9) FL80 axle ratings are 11000/51000 lbs (front/rear), when evaluating Federal Bridge Gross Weight formula
(10) Tow Capacities may be reduced by the weight of any cargo carried on prime mover.

Figure 7. Prime Mover Hitch Height and Rear Axle Distance

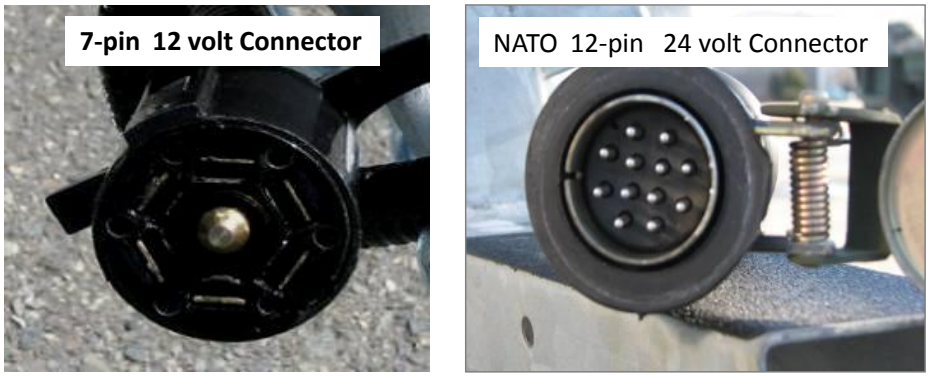


Figure 8. Trailer Electrical Connections

Trailers and Cradles

The trailer and the shipping cradle are typically referred to as ancillary equipment in solicitations or contract documents. Figure 9 shows an example of a craft supported by a cradle on a flat bed trailer. Design considerations for these components are outlined in this section. Appendix C provides additional detail as a guide in developing on-road and off-road trailer specifications, craft contract requirements, and specialized government test plans for certification of rough terrain trailers. Additional guidance is also available from the National Association of Trailer Manufacturers in reference 9.

Trailer Size and Weight. The placement of the craft on the trailer should generally result in a combined (craft and trailer) center of gravity located to produce approximately 10% of the gross vehicle weight (GVW) on the tongue for a hitched trailer, or 20-30% of the GVW on the kingpin for a fifth wheel trailer.

Trailer gross vehicle weight rating (GVWR) should be no less than the combined weight of the craft and the trailer plus margins. Due to discrete increments of trailer component weight ratings (e.g. axles and brakes), assumed margins may be adjusted to achieve a reasonable weight

estimate. The target GVWR should be approximately 105% to 110% of the gross vehicle weight at delivery (without craft and trailer margins).

Figure 9. Rigid Inflatable Boat on Typical Shipping Cradle

TIP: For smaller craft, the trailer should be capable of unrestricted transport on CONUS highways when it is in an unloaded condition.

Construction. Trailers and cradles should always be of a heavy-duty construction, using corrosion- and rot-resistant (or coated) materials and components. Trailer components are likely to be submerged frequently, are regularly exposed to the elements, and typically receive little maintenance during its life cycle. Specific details for component material selection are included in the general guidance in Appendix C.

Craft Interface. The craft is typically supported by solid bunks or roller bunks. Some contracts may require low friction materials to allow for easier or more rapid launch and recovery. If practicable, the bunks should be located along the keel, hull, and chine to provide support at craft transverse bulkheads, longitudinals (especially in way of engine foundations), and frames.

TIP: Support points should not be located in way of spray/lifting strakes or hull appendages (e.g. raw water suction, waterjet grates, depth sounder, etc), and should be positioned and sized for adequate load distribution when the craft is subjected to all applicable accelerations (See Table 9 for road, sea, and air transport design load factors).

All Navy trailers have a bow winch and a bow stop. Several common examples are shown in Figure 10. If not defined in the terms of the solicitation or contract, the winch and its supporting structure should be designed to the same load as the bow eye with a minimum system safety factor of 1.5 on the ultimate strength.

TIP: There are commercially available powered winches that may be capable of parting the cables supplied by the manufacturer. If this condition exists consult with the TPOC regarding use of higher strength cables than those supplied by the manufacturer.

The bow stop should have sufficient strength to resist the craft's maximum thrust at zero speed without yielding, and it should provide self-centering capability. If large angles during launch and recovery are included in mission scenarios, the contract will typically require fairlead rollers to reduce the loading and prevent damage to the winch or the winch cable. All trailers and cradles must be provided with the correct tie-down quantity and strength. This is discussed in detail in the Restraint System Design section of this guide.

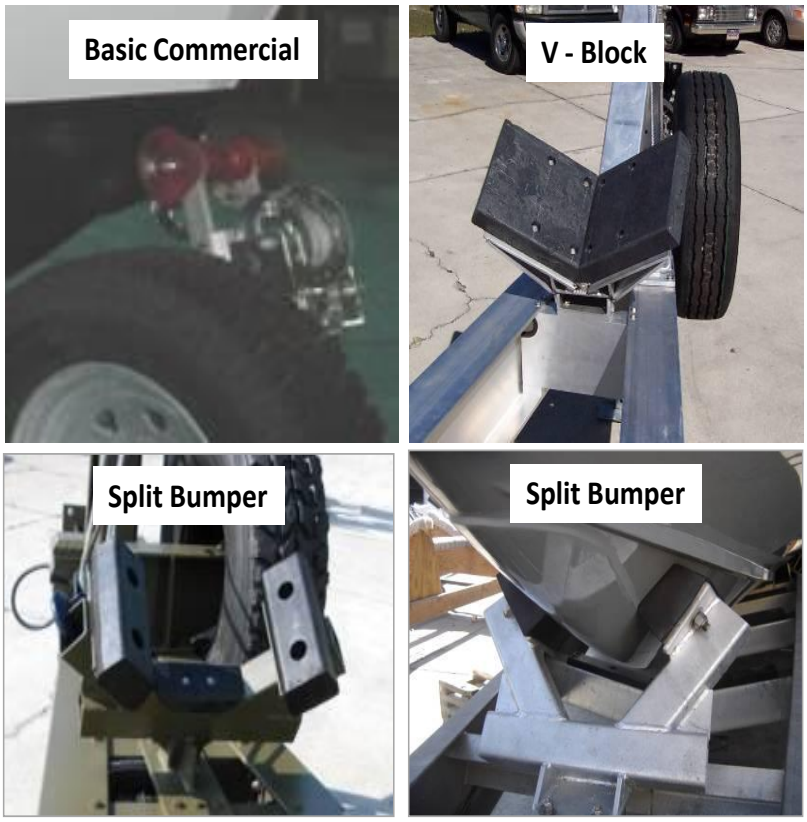


Figure 10. Examples of Bow Stops

Lighting. All tail lights, side marker, and aft marker lights should be 12v and 24v compatible LED lights using NSN 6210-01-482-6105, 6220-01-482-6113, and 6220-01-482-5574, or equal lights conforming to MIL-PRF-32212A (Tail Lights) and 32213 (Marker Lights). Other part numbers may be chosen for other housing colors (tan or black) to suit the application. The 7 pin and 12 pin connectors should be secured to the end of two "pig-tails" that connect to a common trailer wire harness in a NEMA water tight junction box which houses a properly sized

terminal strip and conductors using ring terminals. Means to secure the 12v and 24v wire harness connectors when not connected to a tow vehicle should be provided.

Regulatory Compliance. All highway trailers must adhere to Department of Transportation regulations, including the applicable regulations in 49CFR393 and 49CFR571.

TIP: Consult with the TPOC as soon as possible for cases where federal regulations for CONUS transit violate a military requirement. For example, the use of permanent reflectors to meet a federal transportation regulation could violate a military requirement for tactical blackout conditions. This situation could be satisfied by the use of removable (temporary) reflectors on the trailer during CONUS transit.

TIP: Exemptions to federal Department of Transportation regulations can be approved if the craft is intended to be transported on trailers pulled only by military or government vehicles. But exemptions should be avoided if possible because it limits future flexibility to be able to pull the trailer on CONUS highways with non-military or non-government vehicles.

Maritime Transport Specific Requirements

Navy craft are often transported to an operational area onboard a Navy ship as deck cargo. This form of transport requires accessible lifting and tie-down fittings in addition to the dimensional and weight criteria identified earlier in this guide. This applies to loading on roll-on/roll-off (RO/RO) ramps or by lifting the craft and trailer onto the ship with a pier-side or shipboard crane. Design of tie-down fittings is discussed in the Tie-down Attachment Design section of this guide and in reference 6.

Well Deck Operations.

Some craft are intended for operation from specific Navy ships, particularly from the well decks of amphibious assault ships as shown in Figure 11. Operation from a Navy ship may require information on the maintenance and upkeep of the boat, which must be performed while the ship is underway. The TPOC is responsible for defining additional technical data and testing required for certification, which should be identified in the terms of the contract or solicitation.

Launching the boat directly from the well deck may be performed with or without the craft's trailer. When a trailered launch is required, additional tie-down fittings and length restrictions may apply (this evolution is typically performed on the fold-down stern gate or on the ramp at the head of the well deck). When the craft is to be transported without its trailer in a well deck, the keel must be reinforced to carry the boat's weight, and additional equipment must be included (such as a cradle, bracing, or the "kickstand" pictured in Figure 12) to prevent the boat from tipping over while the well deck is drained. These considerations should be clarified with the TPOC when well deck launch and recovery is required.

Figure 11. Stern Gate Launch and Recovery Operations

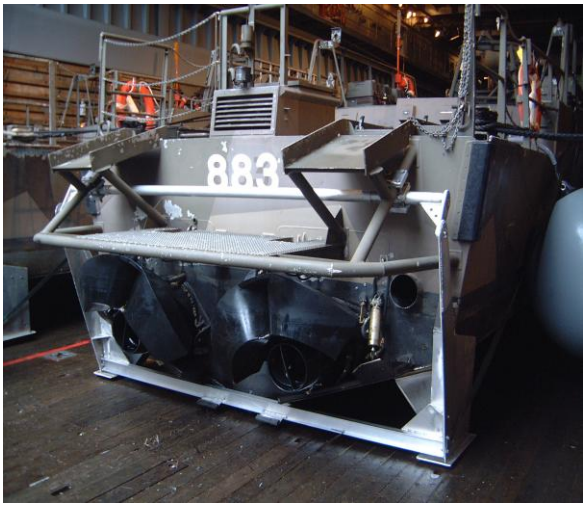


Figure 12. Kickstand Supporting Craft in Well Deck

Dedicated Stern Launch and Recovery.

Ship's boats intended for use with future or developmental ships with dedicated stern launch and recovery systems, such as the Littoral Combat Ship or the DDG-1000, will have unique interface requirements. Any boat intended for this type of use on a future ship class will have interface requirements clearly defined in the solicitation or contract.

Movement with Cranes and Davits.

Since RO/RO ramp access to a ship is not always guaranteed, all craft and their trailers must also be designed to be lifted onto the ship with a crane. While the craft and trailer may be lifted separately, the most direct method of shipboard loading is to lift them together using the craft's hoist fittings. Hoisting requirements for the combined weight and center of gravity of the craft and trailer are identified in reference 1. This requires that the tie-down fittings on the craft and the trailer, as well as the tie-down straps be designed for higher loads and safety factors than

for over-the-road transport. The design loads for these fittings and straps are discussed in the Restraint System Design section of this guide.

A craft that is issued for dedicated use on a ship is known as a ship's boat. For example, a destroyer may have a 7-meter rigid inflatable boat (RIB) onboard at all times. They are typically stowed in a fixed cradle assembly with a dedicated davit as shown in Figure 13. Ship's boats are not considered deck cargo. Nearly all davits on Navy ships are exclusively used for 7 meter or 11 meter Navy standard RIBs. At-sea hoisting system requirements are covered in reference 10.

Figure 13. Ship's Boat Stowed in Davit

Internal Air Transport Specific Requirements

Most craft that are air-transportable are loaded into a US Air Force cargo plane (C-130, C-17, or C-5) on their trailer. In each case, the craft must be capable of being loaded into the plane by its prime mover. Material handling equipment shown in Figure 14 may also be used to load the craft. For a C-5, it is preferable that the craft be able to be loaded through both forward and aft ramps.

Load Plan Development.

A load plan is typically required to be developed by the boat builder as part of the required data package when internal air transport is required. The plan typically includes aircraft dimensional constraints to verify that the craft and trailer can be loaded without interference, and it specifies any shoring that may be required. Figure 15 illustrates the three critical locations of potential interference that should be included in the load plan. An example of a load plan is presented in Appendix D. Dimensions for the cargo compartment cross-sections of all three aircraft are provided in reference 7. Dimensions for the aircraft floor and approach ramps for the C-130 and C-5 are provided in reference 5. The aircraft floor dimensions and ramp dimensions for the C-17 can be provided by the TPOC.

The prime mover dimensions listed in Table 9 may be used to estimate dimensions used in the load plan. In some instances the TPOC may be able to provide prime mover drawings with detailed dimensions. If the prime mover must crest the ramp hinge in the load plan, the TPOC should be consulted to define its mid-span ground clearance (and wheel base dimension) to ensure that a potential critical point is not overlooked.

Figure 14. Air Force Material Handling Equipment

TIP: If a load plan indicates that the craft and trailer with the prime mover will experience interference at any of the critical points, an articulating trailer frame may be an appropriate solution, but its complexity and cost may be prohibitive.

The Air Force reduces the gross vehicle weight rating and the rated strength of all commercial axles by 20%. This requires nearly all trailers to use sleeper shoring for air transport (see reference 5). Sleeper shoring is used to reduce the loads on the aircraft to an acceptable level when subjected to the downward accelerations required for restraint.

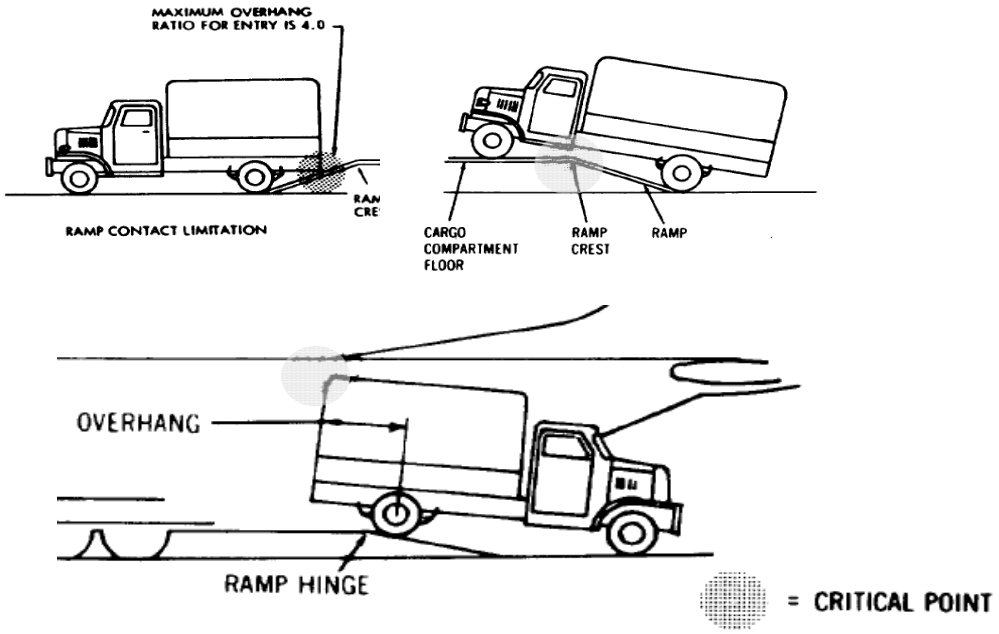


Figure 15. Critical Points for Aircraft Loading

Slow Speed and Static Load Capacity.

The strength ratings for trailer components such as tires and wheels are provided for normal highway speeds. At slow speeds, these components can support significantly higher loads than their highway ratings indicate (See general load multipliers in Appendix C). The component manufacturers can review overload conditions (e.g. one axle of the trailer supporting the boat when starting up the ramp or cresting the ramp hinge), or provide these creep ratings. When internal air transport is required, the creep ratings should always be provided for the trailer's tires, wheels, and any other components with load capacities regularly reported for highway speeds. This information is needed for the data package provided to the Air Force for technical review.

Other load-bearing components on the trailer, specifically the axles and the landing legs, have the potential to overload the aircraft ramp and cargo floor structure. Calculated loads and rated strengths for the axles and landing legs, as well as axle spacing and landing leg footprint dimensions should always be provided in the trailer specifications. This information is needed for the data package that is provided to the Air Force for technical review of the aircraft floor loads.

Transport Packaging Design

In this section the term "packaging" is used to describe the actions taken to prepare the craft for transport. For example, loose gear may have to be stowed or masts may have to be lowered and secured. More than one packaging configuration may be required to accomplish all the different transportation modes, while some modes may require no special transport configurations at all. For each transport mode, the packaging configuration and instructions are typically required to be included in the craft's technical data package. Examples of different packaging configurations and instructions are included in Appendix D.

TIP: The need for special packaging tools should be avoided. The need for common hand tools is acceptable, but the number of different tools and tool sizes should be minimized.

Stowage and restraint of loose or removed gear must also be considered when developing the packaging configurations for transport. All removed or loose gear must be able to be stowed and secured for the applicable acceleration loads on the craft or trailer. Any restraints necessary to secure loose gear for over-the-road transport are typically provided by the builder when the craft is delivered. If additional restraints are necessary for other modes, identification of their strength and quantity should be included in the packaging instructions.

Restraint System Design

The restraint of a craft on a trailer, and the restraint of the craft and trailer (or cradle) combination on a ship or aircraft are critical design considerations. Providing proper restraint will avoid unsafe conditions and help prevent damage to the boat and its prime mover. Figure 16 shows an example of a mishap due to improper restraint of the craft to the trailer.

A restraint system typically consists of tie-down straps (or chains), components used to attach the straps, such as shackles, hooks, or rings, and the fittings (points of attachment) on the craft, cradle, trailer, or transport cargo deck. The points of attachment are often referred to as "tie-down provisions". A thorough review of the restraint system includes the following steps:

- Determination of loads
- Development and analysis of each unique tie-down arrangement
- Design of tie-down provisions
- Selection of restraints (for over-the-road transport)
- Testing of the tie-down provisions and straps.

Figure 16. Results of Improper Restraint

Determine Required Loads

Table 9 provides restraint system load factors for all three modes of transportation (from references 7, 10, 13, and 14). The values are listed as multiples of weight in units of the acceleration due to gravity. A value of 2g means the design load is twice the weight of the items being secured. A value of 0.5g means the design load is equal to half the weight of the items being secured. Each column provides a design load in one of five principle directions relative to the transport vehicle. These directions are independent of the orientation of the craft or the trailer.

For over-the-road transport, the tie-down arrangement must secure the craft to the trailer, or if a cradle is used, it must secure the combined weight of the craft and the cradle to the trailer. For maritime and internal air transport, restraint may be accomplished in either of two ways:

1. Restraint of the craft to the trailer at the craft's weight, and restraint of the trailer to the transport deck at the combined (boat and trailer) weight.
2. Restraint of the craft to the transport deck at the craft's weight and restraint of the trailer to the transport deck at the trailer weight.

TIP: It is often easier to achieve the second restraint method listed above for air transport, because trailers typically are not designed to restrain the loads from the craft at aircraft accelerations.

While it is not typically necessary, the craft's hull structure may need to be evaluated for additional shoring to ensure that it will not be damaged by the bunks on the trailer or shipping cradle.

Table 9. Restraint Accelerations for US Navy Craft Transport Modes

Mode	Forward G's	Aft G's	Lateral G's	Up G's	Down G's
OTR	0.435	0.50	0.25	0.20	0.20
Shipping Cradle	0.50	0.50	1.0	0.5	2.75
Maritime[7]	0.476	0.476	1.164	0.489	2.489
Maritime (Hoisting)	N/A	N/A	N/A	N/A	5.0[8]
USAF C-130, C-17, and C-5	3.0	1.5	1.5	2.0	4.5
USN C-130	3.0	2.0	1.5	2.0	N/A
USN Fixed Wing	3.0	2.0	2.0	2.0	N/A

Tie-down Arrangement and Analysis

A tie-down arrangement and restraint analysis is required for air transport certification, and should be performed for all other transport modes. Where possible, the tie-down arrangement for over-the-road transport and maritime hoisting should be identical to simplify instructions and ensure adequate restraint is always maintained in both operations. An example set of tie-down arrangements and analyses is included in Appendix D.

No single strap or set of tie-down attachments should be expected to fulfill restraint requirements in any one direction. Good designs will always have at least two means of attachment for each direction. In this way, failure of one strap or one of the shared fittings would not result in complete loss of restraint in that direction. Examples of a poor design would be a tie-down arrangement using only the winch cable for aft restraint, or using a strap routed through a shackle on the bow eye to either side of the trailer frame as the only means of restraining the craft from forward or aft movement.

Achievement of the required restraint loads in each of the principle directions is demonstrated through analysis using vector addition. The rated strength of the tie-down strap or chain is multiplied by the vector components to calculate a restraint load in each direction. Total restraint in each direction is the sum of the individual component forces. See Appendix D for examples.

[7] Accelerations are for the worst case motions, calculated per Ref 12 and 13, at worst case well deck locations per Ref 12. These accelerations exceed the values identified in MIL-STD-1366, and should be used for all maritime shipping.

[8] Applies to the restraint of the trailer weight when suspended from the boat.

TIP: Good design practice is to add additional tie-down straps to the restraint system if loads calculated using Table 9 values are within 500 pounds of allowable loads (of straps, cables, or fittings).

Tie-down strap lengths in each arrangement are measured as the distance between tie-down attachment points (e.g. transom tie-down eyes on the craft and a D-ring on the trailer), regardless of whether or not the strap would bend across the chine or deck edge of the craft.

Over-the-Road Transport Tie-down Arrangement and Analysis Details.

Over-the-road transport is the only transportation mode where the winch cable may be included as a restraint (but not the only restraint). When used, the winch cable rated strength should be provided with the trailer documentation. If the strength of the winch cable is not known, the nominal strengths provided in 49CFR393.108 should be used.

Maritime Transport Tie-down Arrangement and Analysis Details.

Ship-specific tie-down plans are not typically developed by the boat builder, because crew members in the deck departments rig uniquely and ships may have different deck fittings. This is illustrated in Figure 17 where the restraint systems for boats on trailers and cable reels are aligned with unique deck fittings.

For this mode of transport the boat builder should demonstrate by analysis that: (1) there are a sufficient number of tie-down attachments points with sufficient strength to meet Table 9 loads, and (2) the structure of the craft and trailer (and shoring if required) can accommodate the loads. An example similar to that in Appendix C of MIL-STD-209 is provided in Appendix D of this guidance.

TIP: If the builder determines a specific tie-down arrangement is necessary to support maritime transport certification, the TPOC can provide additional information regarding the strength, spacing, and locations of deck fittings for the intended transport ships.

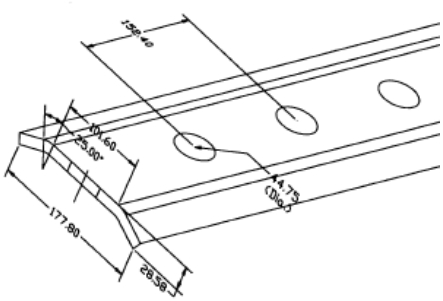
Air Transport Tie-down Arrangement and Analysis Details.

All tie-downs connecting the craft or trailer to the aircraft cargo deck will typically be either MB-1 chain (10,000 lb capacity) or MB-2 chain (25,000 lb capacity). Five-thousand pound capacity tie-down straps (CGU1/B) are part of the USAF inventory, but they are intended for light weight cargo loads and should not be considered for aircraft tie-down arrangements. MIL-HDBK-1791 provides attachment point details for cargo decks in C-130 and C-5 aircraft. Information for the C-17 can be obtained by the TPOC from the US Air Force's Air Transportability Test Loading Agency (ATTLA), and provided to the boat builder or trailer manufacturer. A sample arrangement is included in Appendix D.

TIP: Any loose gear or stowages that must be tied down to the craft or trailer during air transport (e.g. an arch lowered/removed) need to meet the restraint loads (at the item's weight) calculated using Table 9. This will also affect the rated strength for the necessary fittings and straps.

Flush Cloverleaf

NAVSEA 805-1213717 STD DWG



Typical Deck Track System (dimensions in mm)

Figure 17. Unique Equipment Tie-downs on Navy Ships

Tie-down Attachment Design

The attachment fittings for the tie-down straps on the craft and the trailer must be designed to meet or exceed the highest load for each transport direction. Wherever possible, they should be of common type and have common strength to avoid confusion in their use (e.g., all 15,000 lb safe working load D-Rings on the trailer, and all 25,000 lb. fittings on the craft).

> *TIP: The overall strength of the restraint system design is governed by the weakest link in the design. If attachment fittings have lower strength than tie-down straps, then the analysis results should reflect the lower strength value of the fittings.*

Many types of attachment fittings are commercially available with documented rated strengths. Both commercially-available fittings and those fabricated by the builder or trailer manufacturer should conform to the guidance in MIL-STD-209. Figure 18 shows examples of different types of attachment fittings.

When air transport is required, the attachment fittings should be able to accept the hooks on an MB-1 or MB-2 chain, or they should allow the chains to pass through the fitting. If this is not practical they should be provided with transition elements such as loops or non-swiveling adapters that have equivalent or higher strength.

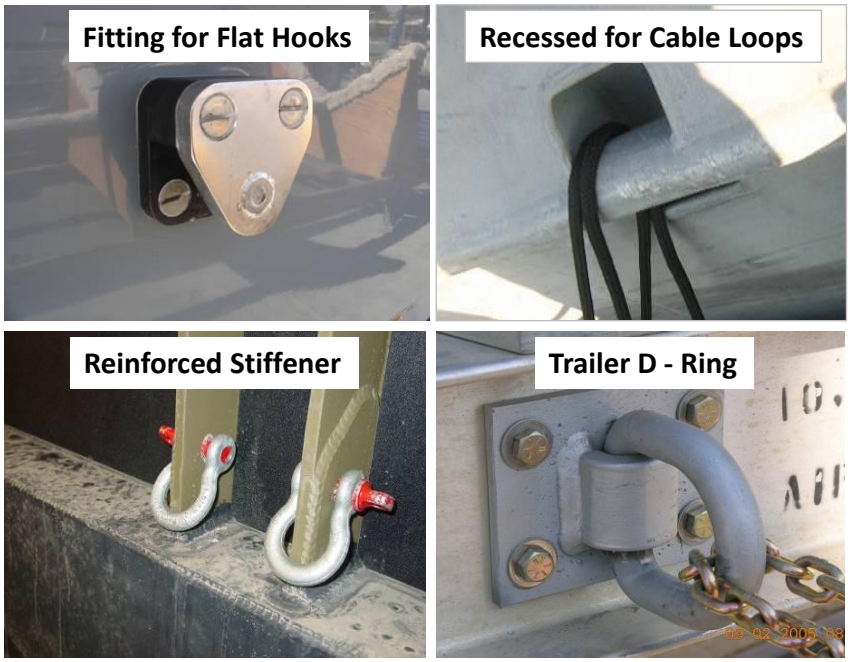


Figure 18. Examples of Different Tie-down Fittings

Tie-down Strap Selection

Craft trailers (and cradles when required) should be delivered with all the tie-down straps necessary for over-the-road transport. All tie-down straps should have the same rated strength and be supplied with closed-end hardware compatible for use with the craft and trailer. For example, all straps are 3,000 lb. working load limit (WLL) straps with one end that fits the craft tie-down fitting and the other end that fits the trailer's tie-down fitting.

Some of the tie-down straps may lie against the hull (chine or gunwale) when the craft is properly secured. Per 49CFR393.104, wherever a tie-down strap is subject to abrasion or cutting, it should be provided with edge protection capable of resisting abrasion, cutting, and crushing. This protection may be as simple as a piece of fire hose that fits over the webbing. Whenever this is necessary, it is preferable that chafe protection be provided on all straps with a common area of coverage so that any strap may be used at any position in the tie-down arrangement.

TIP: Good design practice is for all tie-down straps to have the same working load limit that exceeds the highest design load for each applicable transport mode. Using tie-down straps that comply with Web Sling and Tie Down Association (WSTDA) T-1 Standards is a recommended practice.

Maritime and air transport tie-down straps and chains are typically provided by the ship or aircraft. For these modes, the builder is typically only responsible for providing transition elements such as loops or non-swiveling adapters, when they are necessary.

Restraint System Testing

Testing requirements for tie-down fittings are described in the next section. If the tie-down fittings and straps will be used to lift the craft with the trailer, they should be tested as described in reference 1.

System Verification

All design data required for transport certification is typically verified by the TPOC through physical validation measurements and testing after construction of the craft and trailer are complete. Incomplete or incorrect information in the builder's technical data package could result in certification delay or non-approval for maritime or air transport. The TPOC and the builder must therefore work collaboratively to ensure data packages are complete and accurate before the TPOC recommends acceptance and submits certification requests to approval authorities.

Physical Validation

Packaging for Transport.

Inspection of the fit-up between the craft and trailer is conducted when the craft is delivered for its pre-delivery inspection and trials (PDITs). This inspection verifies for all required modes of transport that the longitudinal center of gravity location on the trailer is acceptable through measurement of the axle and tongue loads. The inspection checks for interferences between the trailer and the hull, and verifies compliance with federal safety regulations. Tie-down arrangements and analyses are validated, and checks are conducted to ensure that adequate stowage and restraint of any displaced, removed, or loose equipment is considered and documented.

Dimensions.

Over-the-road, maritime, and internal air transport dimensions should all be measured and verified for compliance to the required design constraints. Due to the potential inaccuracy of field measurements (typically performed using only a measuring tape and approximating the locations for measurement), this verification should be performed for each packaging configuration using the most accurate means possible, including projecting extremities to the ground where measurements are difficult to perform. When internal air transport is required, the US Air Force's data sheet (provided by the TPOC) requires confirmation measurements as a deliverable in the technical data package. An example of this data sheet is presented in Appendix D.

Testing

Weight.

The craft and the trailer should be weighed by scale to confirm that the combination (1) does not exceed the GVWR of the trailer, (2) does not exceed the tow capacity of the prime mover, and (3) meets the applicable weight restrictions. It also can verify the location of the longitudinal center of gravity. This test is typically performed with the delivery of the first trailer and craft of each contract. The most accurate means of measuring the weight of the craft and the trailer is through lifting with a calibrated load cell. Certified roadside truck scales are acceptable, but they are typically less accurate than load cells. Individual wheel scales are the least accurate and are not a desirable means to certify the initial weight and center of gravity of the craft and trailer.

Tie-down Fitting Pull Test.

Pull testing of all fittings (with design load safety factors) is typically required by the terms of the solicitation or contract. When testing details are not specified, pull testing should be accomplished as prescribed in the applicable section of MIL-STD-209. If more than one section is applicable (e.g. hoisting and tie-down), the fitting must be tested such that it satisfies both sets of criteria.

Testing boat and trailer tie-down fittings not intended for hoisting the trailer beneath the craft should be accomplished in three orthogonal directions (i.e. fwd/aft, up/down, and port/starboard) for each fitting. Where this is not possible, the preferred alternative is to anchor the tie-down and pull each fitting to the maximum applicable load (calculated using Table 9 values) at the intended angle. Sometimes, the direction of the required pull test cannot be achieved. In this case the test load (P_{Test}) should be increased above the required load (P_{Req}) and pulled in a direction that can be achieved in the physical test. Figure 19 shows the force vectors and the equation used to calculate the test load (P_{Test}). In the figure, x and y represent the distances between the fitting and the point of load application (e.g., the anchor point at the other end of a chain).

$$P_{Test} = \frac{P_{Req}}{\cos\left(\tan^{-1}\left(x/y\right)\right)}$$

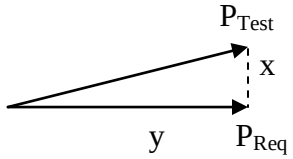


Figure 19. Calculation of Applied Test Load for Out-of-Plane Loading

Testing of craft and trailer tie-down fittings used for hoisting the trailer beneath the craft is addressed in reference 1.

Road Testing.

All new trailer designs should be fully tested at their gross vehicle weight rating prior to delivery in accordance with the applicable federal regulations, including all component and performance testing required by the Federal Motor Vehicle Safety Standards (FMVSS, reference

2). For a commercially-available trailer, where the same model trailer has already been tested, documentation verifying compliance should be provided at PDIT.

Where certain tactical vehicles (e.g. MTVR, HMMWV, MRAP, etc) are being used as the prime mover, the program office responsible for that vehicle may require testing to be performed before issuing certification to transport the craft. This testing varies based on the vehicle program, but likely includes tests such as static stability/rollover testing, parking brake and stopping distance tests, a dynamic stability (lane changing) evaluation, and a mission profile endurance test over the appropriate terrain types.

Maritime Testing.

The majority of testing requirements for maritime transport are satisfied through over-the-road transport testing (described above) and hoist fitting tests (reference 1). Where testing is required for certification on Navy ships, such as launch and recovery from a well deck or from an LCAC, the TPOC will typically ensure all technical information or contractor support is included in the terms of the contract or solicitation, and will coordinate post-delivery test schedules with the ship and end-users.

Aircraft Validation and Load Testing.

For internal air transport, most certifications are completed through design reviews and analyses of the builder's technical data and validation measurements. Typically, after review and concurrence, the TPOC submits a certification request to US Air Force's Air Transportability Test Loading Agency (ATTLA) for approval and certification. If ATTLA can positively determine that the craft can be safely stowed and airlifted, no further testing is required, and a certification letter is issued for the specific craft and trailer combination.

ATTLA may determine that testing is required to verify safe air transportability. There are two types of air transport certification tests that depend upon the degree of risk. They are referred to as either a validation load or a test load.

A validation load is performed when it is likely, but not positively certain, that the craft can be loaded without issue. Once the craft is loaded and restraint is verified, the loadmaster on site can immediately approve it for flight. The loadmaster is then responsible to provide any modifications to the Air Force's load plan for finalization of the documentation for later flights.

A test load is performed when documentation review and analysis cannot positively determine that the craft and trailer (or cradle) can be safely loaded and airlifted. This test is performed prior to any air transport, and the lessons learned are used to revise the certification documentation, typically with special loading instructions.

Documentation and Labeling

Documentation

Technical data packages required for transportability approvals and certifications typically include the following items.

- Transportability Report in accordance with Data Information Package (DI-PACK) 80880 to support certification (required by MIL-STD-1366)
- Photos of the craft on its trailer in all unique transport configurations (recommended to be included in Transportability Report/DI-PACK)
- Instructions for packaging craft and trailer for transport in each mode (should reflect sectionalization discussion in Transportability Report/DI-PACK)
- Craft and trailer manuals, including technical specifications, gross dimensions, and weights
- Tie-down arrangements and restraint analyses for all transport modes (including arrangements for each aircraft, as applicable)
- Identify load capacities and locations for all unique types of trailer and craft tie-down fittings
- Tie-down fitting pull test documentation
- Sketch illustrating ability to negotiate the crest of a 15-degree ramp, using the hitch height and distance from the rear axle for the assumed prime mover.
- Completed USAF Air Transport Data Sheet for craft and trailer in air transport configuration (as applicable)
- Three-view drawing showing dimensions identified in USAF Air Transport Data Sheet (as applicable)
- Load plan for each aircraft (as applicable)
- Axle, Wheel, and Tire slow speed/“creep” load capacities for aircraft load plan (as applicable)

Equipment Labeling

The following labels may be required on the craft or trailer for the different transportation modes.

- Shipping Data Plate, required by MIL-STD-209
- Packaging instructions, if any, for over-the-road transport permanently mounted on the craft, trailer, or both vehicles.
- Over-the-road trailer tie-down arrangement plate, mounted on the trailer.
- Trailer Capacity, Vehicle Identification Number, etc, as required by the CFR
- Trailer operating and safety instructions for over-the-road transport
- Marking of trailer tie-down fittings to specifications in MIL-STD-209
- Tags sewn onto tie-down straps, identifying their safe working load

Symbols, Abbreviations, and Acronyms

ATTLA ..... Air Transportability Test Loading Activity
CCD ..... Combatant Craft Division
CFR ..... Code of Federal Regulations
CONUS ..... Continental United States
DI-PACK ..... Data Information Package
EMP ..... Enhanced Mobility Package
FMVSS ..... Federal Motor Vehicle Safety Standards
GCW ..... gross combined weight
GVW ..... gross vehicle weight
GVWR ..... gross vehicle weight rating
HMMWV ..... High Mobility Multi Wheeled Vehicle
IAT ..... internal air transport
lb / lbs ..... pound / pounds
LCAC ..... Landing Craft Air Cushion
LSSV ..... Light Service Support Vehicle
MTVR ..... Medium Tactical Vehicle – Replacement
MIL-HDBK ..... Military Handbook
MIL-STD ..... Military Standard
MRAP ..... Mine Resistant Ambush Protected
NATO ..... North Atlantic Treaty Organization
NAVAIR ..... Naval Air Systems Command
NSTM ..... Naval Ships Technical Manual
NSWCCD ..... Naval Surface Warfare Center, Carderock Division
OTR ..... over-the-road
PDIT ..... pre-delivery inspection and trial
PEO ..... Program Executive Office
PEO Ships, PMS 325G ..... US Navy Small Boats Program Office
RIB ..... rigid inflatable boat

Symbols, Abbreviations, and Acronyms

RO/RO ..... Roll-on/Roll-off
SEAOPS.....Safe Engineering and Operations
SLCP ..... Ship's Loading Characteristics Pamphlet
TPOC ..... technical point of contact
UDL .....uniform distributed load
USAF .....United States Air Force
USN..... United States Navy
WLL.....working load limit

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Appendix A: Transportability Design and Certification Process Summary

- Define Applicable Transport Modes
  - Over-the-Road Transport (Assumed for nearly all craft)
  - Maritime Transport
    - Movement as deck cargo and hoisting trailer and craft together is assumed for all road transportable craft
    - Use in Well Deck may require testing/validation
  - Internal Air Transport
    - Define applicable aircraft (C-130, C-17, C-5)
    - USAF ATTLA Certification required
  - Special Modes (Rail, External Air Transport, Low velocity Air Drip, etc)
- Establish Weight
  - Define Craft Weight Conditions
    - Over-the-Road (OTR) transport
      - ❖ Includes the completed craft weight, full fuel and operating fluids
      - ❖ Deducts water in jets, strainers, etc (free flood volumes)
      - ❖ Maximum combat load-out including mission equipment (fittings, weapons, ammo, etc) and personnel at 285 lb each
      - ❖ Deduct personnel (at 220 lbs each) for personnel gear weight
      - ❖ 5-10% margin
    - Maritime transport
      - ❖ Includes the completed craft weight, full fuel and operating fluids
      - ❖ Deducts water in jets, strainers, etc (free flood volumes)
      - ❖ Mission equipment and personnel gear identified by TPOC (typically may include weapons and ammo)
      - ❖ 10% margin (for hoisting)
    - Air
      - ❖ Includes completed craft weight and 5% fuel
      - ❖ Deducts water in jets, strainers, etc (free flood volumes)
      - ❖ Additional cargo weight identified by TPOC (typically may include equivalent weight of additional fuel)
      - ❖ For air transport, the weights of the craft and trailer should each be rounded up to the nearest 1000, pounds, minimum, unless otherwise directed by the TPOC.
  - Define Trailer Weight
    - Full operation fluids (hydraulics, as applicable)
    - Tools/Stowages

- Over-the-road tie-down straps
- Miscellaneous material required for OTR transport (e.g. boat covers, etc)
- 5-10% margin (10%, minimum for hoisting in maritime transport)
- Trailer gross vehicle weight rating (GVWR) should be no less than the combined weight (including margins) of the craft and trailer for road transport
- Due to discrete increments of trailer component ratings (i.e. axles and brakes), assumed margin may be adjusted to achieve a reasonable end time. The target GVWR of the trailer should be approximately 105%-110% of the gross vehicle weight at delivery (without craft and trailer margins).

  - Define Dimensions for craft on trailers
    - Over-the-Road
      - ❖ Unrestricted transport on CONUS highways should be pursued
      - ❖ When unrestricted transport is not possible, "minimal restrictions" (trailered width ≤ 10 feet) is preferred
    - Maritime Transport
      - ❖ May limit craft and trailer combination's geometry due to deck height restrictions
      - ❖ Requires ability to crest the ramp between decks.
    - Internal Air Transport
      - ❖ Dimensions of a craft and trailer are restricted by the cargo compartment cross-section and projections during loading
      - ❖ Guidance in MIL-STD-1366 and MIL-HDBK-1791

- Over-the-Road Transport Specific Requirements
  - Define Operational Area
    - Define Terrain Types (Primary Roads, Secondary Roads, Trails, Cross-Country) to negotiate
    - Define Launch and Recovery Site
      - ❖ Ramp (Primary/Secondary Road terrain type) assumed for all road transportable craft
      - ❖ Hoisting directly into the water assumed for all craft
      - ❖ Consider launching over an embankment
      - ❖ For ramp launching and launching over an embankment, accessibility, approach slope (and potential need for additional braking), terrain type and water depth are factors to be taken into consideration
  - Establish Prime Mover Interface
    - Identify planned prime mover
      - ❖ Establish parameters for gross vehicle weight ratings, critical dimensions for trailer hitch types, hitch height ranges, cresting angles and approach angles
      - ❖ Establish electrical interface
        - 7-pin (flat terminal) connector for 12-volt direct current connections

        - 12-pin connector for 24-volt direct current connections (NATO Plug)
        - Standard NSN trailer lighting if it is on the prime mover
        - NATO Slave plug on craft if prime mover has 24-volt electrical system
      - ❖ Establish Service Air Interface
        - Glad-hands (with or without associated hoses) to suit a prime mover that is equipped to provide service air
  - Trailers and Cradles
    - Combined (craft and trailer) CG location
      - ❖ ~10% of the gross vehicle weight (GVW) on the tongue for hitched trailer
      - ❖ 20-30% for the GVW on the kingpin for a fifth wheel trailer.
    - Construction
      - ❖ Always heavy-duty construction using corrosion-resistant materials and components.
    - Craft Interface
      - ❖ Trailer bunks and rollers
        - Located at craft transverse bulkheads, longitudinals (especially in way of engine foundations), and frames
        - Not located in way of spray/lifting strakes or hull appendages (e.g. raw water suction, waterjet grates, depth sounder, etc)
      - ❖ Sized for adequate load distribution when craft subjected to all applicable vertical accelerations (road, sea, air)
      - ❖ Self-centering bow stop
      - ❖ Winch and supporting structure should be designed to the same load as the bow eye with a minimum safety factor of 1.5 on ultimate strength
    - Regulatory Compliance
      - ❖ Adhere to applicable Department of transportation regulations, particularly 49CFR393 and 49CFR571
      - ❖ Military equipment exemptions should be avoided since the craft will likely be towed using a commercial vehicle during its life-cycle.
- Maritime Transport Specific Requirements
  - Deck Cargo as assumed capability
    - Accessible lifting and tie-down fittings
    - Minimum 15-degree cresting angle (may be greater to access more ramps/decks)
  - Well Deck Operation
    - Additional technical data and testing required for certification (defined by TPOC)
    - Launching from the well deck with trailer
      - ❖ Additional tie-down fittings may be needed
      - ❖ Additional length restrictions may apply
    - Launching from the well deck without trailer
      - ❖ Reinforced keel to carry the craft's weight
      - ❖ Additional equipment (e.g. cradle, bracing, "kickstand") to prevent the craft from tipping over while the well deck is drained

- Movement with Cranes and Davits as assumed capability
  - Lift the craft and trailer together using the craft's hoist fittings
    - ❖ Craft and trailer tie-down fittings and straps designed for higher loads and safety factors than for OTR transport.
    - ❖ Pull testing tie-down fittings
  - Ship's Boats / Davit Lift considerations
    - ❖ Dimensions, weight, and center of gravity restricted by the ship's davit or crane, and well-defined in the terms of the solicitation or contract
- Establish Ship-Specific Requirements (e.g., Littoral Combat Ship or LCAC)

- Internal Air Transport Specific Requirements
  - Load Plan Development
    - Identify the dimensional constraints while loading craft into aircraft cargo compartment
    - At a minimum identify the clearance at three critical points: approaching the ramp, cresting the ramp hinge, and rear overhang projection
    - Assume craft is loaded into the aircraft using the intended prime mover unless specified by the TPOC
    - The use of shoring or loading with other material handling equipment may be required.
    - Air Force down-rates the gross vehicle weight rating and the strength rating of all commercial axles by 20%, which requires nearly all trailers to need sleeper shoring for air transport.
  - Slow Speed and Static Load Capacity
    - Creep ratings should always be provided for the trailer's tires, wheels and any other components with load capacities regularly report for highway speeds and needed for the data package that is provided to the Air Force for technical review of the aircraft floor loads.

- Transport Packaging Design
  - More than one packaging configuration may be required for all the different transportation modes
  - Avoid the need for special tools when considering to package the craft and trailer for transport and try to minimize the number of different tools and sizes
  - Consider the stowage and restraint of lose or removed gear for transport

- Restraint System Design
  - Determine Required Loads
    - Total restraint loads should be calculated for all applicable transport modes
    - Air transport loads will be highest and govern the sizing of the tie-down fittings
    - For OTR, tie-down arrangement secure the craft to the trailer
    - With a shipping cradle, the restraint of the craft to the cradle (at the craft's weight) as well as the cradle to an assumed flat-bed trailer (at the combined weight) is appropriate. (Include reasonable margin since flat-bed trailers used for movement may vary.)

        - Maritime and internal air transport restraint may be accomplished in either of two ways:
            - ❖ Restraint of the craft to the trailer at the craft's weight, and restraint of the trailer to the aircraft at the combined (craft and trailer weight)
            - ❖ Restraint of the craft to the aircraft at the craft's weight and restraint of the trailer to the aircraft at the trailer weight
    - Tie-down Arrangement and Analysis
        - Required for each aircraft for air transport certification
        - Road Transport is the only transportation mode where the winch cable may be included as a restraint
            - ❖ Winch cable rated strength should be provided with trailer documentation. If unknown use 49CFR393.108 for nominal strength
        - Maritime transport restraint analysis should demonstrate sufficient capacity in tie-down fittings and sufficient strength in the craft and trailer to accommodate the loads, see MIL-STD-209
        - Internal Air Transport Tie-down Arrangement and Analysis Details
            - ❖ All tie-downs connecting the craft or trailer to the air deck are assumed to be ether MB-1 (10,000 lbs) or MB-2 (25,000 lbs) chains.
            - ❖ Tie-down straps (CGU1/B, 5,000 lbs) are part of the USAF inventory, but are intended for light weight cargo loads and should not be used in IAT tie-down arrangements.
            - ❖ Guidance in MIL-HDBK-1791
    - Tie-down Fitting Design
        - Should be designed to parameters in MIL-STD-209
        - Safe working load limits of the tie-down fittings on the craft and trailer must be designed to meet or exceed the highest load to which the provision will be subjected (road, maritime, hoisting trailer, or air)
        - Should be a common type and strength to avoid confusion in their use
    - Tie-down Strap Selection
        - All tie-down straps should have the same rated strength and be supplied with closed-end hardware on the ends compatible for use with the craft and trailer
        - Chafe protection when needed should satisfy 49CRF393.104
- System Verification
    - Physical Validation
        - Inspection of the fit-up between the craft and trailer is conducted when the craft is delivered and is recommended for pre-delivery inspection and trials (PDITs)
        - Inspections verify an acceptable LCG, no interferences between the trailer and hull, and compliance to federal safety regulations
        - Verify packaging instructions, validate tie-down arrangements and analysis, ensure adequate stowage and restraint of any displaced, removed, or loose equipment is considered and documented

- OTR, maritime, and internal air transport dimensions should all be measured and verified for compliance to the required design constraints in each packaging configuration

  - Testing
    - Weighing both the craft and trailer by scale should be performed to confirm the combination does not exceed the GVWR of the trailer or tow capacity of the prime mover, meets the applicable weight restrictions, and verify the LCG
    - Restraint System Testing
      - ❖ Every fitting must be pull tested where required
      - ❖ Testing Guidance in MIL-STD-209
      - ❖ If testing cannot be accomplished in the required direction, the applied test load must be increased and applied at an angle that achieves the required load in the required direction
    - New trailers should be fully road-tested at their gross vehicle weight rating prior to delivery
    - Maritime Testing
      - ❖ Majority of testing is done as part of the hoist fitting and tie-down fitting testing for the craft the trailer
      - ❖ May require compatibility demonstrations for well deck operations
    - Aircraft Validation and Load Testing
      - ❖ Most certifications for internal air transport are completed by design reviews and analyses
      - ❖ Technical information reviewed by CCD and submitted to ATTLA
      - ❖ ATTLA may require validation load demonstration or test load

- Documentation and Labeling
  - Documentation
    - ❖ Transportability Report in accordance with Date Information Package (DI-PACK) 80880 to support certification (required by MIL STD 1366)
    - ❖ Pictures of craft on trailer in all unique transport configurations
    - ❖ Instructions for packaging craft and trailer for transport in each mode
    - ❖ Craft and trailer manuals, including technical specifications, gross dimensions and weights
    - ❖ Tie-down arrangements and restraint analysis for all transport modes (including arrangements for each aircraft, as applicable)
    - ❖ Identify load capacities and locations for all unique types of trailer and craft tie-down fittings
    - ❖ Tie-down fitting pull test documentation
    - ❖ Sketch illustrating ability to negotiate the crest of a 15-degree ramp, using the hitch height and distance from the rear axle for the assumed prime mover
    - ❖ Completed USAF Air Transport Data Sheet for craft and trailer in air transport configuration (as applicable)
    - ❖ Three-view drawing showing dimensions identified in USAF Air Transport Data Sheet (as applicable)
    - ❖ Load plan for each aircraft (as applicable)

- ❖ Axle, Wheel, and Tire slow speed/"creep" load capacities for aircraft load plan (as applicable)

- Equipment Labeling
  - ❖ Shipping Data Plate required by MIL STD 209
  - ❖ Packaging instructions, if any, for over-the-road transport permanently mounted on the craft, trailer, or both vehicles
  - ❖ Over-the-road trailer tie-down arrangement plate, mounted on the trailer.
  - ❖ Trailer Capacity, Vehicle Identification Number, etc, as required by the CFR
  - ❖ Marking of trailer tie-down fittings to specification in MIL STD 209
  - ❖ Tags sewn onto tie-down straps, identifying their safe working load

Appendix B: Design Parameters Matrix

Design Process Considerations Summary

		Maritime		Internal Air Transport		
Requirement	Over-the-Road	Naval	Hoisting (Trailer and Craft Together)	C-130	C-17	C-5
15-Degree Ramp Cresting Verification		X				
Aircraft validation/load testing				X	X	X
Craft to trailer fit-up testing	X					
Combined (craft and trailer) LCG and axle load verification	X	X		X	X	X
Coverage of bunks/rollers on trailer	X	X		X	X	X
Documentation	X	X	X	X	X	X
Federal Bridge Formula Verification	X					
Labeling	X	X	X	X	X	X
Length Restriction	X[9]			X	X	X
Lifting fitting designed for combined weight			X			
Load Plan				X	X	X
Height Restriction	X	X		X	X	X
MIL-STD-209 Tie-down Calculation		X				
MIL-STD-209 Lifting Calculation			X			
Packaging validation	X	X	X	X	X	X
Prime Mover Electrical Supply	X					
Prime Mover Service Air connections	X					
Prime Mover Tow Capacity	X					
Prime Mover Tongue Weight	X					
Restraint Analysis	X		X	X	X	X
Restraint Load Determination	X	X	X	X	X	X
Road testing (new trailer designs)	X					
Safety Aisle Check				X		
Scale weighing (craft and trailer)	X		X	X	X	X

[9] Applicable only to semitrailers and combination semitrailer-trailer configurations.

		Maritime		Internal Air Transport		
Requirement	Over-the-Road	Naval	Hoisting (Trailer and Craft Together)	C-130	C-17	C-5
Ship loading and launching testing		X				
Shoring Evaluation		X		X	X	X
Slow speed / creep ratings				X	X	X
Special Capabilities for Launch and Recovery Site	X					
Special Capabilities for Terrain Type	X					
Tactical vehicle considerations (blackout lights, slave receptacle, etc)	X					
Tie-down Arrangement	X		X	X	X	X
Tie-down fitting design	X	X	X	X	X	X
Tie-down fitting pull testing			X	X	X	X
Tie-down strap selection	X		X			
Trailer bow stop	X					
Trailer or Shipping cradle	X	X	X	X	X	X
Transport Packaging design	X	X	X	X	X	X
Weight Restriction	X			X	X	X
Width Restriction	X	X		X	X	X
Well deck operations – launch method		X				

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Appendix C: Trailer Guidance

This appendix is provided as a guide for the TPOC in developing trailer specifications, craft contract requirements, and specialized government test plans for certification of rough terrain trailers.

Trailer Specifications

Trailers are primarily used for road transport, but are also affected by maritime and air transport requirements. For most applications, the following items should be included in the delivery of all trailers, unless they are excluded from the contract terms by the end user or the acquisition authority.

- GVWR not less than defined GVW or available prime mover tow capacity
- Heavy-duty construction of aluminum or hot-dipped galvanized steel
- Light Truck (LT) series tires, as a minimum
- Actuation components capable of total submersion in salt water for short periods of time
- Brakes (surge, air-over-hydraulic, or full air brakes) on each axle using all stainless steel disc brake components (stainless steel rotors, stainless steel brake caliper assembly with stainless steel cylinder and guide pins). *Note: No electric brakes*
- Stainless steel brake lines with smooth, regular bends (2" min. radius). Flex hoses, where necessary, should be stainless steel braided or Kevlar, and have a minimum rating of 3000 psi.
- If surge brakes are used, the master cylinder should have a provision for locking out when backing, and the master cylinder should be powder coated for corrosion protection.
- For ease of maintenance and repair locate air or air-over-hydraulic isolation valves at each brake.
- Brake lines and cable runs should be protected from impacts and chaffing.
- Matching and mounted spare tire and wheel
- On-trailer stowage for tools and tie-down straps
- Winch with cable and closed end hook. Entire system designed to the same load as the bow eye with a minimum system safety factor of 1.5
- Heavy duty jack stand (foot)
- Interchangeable hitch with lunette ring and ball receiver (both provided when consistent with trailer GVWR)
- Fenders with sufficient strength to serve as a step, or provide other stepping points (or ladder) up to the boat.
- Bunks sized to support craft under accelerations for applicable transport modes.
- Service air connections (if necessary for brake operation)
- Electrical system equipped for 12 Vdc (with commercial 7-pin round plug w/flat connectors) and 24 Vdc (with 12-pin NATO plug)
- Electrical system components to be marine-grade using ring terminals sealed with heat shrink at all connections.
- Lighting to be submersible 12v and 24v LED lights (Use standard NSN numbers).

- ASTM A 276, type 316L stainless steel fasteners, flat washers, and Nyloc nuts throughout (No threading of Aluminum).
- Aluminum or 316 stainless steel components used where possible (e.g. fenders, brackets, etc), hot-dipped galvanized steel elsewhere (e.g. axles).
- Avoid plastic tie wraps when securing brake lines or wiring to the trailer.
- Suspension type (e.g. leaf spring, torsion axle, or air with trailing arm) and strength consistent with trailer GVWR
- Each individual axle should be rated to carry at slow speeds the entire weight of the vessel and trailer in max load transport condition.
- Hubs rated at highway speeds for a minimum of 50% of the axle rating.
- Positive pressure hub system to prevent contamination of hub lubrication.
- Loaded trailer dimensions within acceptable limits for all applicable transport modes
- Axle, wheel, and tire creep load capacities provided with trailer technical information.
- Tie-down provision rated capacities to suit hoisting and tie-down requirements
- Tie-down fittings labeled per MIL-STD-209
- Stowage box(es) with watertight lids and bungee tie-downs (stowage sized to hold all OTR straps), and provide a lockable tool box with a suitable hydraulic jack and a breaker bar.
- Provide a safety cable from the craft to the trailer, in addition to the bow winch cable.

If service and emergency air are required to operate the trailer (e.g. equipped with air-over-hydraulic or full air brakes), the technical point of contact should confirm that the intended prime mover is equipped to supply air, and whether or not it has dead-ended glad hands or hoses similar to a commercial tractor. If the prime mover does not have service air supply hoses, then a requirement for the trailer to include connecting hoses and glad hands should be included in the contract or solicitation.

General Overload Limits for Truck and Bus Tires (Ref 4)

1. For Metric and Wide Base Tires

Original Table Based On 65 mph Maximum Speed Limits

The service load and minimum cold inflation must comply with the following limitations unless a speed restriction is indicated on the tire or the manufacturer rates the tire at 75 mph or above.

SPEED RANGE (MPH)	RADIAL PLY TIRES		DIAGONAL (BIAS) TIRES	
	% LOAD CHANGE	INFL. PRESSURE CHANGE	% LOAD CHANGE	INFL. PRESSURE CHANGE
71 thru 75	-12%	+5psi	-12%	+10psi
66 thru 70	-4%	+5psi	-4%	+10psi
51 thru 65	None	No Increase	None	No Increase
41 thru 50	+7%	No Increase	+7%	No Increase
31 thru 40	+9%	No Increase	+9%	No Increase
21 thru 30	+12%	+10psi	+12%	No Increase
11 thru 20	+17%	+15psi	+17%	No Increase
6 thru 10	+25%	+20psi	+25%	No Increase
2.6 thru 5	+45%	+20psi	+45%	No Increase
Creep thru 2.5	+55%	+20psi	+55%	No Increase
Creep [2]	+75%	+30psi	+75%	+10psi
Stationary	+105%	+30psi	+105%	+10psi

2. For Conventional Tires

Original Table Based On 65 mph Maximum Speed Limits

The service load and minimum cold inflation must comply with the following limitations unless a speed restriction is indicated on the tire or the manufacturer rates the tire at 75 mph or above.

SPEED RANGE (MPH)	RADIAL PLY TIRES		DIAGONAL (BIAS) TIRES	
	% LOAD CHANGE	INFL. PRESSURE CHANGE	% LOAD CHANGE	INFL. PRESSURE CHANGE
71 thru 75	-12%	+5%	-12%	+10psi
66 thru 70	-4%	+5%	-4%	+10psi
51 thru 65	None	No Increase	None	No Increase
41 thru 50	+9%	No Increase	+9%	No Increase
31 thru 40	+16%	No Increase	+16%	No Increase
21 thru 30	+24%	+10psi	+24%	No Increase
11 thru 20	+32%	+15psi	+32%	No Increase
6 thru 10 [1]	+60%	+30psi	+60%	+10psi
2.6 thru 5 [1]	+85%	+30psi	+85%	+10psi
Creep thru 2.5 [1]	+115%	+30psi	+115%	+10psi
Creep [1][2]	+140%	+40psi	+160%	+20psi
Stationary [1]	+185%	+40psi	+210%	+20psi

1) Apply these increases to dual loads & inflation pressures.
2) Creep: Motion for not over 200 feet in a 30-minute period.

Note: The inflation pressures shown in the referenced tables are minimum cold pressures for the various loads listed. Higher pressures should be used as follows:

A. When required by the above speed/load table.
B. When higher pressures are desirable to obtain improved operating conditions.

For speeds above 20 mph, the combined increases of A and B should not exceed 10 psi above the inflation specified for the maximum of the tire.

THE MAXIMUM LOAD & INFLATION CAPACITY OF THE RIM MUST NOT BE EXCEEDED.

This information is also provided in the 2008 Tire and Rim Association Yearbook guidelines.

Rough Terrain Trailer Test Guidance

Standards applicable to road testing include the following: Society of Automotive Engineers (SAEs) J2180 and J2181, TOP 2-2-609, and NATO Allied Vehicle Testing Publication (AVTP) 03-160W, applicable portions of SAE J46 and Federal Motor Vehicle Safety Standard (FMVSS) 121. Specific tests of interest are: Static Rollover, Steering and Handling, Brake Performance, and Trailer Durability.

Static Rollover Test. A Static Rollover Stability Evaluation (Tilt Test) of the combined prime mover, craft, and trailer may be required using SAE J2180, Tilt Table Procedures as a guide. The following would be anticipated during this test to quantify static roll. Instrumentation should include data recorder with an "ident" to mark tilt initiation and completion of the tilt event, inclinometer to measure tilt table angle in degrees, inclinometer to measure axle angle in degrees, inclinometer to measure cargo bed angle in degrees. During tilting, sufficient observers should be positioned around the tilt table in order to monitor all testing activities and to record any points of interest, i.e. tire slip, shift, etc. During the tilt table evaluation, a tilt table safety plan will be followed. If any anomalies are observed which may cause damage to the vehicle or present a safety hazard, the tilt will be terminated and the table lowered.

Steering and Handling - (Dynamic Stability). The prime mover and trailer should be tested in several dynamic events to determine the limits of dynamic IAW TOP-2-2-800 for Weight and CG guidance, AVTP 03-160W for lane change maneuvers, SAE J2180 for lateral acceleration, and SAE J2181 for steady state cornering. Outriggers should be utilized in order to reduce the potential for damage to the trailer during efforts to establish operational speed limits for on highway use. Turning circle diameter test procedures are in TOP 2-2-609, Method 1. The obstacle avoidance and lane change maneuver should be performed at the trailer's CW and GVW.

Brake Performance Testing - (Stopping Distance). A stopping distance test will be conducted by performing three stops in each direction for a total of six stops of 20 to 0 mph, with a requirement of a stopping distance in 30 feet on a dry, hard, smooth-surfaced road as pass/fail criteria. A series of panic stops on hard surface and gravel roads from the recommended maximum speeds for those surfaces (nominally 55 MPH on hard surface and 25 MPH on gravel) will be conducted to evaluate stopping distances, capabilities, interaction between the prime mover brakes and the trailer brakes, and stability/controllability during the braking process. Due to the insufficient brake lockout capability of surge brake system, a backing test (on road and on sand) is recommended if surge brakes are present.

Trailer Durability Testing. A test will be conducted based on a modified MTVR mission profile of 30% pavement, 50% secondary roads, and 20% trails representing conditions found in the Marine Corps mission scenarios. This will allow a safety check of the vehicle structure and will help establish maximum recommended speeds for the trailer over various terrain types. It is assumed that this test will be conducted with the trailer equipped with full mission load. Accelerometers should be installed at the axles and the cargo bed to measure the energy transfer from the wheels to the trailer/cargo to quantify the dynamics.

500-MI TRAILER DURABILITY CYCLE

Test Course	Classification	Mi
BB, paved	Secondary/primary	60
BB&G		50
PTA 1	Secondary	290
PTA 2	Cross-country	50
PTA 3		50
Total	500	

BB = Belgian Block, BB&G = Belgian Block and Gravel, PTA = Perryman Test Area.

Primary Roads**.** There are three types of primary roads, high quality paved, secondary pavement, and rough pavement. All may consist of two or more lanes, all weather, maintained, hard surface (paved) roads with good driving visibility used for heavy and high density traffic. These roads have lanes with a minimum width of 108 inches, road crown to 2 degrees and the legal maximum GVW/GCW for the county and state is assured for all bridges. The wave number spectrum equation, percentages of total travel, and average travel speed for the three levels of pavement roughness are listed as follows:

Surface	Wave Number Spectrum	Percent of total Miles	Average Speed (mph/kph)
High Quality Paved Road	$G_{xx}(n)=1.4 \times 10^{-8} (n)^{-2.5}$	20%	55 / 89
Secondary Pavement (Two Lane Paved Road)	$G_{xx}(n)=1.9 \times 10^{-7} (n)^{-2.5}$	10%	50 / 80
Rough Pavement (Degraded Paved Road)	$G_{xx}(n)=8.0 \times 10^{-7} (n)^{-2.5}$	10%	45 / 72

High quality paved roads have surfaces having an average Root Mean Square (RMS) value of 0.1 inches.

Secondary pavement has an average RMS of 0.2 inches and can include significantly degraded concrete, macadam concrete or asphalt pavements (potholes, alligator cracking, freeze/thaw breakup).

Rough pavement consists of two lane roads with degraded shoulders, and marginal subgrades, which produce long wavelength swells and additional degradation of the surface. Rough pavements have an average RMS of 0.3 inches RMS.

Secondary Roads. There are three types of secondary roads: loose surface, loose surface with washboard and potholes, and Belgian block. These roads are one or more lanes, all weather, occasionally maintained, varying surface (e.g., large rock, crushed rock and gravel) intended for medium-weight, low-density traffic. These roads have no guarantee that the legal maximum GVW/GCW for the county and state is assured for all bridges. These roads are surfaces having a RMS value varying between 0.3 inches to 1.0 inch. The wave number

spectrum equation, percentages of total travel, and average travel speed for the three levels of pavement roughness are as follows:

Surface	Wave Number Spectrum	Percent of total Miles	Average Speed (mph/kph)
Loose Surface	$G_{xx}(n)=3.0 \times 10^{-5} (n)^{-2.0}$	20%	35 / 56
Loose Surface with Washboard and Potholes	$G_{xx}(n)=4.0 \times 10^{-6} (n)^{-2.4}$	15%	25 / 40
Belgian Block	$G_{xx}(n)=4.0 \times 10^{-1} (n)^{-1.4}$	10%	20 / 32

Loose surface with washboard roads have peak amplitude of 5.0 x 10-3 ft2/cycle/ft at 0.3 to 0.5 cycle ft (2 to 3-foot wavelengths). Loose surface roads with a high density of potholes have peak amplitude of 9.0 x 10-3 ft2/cycle/ft at 0.1 to 0.2 cycle/ft (5 to 10 foot wavelengths). Generally, washboard occurs in operational areas that are dry, whereas pothole gravel roads occur in wet operational areas.

Belgian Block secondary roads have peak amplitude of 8.0 x 10-2 ft2/cycle/ft at.083 cycle/ft (12 foot wavelengths) and these wavelengths are 180^{o} out-of-phase left to right, which produces a racking, input to the vehicle. The cobblestone blocks dominate the amplitude of the wavelengths at 1 cycle/ft.

Trails. One lane, unimproved, seldom maintained loose surface roads, intended for low density traffic. Trails have no defined road width and can include large obstacles (boulder, logs, and stumps) and no bridging. These are surfaces having a RMS value varying between 1.0 inches and 3.4 inches. The wave-number spectrum equation for the trail roughness is as follows:

Surface	Wave Number Spectrum	Percent of total Miles	Average Speed (mph/kph)
Trails	$G_{xx}(n)=4.6 \times 10^{-1} (n)^{-1.9}$	10%	20 / 32

Cross-Country Terrain. Vehicle operations over terrain not subject to repeated traffic. No roads, routes, well-worn trails, or man-made improvements exist. (This definition does not apply to vehicle test courses that are made to simulate cross-country terrain.) In addition, cross-country terrain can consist of tank trails with crushed rock or having large exposed obstacles (rocks, boulders, etc). These are surfaces having a RMS value varying between 1.5 inches and 4.8 inches. The wave-number spectrum equation for the cross-country roughness is as follows:

Surface	Wave Number Spectrum	Percent of total Miles	Average Speed (mph/kph)
Cross Country	$G_{xx}(n)=9.2 \times 10^{-1} (n)^{-2.1}$	5%	15 / 24

Appendix D: Design Example

The information in this example should not be interpreted as providing any preference for configuration, arrangement, or analysis method. All technical data for transportability should be technically accurate and comprehensive, and provided in the builder's format, such that it communicates the required information in a clear and straightforward manner.

Introduction

The calculations and sketches in this appendix are provided to illustrate the considerations necessary for a complete transport analysis.

This example has been abridged, and illustrates only one sample of each type of analysis that may be required. Additional analyses (e.g. for multiple aircraft or for multiple transport configurations) may be appropriate.

Craft Description	RIB, with specifications requiring unrestricted over-the-road transport, and internal air transport in a C-130.
Length:	27ft
Beam:	9.5ft (sponsons inflated) 8 ft-2 in sponsons deflated
Craft Height:	8 ft (Above Keel) 6 ft (console folded)
Craft Weight:	4200 lbs (Completed Craft) 9400 lbs (Full Load)
Trailer Weight:	2000 lbs
Prime Mover:	LSSV or similar
Height of keel on trailer:	2 ft.

For the purposes of this example, the "Completed Craft" weight is the weight used for maritime and air transport design calculations.

Technical Information for Over-the-Road Transport

Trailer Specifications
See *Trailer Specifications* Section

Trailered dimensions and weight

Page D-3 shows the evaluation of the Federal Bridge Weight Formula. This is rarely a concern except for very large or heavy craft, but is a prudent check to perform. In this example, the "axle loads" for the prime mover are actually the axle ratings. Wherever possible, actual measured axle loads for the prime mover should be used. Page D-4 shows the gross dimensions and estimated axle and tongue loads for over the road transport.

Tire and Rim Selection Check

The assumed tires for this example are: Michelin LTX A/T2 tires, LT215/85R16/E. The specification for these tires states a maximum load of 2680 lbs at an inflation pressure of 80psi (single wheel installation). Comparing this rating against the projected axle loads, these tires have acceptable load carrying capacity for the assumed dual axle trailer and loads.

Wheel strength (specifically referring to the rim the tire is mounted onto) generally requires rating information from the manufacturer and should be included with trailer specifications. For the purposes of this example, the trailer is assumed to be equipped with steel wheels, each of which has a higher load rating than the assumed tire.

Restraint analysis of the craft to the trailer

The restraint analysis on page D-5 reflects the over-the-road transport tie-down arrangement. All restraint criteria are satisfied, but a cursory review reveals that the lateral load restraint is the most difficult criteria to satisfy. This is typical for craft where there is not a great deal of lateral separation between the tie-down fittings.

Load capacities and locations for all unique craft and trailer tie-down fittings

The sketches note assumed load capacities of 10,000 pounds for the craft and 15,000 pounds for the trailer tie-downs.

Tie-Down Strap Selection

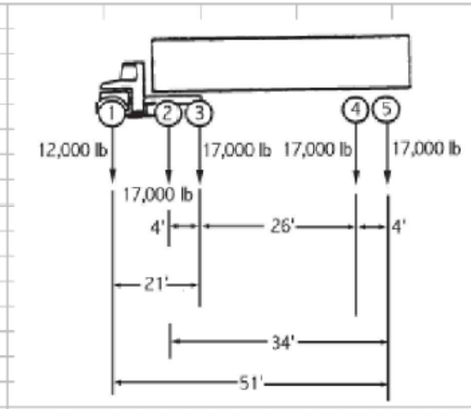
The tie-down straps and their working load limit assumed in this example are for illustrative purposes, showing the difficulty in meeting lateral restraint criteria for OTR transport. Tie-down straps should be selected to ensure that they meet the working load limits and safety factors for both OTR and hoisting the trailer beneath the craft.

Special Packaging Instructions for Road Transport

None

Weight at each axle	
Axle 1	4500
Axle 2	6084
Axle 3	5076
Axle 4	5076
Axle 5	0
Axle 6	0
GVW	20736

Distances between Axles **[inches]**	
Axle 1 to 2	167
Axle 2 to 3	295.25
Axle 3 to 4	40
Axle 4 to 5	
Axle 5 to 6	

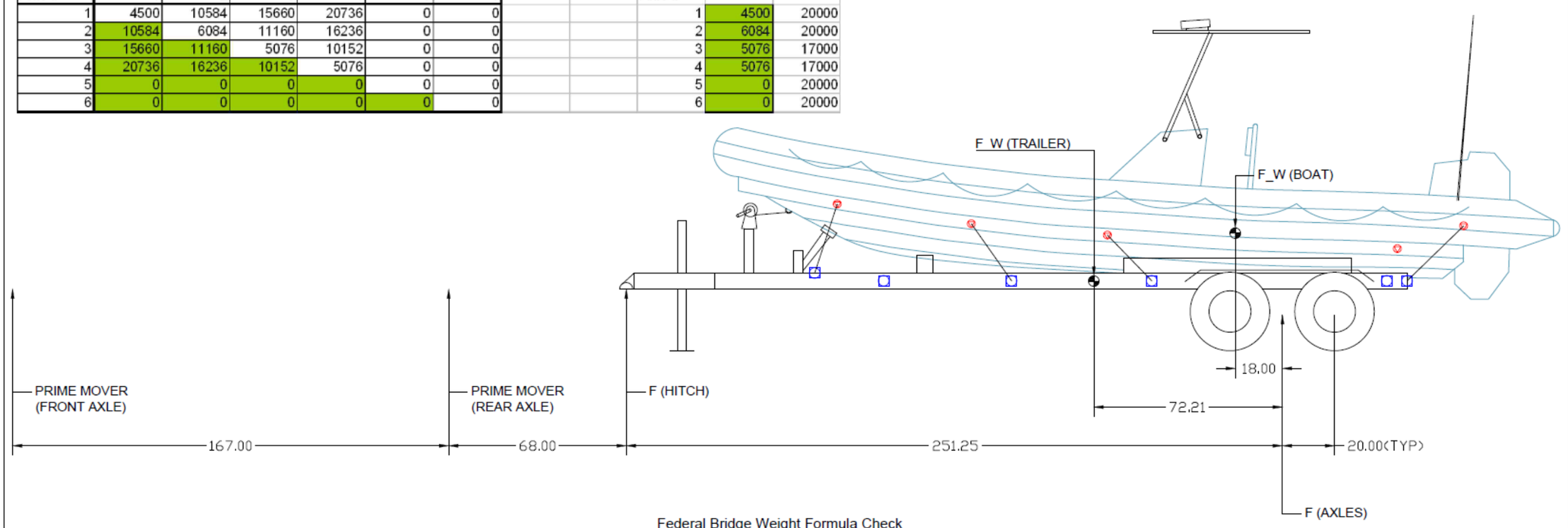


Example for Calculation from MIL-STD-1366E

Actual Loads between Axles

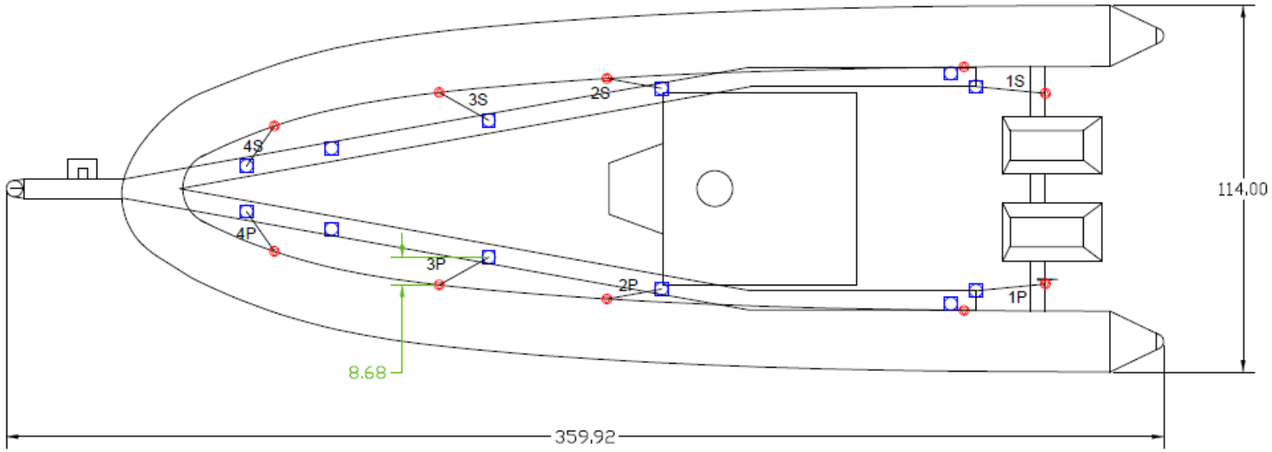
Axle #	1	2	3	4	5	6
1	4500	10584	15660	20736	0	0
2	10584	6084	11160	16236	0	0
3	15660	11160	5076	10152	0	0
4	20736	16236	10152	5076	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0

Axle Load	Actual	Maximum
Axle #		
1	4500	20000
2	6084	20000
3	5076	17000
4	5076	17000
5	0	20000
6	0	20000



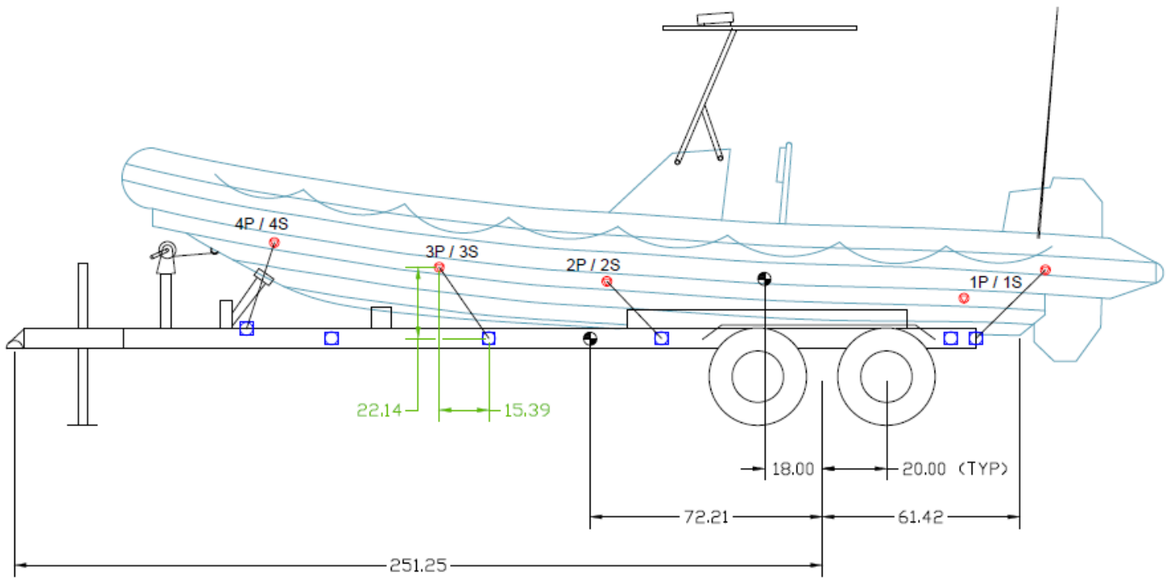
Federal Bridge Weight Formula Check

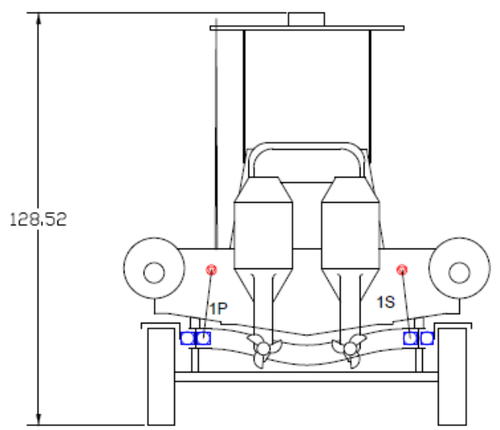
No preference for configuration, arrangement, or analysis method should be inferred from this example.



Craft Weight: 9400 lbs
Trailer Weight: 2000 lbs
Projected Axle Loads (each):
5075.88 lbs
Projected Tongue Load:
1248.24 lbs

Sample Tie-down dimensions shown in green





BOAT TIE-DOWN - 10,000 LBS

TRAILER TIE-DOWN - 15,000 LBS

Over-the-Road (OTR) Transport Configuration

No preference for configuration, arrangement, or analysis method should be inferred from this example.

TITLE: Transportability Guidance Example
PREPARED: M. Rugnetta

Drawing SAMPLE
DATE: 6-Oct-09

Craft on Trailer

CARGO WEIGHT 9,400 lb

Tie-Down Strap/Chain Rating (WLL) 3333 lb

	DIMENSION				Vector			AVAILABLE RESTRAINT (lb) FROM MOVING… **(TRAILER CENTERED FRAME OF REF.)**				
STRAP #	FORE/AFT EFFECTIVE LENGTH (D)	LATERAL EFFECTIVE LENGTH (E)	VERTICAL EFFECTIVE LENGTH (B)	TIEDOWN STRAP LENGTH (A)	X	Y	Z	FORWARD	AFT	LATERAL (PORT)	LATERAL (STBD)	VERTICAL
1S	21.66	2.08	21.31	30.5	-1.0	1.0	1.0		2370.4	227.6		2332.1
2S	18.98	3.07	17.73	26.2	1.0	-1.0	1.0	2418.8			391.2	2259.5
3S	15.39	8.68	22.14	28.3	1.0	-1.0	1.0	1810.9			1021.3	2605.1
4S	8.67	12.42	26.81	30.8	-1.0	-1.0	1.0		938.4		1344.3	2901.9
1P	21.66	2.08	31.31	38.1	-1.0	-1.0	1.0		1893.4		181.8	2736.9
2P	18.98	3.07	17.73	26.2	1.0	1.0	1.0	2418.8		391.2		2259.5
3P	15.39	8.68	22.14	28.3	1.0	1.0	1.0	1810.9		1021.3		2605.1
4P	8.67	12.42	26.81	30.8	-1.0	1.0	1.0		938.4	1344.3		2901.9
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
REQUIRED RESTRAINT (lb-f)								4,089	4,700	2,350	2,350	1,880
LOAD FACTOR								0.435	0.5	0.25	0.25	0.2
TOTAL RESTRAINT (lb-f) PROVIDED								**8,459**	**6,141**	**2,985**	**2,939**	**20,602**
Actual Load Factor Provided								0.90	0.65	0.32	0.31	2.19

Over the Road (OTR) Restraint Calculation Example

No preference for analysis method should be inferred from this example.

Technical Information for Maritime Transport

Since no maritime shipping requirement was specified, only hoisting the trailer beneath the craft and Sealift/commercial shipping is applicable.

Trailered dimensions and weight for maritime shipping

Page D-8 shows the craft and trailer packaged for Maritime transport. No width specification was provided, so the deflation/removal of the sponson is not required, but is illustrated here. The center of gravity was assumed constant in this example, but should be re-calculated for each unique packaging arrangement, as equipment removal and sectionalization may have a significant effect.

Sketch illustrating 15-degree crest

Page D-8 illustrates a 15 degree crest, centered between the rear axle of the prime mover and the center of the axles on the trailer. In this sketch, there appears to be clearance, but it is a small enough distance that it should be verified at fit-up, as the sketch does not accurately represent tire and axle compression, build tolerances, etc.

Restraint Analysis for hoisting trailer under craft.

The restraint analysis on page D-9 reflects the hoisting of the trailer weight under the craft using the OTR tie-down arrangement. The analysis shows that there is adequate restraint to meet the prescribed safety factor for a shore lift.

Restraint of Trailer and Craft Package to Maritime Shipping Loads

Pages D-10 through D-12 illustrate the calculation for restraint from MIL-STD-209 for the maritime shipping accelerations for Naval Shipping identified in this guidance document. Coefficients in the red circles are from Table 9.

Similar to one method of aircraft restraint, this analysis assumes that the craft is adequately restrained to the trailer, and only calculates the loads applied to the empty trailer D-Rings from the maritime shipping tie-down arrangement. The D-rings on the trailer are rated for a far greater load than this calculation predicts. However, a verification of the assumed restraint of the craft (Page D-13) indicates that there is not enough lateral restraint in the OTR tie-down arrangement for these accelerations. While there is adequate restraint capacity in the design, based on the rated strength of the tie-down fittings and predicted loads, the craft may have to be tied down separately from the trailer in order to ensure adequate restraint is applied under high lateral loads.

Testing of hoisting fittings (to combined craft and trailer weight)

Testing of hoisting fittings to the combined weight should be accomplished when fittings are tested.

Testing of tie-down fittings (to trailer hoisting loads) on both craft and trailer

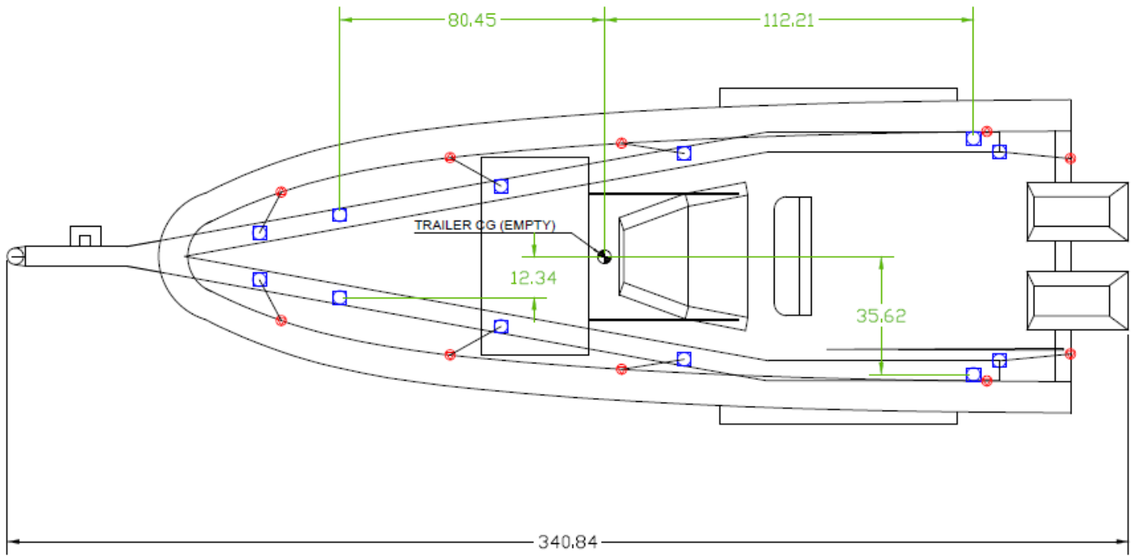
A sample test matrix illustrates the testing necessary for testing the tie-down fittings for hoisting the trailer under the craft. Actual target loads should be based on the limiting strength component involved (e.g. boat/trailer fittings, strap, etc.). The target duration shown reflects MIL-STD-209.

Provision	Target Load	Direction	Target Duration [s]	Actual Load	Actual Duration	Inspection
B1P	7700	In-Line	90	7800	120	SAT
T1P	7700	In-Line	90	7800	100	SAT
B2P	7700	In-Line	90	8500	150	SAT
T2P	7700	In-Line	90			

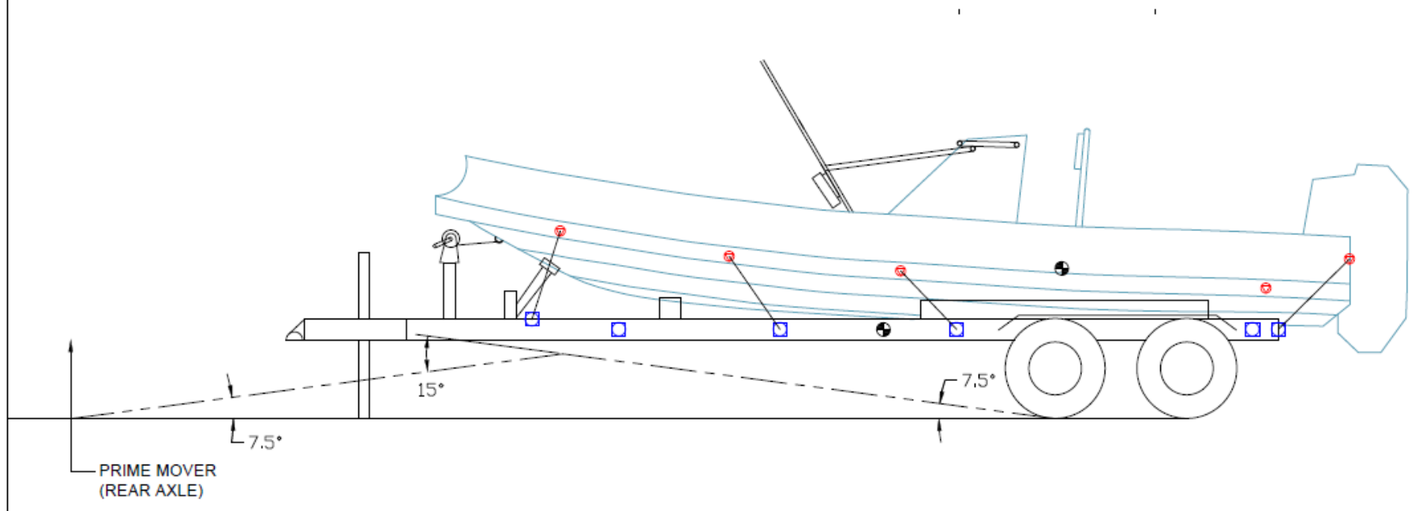
Special instructions to package craft for maritime transport

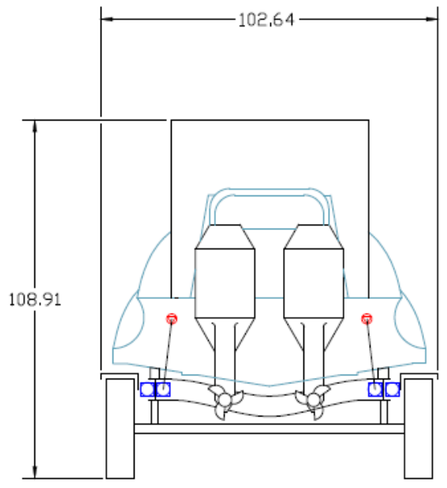
The following instructions are generalized to illustrate steps taken. Specific instructions should be provided for each craft so that an unfamiliar user (e.g. Air Force personnel unfamiliar with basic craft handling practices and terminology) could perform the intended tasks and properly prepare the craft and trailer for transport. Pictures to illustrate the instructions may also be helpful and are encouraged.

- Lower console top and tie-down to deck
- Lower VHF antenna
- Deflate air sponson (illustrated, may be optional in this example)
- Stow all loose cargo
- Tie-down removable mast to withstand maritime accelerations



Sample Maritime Restraint Dimensions shown in green.





Naval Shipping and Ramp Cresting Check

Sketch is for illustration purposes only. No preference for configuration, arrangement, or analysis method should be inferred from this example.

TITLE: Transportability Guidance Example
PREPARED: M. Rugnetta

Drawing SAMPLE
DATE: 6-Oct-09

Trailer Suspended from Craft

CARGO WEIGHT 2,000 lb

Tie-Down Strap/Chain Rating (WLL) 3333 lb

	DIMENSION				Vector			AVAILABLE RESTRAINT (lb) FROM MOVING… **(CRAFT CENTERED FRAME OF REF.)**				
STRAP #	FORE/AFT EFFECTIVE LENGTH (D)	LATERAL EFFECTIVE LENGTH (E)	VERTICAL EFFECTIVE LENGTH (B)	TIEDOWN STRAP LENGTH (A)	X	Y	Z	FORWARD	AFT	LATERAL (PORT)	LATERAL (STBD)	VERTICAL
1S	21.66	2.08	21.31	30.5	1.0	-1.0	-1.0	2370.4			227.6	2332.1
2S	18.98	3.07	17.73	26.2	-1.0	1.0	-1.0		2418.8	391.2		2259.5
3S	15.39	8.68	22.14	28.3	-1.0	1.0	-1.0		1810.9	1021.3		2605.1
4S	8.67	12.42	26.81	30.8	1.0	1.0	-1.0	938.4		1344.3		2901.9
1P	21.66	2.08	31.31	38.1	1.0	1.0	-1.0	1893.4		181.8		2736.9
2P	18.98	3.07	17.73	26.2	-1.0	-1.0	-1.0		2418.8		391.2	2259.5
3P	15.39	8.68	22.14	28.3	-1.0	-1.0	-1.0		1810.9		1021.3	2605.1
4P	8.67	12.42	26.81	30.8	1.0	-1.0	-1.0	938.4			1344.3	2901.9
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					

	FORWARD	AFT	LATERAL (PORT)	LATERAL (STBD)	VERTICAL
REQUIRED RESTRAINT (lb-f)	0	0	0	0	10,000
LOAD FACTOR	0	0	0	0	5
TOTAL RESTRAINT (lb-f) PROVIDED	**6,141**	**8,459**	**2,939**	**2,985**	**20,602**
Actual Load Factor Provided	3.07	4.23	1.47	1.49	10.30

Combined (Craft and Trailer) Hoisting Restraint Calculation Example

No preference for analysis method should be inferred from this example.

MIL-STD-209K Tiedown Calculations

These calculations determine the design loads and ultimate loads for MIL-STD-209K. The data from these calculations should be used for design purposes and for testing.

Please enter the numbers shown in red for your specific equipment. See figure 1 for examples of each of the variables.

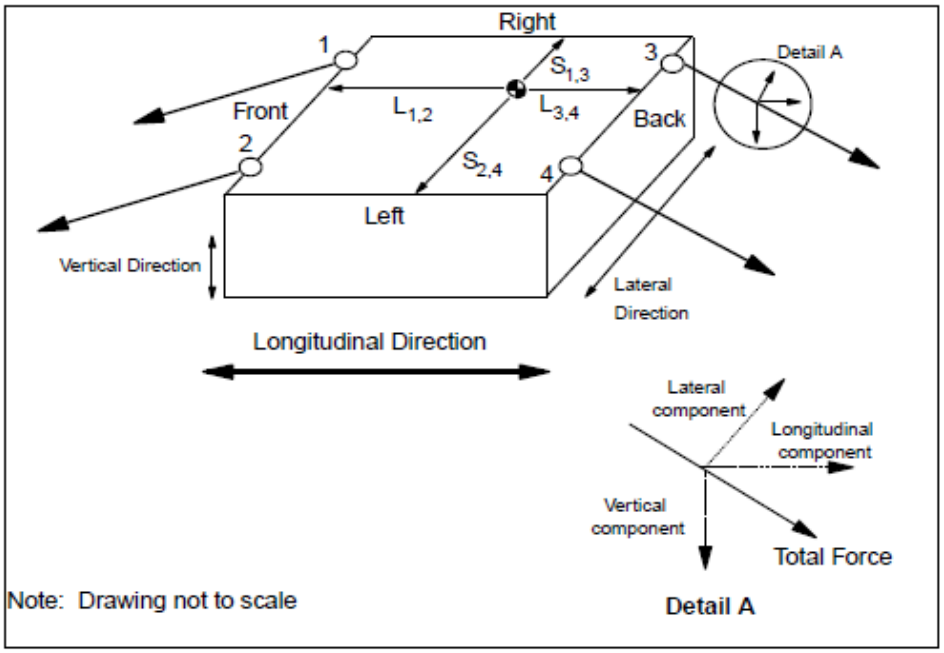


Figure 1

No. of provisions that prevent movement in the:

Forward Direction -	2
Aft Direction -	2
Left Direction -	2
Right Direction -	2
Vertical Direction -	4

Given Data:

S_1 =	112.21	inches	L_1 =	35.62	inches
S_2 =	80.45	inches	L_2 =	12.34	inches
S_3 =	112.21	inches	L_3 =	35.62	inches
S_4 =	80.45	inches	L_4 =	12.34	inches
GW	6,200	pounds			

MIL-STD-209K Tiedown Calculations

Results of the MIL-STD-209K Tiedown Calculations

Provision Number	Longitudinal Load (lb)	Vertical Load (lb)	Lateral Load (lb)
Provision 1 *front right*	1,232	633	3,608
Provision 2 *front left*	1,719	883	3,608
Provision 3 *back right*	1,232	633	3,608
Provision 4 *back left*	1,719	883	3,608

Below are the equations and formulas used for arriving at the values in the above table. The equations are exactly the same as in Appendix C of MIL-STD-209K.

Longitudinal Direction:

The longitudinal inertia force acting through the CG is:

0.476*GW = 2,951 pounds

To restrict movement in the forward direction, two provisions can be used:

$T_{3L} + T_{4L}$ = 2,951 pounds

$T_{3L} = S_4*(T_{3L} + T_{4L})/(S_3 + S_4)$ = 1,232 pounds

$T_{4L} = S_3*(T_{3L} + T_{4L})/(S_3 + S_4)$ = 1,719 pounds

To restrict movement in the aft direction, two provisions can be used:

$T_{1L} + T_{2L}$ = 2,951 pounds

$T_{1L} = S_2*(T_{1L} + T_{2L})/(S_1 + S_2)$ = 1,232 pounds

$T_{2L} = S_1*(T_{1L} + T_{2L})/(S_1 + S_2)$ = 1,719 pounds

Ultimate load requirements (1.5 x design limit load) are:

Forward	$U_{3L} = 1.5*T_{3L}$ =	1,849 pounds
	$U_{4L} = 1.5*T_{4L}$ =	2,578 pounds
Aft	$U_{1L} = 1.5*T_{1L}$ =	1,849 pounds
	$U_{2L} = 1.5*T_{2L}$ =	2,578 pounds

MIL-STD-209K Tiedown Calculations

Vertical Direction:

The vertical inertia force acting through the CG is:

0.489*GW = 3,032 pounds

To restrict movement in the vertical direction, four provisions can be used:

$T_{1V} + T_{2V} + T_{3V} + T_{4V}$ = 3,032 pounds

$T_{1V} = S_2/(S_1 + S_2)*L_3/(L_1 + L_3)*(T_{1V} + T_{2V} + T_{3V} + T_{4V})$ = 633 pounds

$T_{2V} = S_1/(S_1 + S_2)*L_4/(L_2 + L_4)*(T_{1V} + T_{2V} + T_{3V} + T_{4V})$ = 883 pounds

$T_{3V} = S_4/(S_3 + S_4)*L_1/(L_1 + L_3)*(T_{1V} + T_{2V} + T_{3V} + T_{4V})$ = 633 pounds

$T_{4V} = S_3/(S_3 + S_4)*L_2/(L_2 + L_4)*(T_{1V} + T_{2V} + T_{3V} + T_{4V})$ = 883 pounds

Ultimate load requirements (1.5 x design limit load) are:

$U_{1V} = 1.5 * T_{1V}$ = 950 pounds

$U_{2V} = 1.5 * T_{2V}$ = 1,324 pounds

$U_{3V} = 1.5 * T_{3V}$ = 950 pounds

$U_{4V} = 1.5 * T_{4V}$ = 1,324 pounds

Lateral Direction:

The lateral inertia force acting through the CG is:

1.164*GW = 7,217 pounds

To restrict movement toward the right, two provisions can be used:

$T_{2S} + T_{4S}$ = 7,217 pounds

$T_{2S} = L_4*(T_{2S} + T_{4S})/(L_2 + L_4)$ = 3,608 pounds

$T_{4S} = L_2*(T_{2S} + T_{4S})/(L_2 + L_4)$ = 3,608 pounds

To restrict movement toward the left, two provisions can be used:

$T_{1S} + T_{3S}$ = 7,217 pounds

$T_{1S} = L_3 * (T_{1S} + T_{3S})/(L_1 + L_3)$ = 3,608 pounds

$T_{3S} = L_1 * (T_{1S} + T_{3S})/(L_1 + L_3)$ = 3,608 pounds

Ultimate load requirements (1.5 x design limit load) are:

Right	$U_{2S} = T_{2S}*1.5$ =	5,413 pounds
	$U_{4S} = T_{4S}*1.5$ =	5,413 pounds
Left	$U_{1S} = T_{1S}*1.5$ =	5,413 pounds
	$U_{3S} = T_{3S}*1.5$ =	5,413 pounds

TITLE: Transportability Guidance Example
PREPARED: M. Rugnetta

Drawing SAMPLE
DATE: 6-Oct-09

Craft to Trailer - Maritime Shipping

CARGO WEIGHT 4,200 lb

Tie-Down Strap/Chain Rating (WLL) 3333 lb

	DIMENSION				Vector			AVAILABLE RESTRAINT (lb) FROM MOVING… **(TRAILER CENTERED FRAME OF REF.)**				
STRAP #	FORE/AFT EFFECTIVE LENGTH (D)	LATERAL EFFECTIVE LENGTH (E)	VERTICAL EFFECTIVE LENGTH (B)	TIEDOWN STRAP LENGTH (A)	X	Y	Z	FORWARD	AFT	LATERAL (PORT)	LATERAL (STBD)	VERTICAL
1S	21.66	2.08	21.31	30.5	1.0	-1.0	-1.0	2370.4			227.6	2332.1
2S	18.98	3.07	17.73	26.2	-1.0	1.0	-1.0		2418.8	391.2		2259.5
3S	15.39	8.68	22.14	28.3	-1.0	1.0	-1.0		1810.9	1021.3		2605.1
4S	8.67	12.42	26.81	30.8	1.0	1.0	-1.0	938.4		1344.3		2901.9
1P	21.66	2.08	31.31	38.1	1.0	1.0	-1.0	1893.4		181.8		2736.9
2P	18.98	3.07	17.73	26.2	-1.0	-1.0	-1.0		2418.8		391.2	2259.5
3P	15.39	8.68	22.14	28.3	-1.0	-1.0	-1.0		1810.9		1021.3	2605.1
4P	8.67	12.42	26.81	30.8	1.0	-1.0	-1.0	938.4			1344.3	2901.9
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
0	0.00	0.00	0.00	0.0	0.0	0.0	0.0					
REQUIRED RESTRAINT (lb-f)								1,764	1,764	3,402	3,402	2,054
LOAD FACTOR								0.42	0.42	0.81	0.81	0.489
TOTAL RESTRAINT (lb-f) PROVIDED								**6,141**	**8,459**	***2,939***	***2,985***	**20,602**
Actual Load Factor Provided								1.46	2.01	0.70	0.71	4.91

Naval Shipping (Craft to Trailer) Restraint Calculation Example

No preference for analysis method should be inferred from this example.

Internal Air Transport

Completed USAF Air Transport Data Sheet for craft and trailer in air transport configuration

Pages D-16 and D-17 show the data sheet required by the Air Force for technical review prior to certification. The information has been partially filled out as applicable to this example.

Three-view drawing showing dimensions identified in USAF Air Transport Data Sheet

Page D-18 shows the origin of the dimensions provided in the data sheet. The purpose of this drawing is to illustrate the dimensions to avoid any miscommunication with the Air Force.

Load plan

Pages D-19 – D-22 illustrate a preliminary load plan for loading the craft into a C-130, identifying the critical points for the craft and the prime mover. Interferences have been illustrated to show potential problems.

Tie-down arrangements and restraint analyses for all applicable aircraft

The restraint analysis on Page D-23 shows that there is not adequate restraint to keep the craft from moving forward relative to the aircraft in a crash. This is easily remedied by adding additional tie-downs or relocating the attachment points (Labeled B4P and B4S) one spot further aft on the air deck (toward the ramp).

Identify load capacities and locations for all unique types of trailer and craft tie-down fittings

Included in Road Transport Data

Testing of all trailer and craft tie-down fittings for air transport

The sample matrix below assumes that testing was done orthogonally during construction at the trailer manufacturer's facility and was accomplished on the craft by anchoring each attachment point to the ground.

Provision	Target Load	Direction	Target Duration [s]	Actual Load	Actual Duration	Inspection
B1P	10000	As ID on arrangement	6	10100	20	SAT
T1P	10000	Vertical	6	10250	10	SAT
T1P	10000	Longitudinal (Aft)	6	10150	15	SAT
T1P	10000	Transverse (Inboard)	6	10075	12	SAT
B2P	10000	In-Line	6	10550	150	SAT
T2P	10000	Vertical	6			

Axle, Wheel, and Tire slow speed/"creep" load capacities

The tire overload factors (See Appendix C) for this tire type indicates a creep load rating of 4154 lbs per tire at an inflation pressure of 110 psi. For the combined craft and trailer weight for IAT of 6,200 lbs, the tires should be acceptable for loading if only one axle is "landed" on the aircraft floor during loading, as depicted.

For the purposes of this example, wheel creep ratings and axle rated strength are both assumed to exceed the tire creep ratings as well. These component strengths should be verified and included with the trailer technical data.

Data Information Package (DI-PACK) 80880

Not included in this example. See DI-PACK instructions

Pictures of the craft on its trailer in the air transport configuration

Not included in this example. This information should be incorporated into the Transportability Report/DI-PACK.

Technical specifications for the craft and trailer

Not included in this example. Boat Specifications should be included in Boat Owner's Manual, per ABYC T-24 (Contents guidance, item e.4) Trailer Specifications are not included in this example. See *Trailer Specifications* Section for general information.

Special instructions to package craft for air transport

The following instructions are generalized to illustrate steps taken. Specific instructions should be provided for each craft so that an unfamiliar user (e.g. Air Force personnel unfamiliar with basic craft handling practices and terminology) could perform the intended tasks and properly prepare the craft and trailer for transport. Pictures to illustrate the instructions may also be helpful and are encouraged.

- Lower console top and tie-down to deck
- Lower VHF antenna
- Deflate air sponson
- Stow all loose cargo
- Tie-down removable mast to withstand aircraft accelerations

TRAILER TYPE 1 DATA SHEET File Number 200X.XX.XX

DIMENSION DATA INPUT		Length	Pressure	Weight	
	Unit of Measure	in	psi	lbm	
A.	Length	340.84			
B.	Width	114			
C.	Reduced Width	102.04			
D.	Height at Front of Vehicle	79.85			
E.	Maximum Height	108.97			
F.	Height at Rear of Vehicle	77.23	Instead of lower overhangs/ground		
G.	Lower Forward Overhang	N/A	clearances, angles may be given		
H.	Upper Forward Overhang	N/A	Approach		
I.	Lower Rear Overhang	66.61			
J.	Upper Rear Overhang	67.09	Departure		
K.	Forward Ground Clearance	17.97	18.64		
L.	Mid-Wheelbase Ground Clearance	23.97	Cresting		
M.	Rear Ground Clearance	20.14	17.08		
N.	Fifth Wheel If Applicable	N/A			
O.	Fifth Wheel Height If Applicable	N/A			
P.	Lunette/Kingpin Height	23.97			
Q.	Lunette/Kingpin to First Axle Distance	231.25	Length	Width	
R.	Landing Gear Pad Area	81	9	9	
S.	Landing Gear Distance	21.25			
T.	Wheelbase	251.25			
U.	Width Outside Wheels	99.07			

WHEEL DATA INPUT						
X.	Axle Articulation (Deg)/Travel					
Y.	Number of Axles	2				
		1st to 2nd	2nd to 3rd	3rd to 4th	4th to 5th	
Z.	Axle Spacing (Front to Rear)	40				
		1st Axle	2nd Axle	3rd Axle	4th Axle	5th Axle
AA.	Number of Wheels per Axle	2	2			
BB.	Tire Size (xx R zz)	LT215 85R1	LT215 85R16 /E			
CC.	Ply Rating					
DD.	Tire Pressure	80	80			
EE.	Tire Contact Length	8.57	8.57			
FF.	Tire Contact Width	7	7			

USAF Air Transport Data Sheet (1 of 2)

TRAILER TYPE 1 DATA SHEET File Number 200X.XX.XX

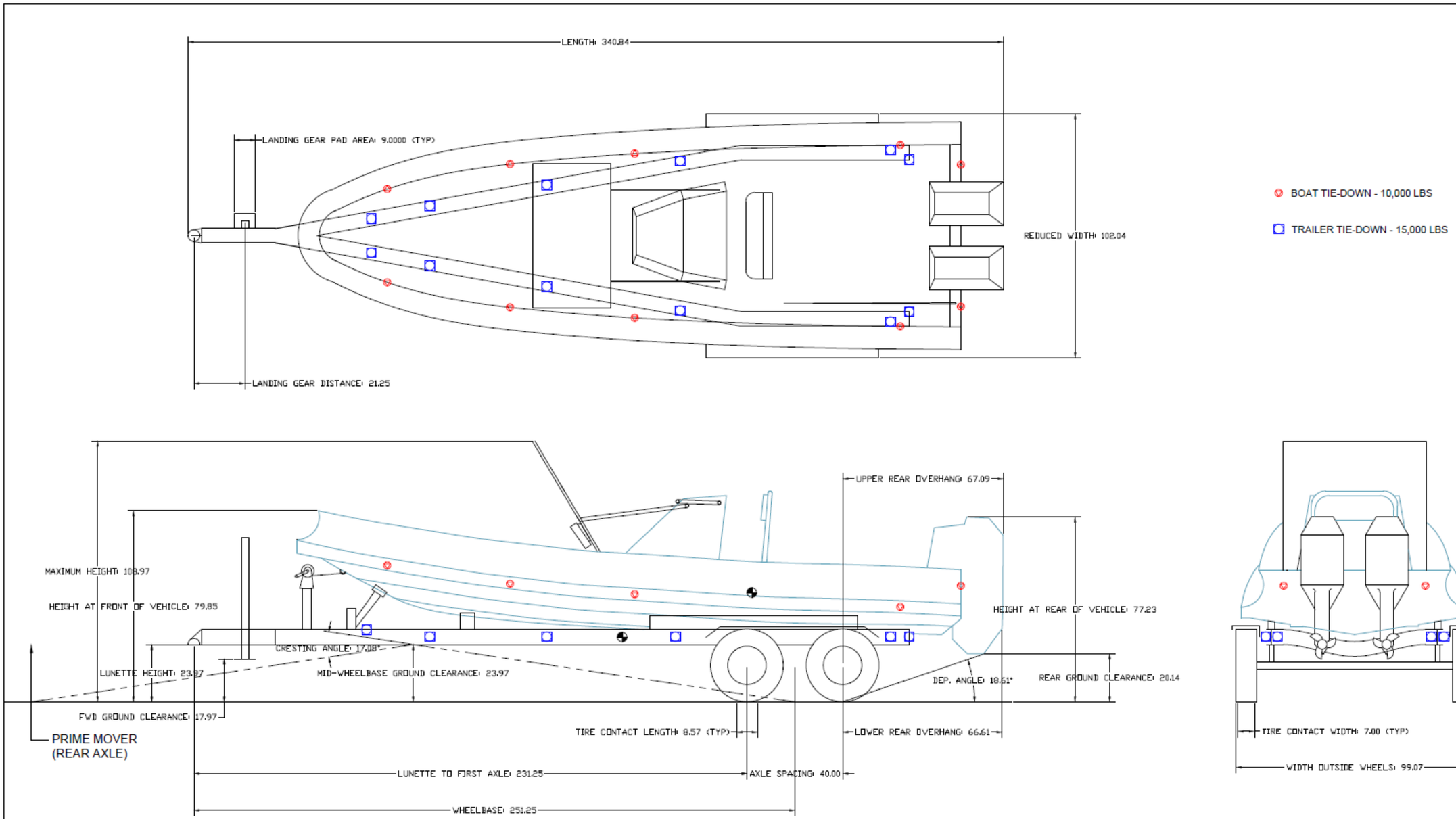
WEIGHT DATA INPUT

GG.	Gross Vehicle Weight	6200						
HH.	Gross Vehicle Weight Rating (GVWR)	12000						
		1st Axle	2nd Axle	3rd Axle	4th Axle	5th Axle		
II.	Axle Weights (Front to Rear)	2663	2663					
JJ.	Axle Ratings (Front to Rear)	5000	5000					
KK.	Tire Load Rating (55 MPH/88KPH)	2680	2680					
LL.	Landing Gear Rating (per Leg)	5000						
MM.	Fifth Wheel Rating	N/A						
NN.	Front Tiedown Capacity	10000		Quantity	5			
		10000	Longitudinal					
	MIL-STD-209K data	10000	Lateral					
		10000	Vert					
OO.	Side Tiedown Capacity	10000		Quantity	2	Each Side		
		10000	Longitudinal					
	MIL-STD-209K data	10000	Lateral					
		10000	Vert					
PP.	Rear Tiedown Capacity	10000		Quantity	4			
		10000	Longitudinal	Verification/validation of tiedown capacities either via testing or analysis is required				
	MIL-STD-209K data	10000	Lateral					
		10000	Vert					

TRAILER DATA

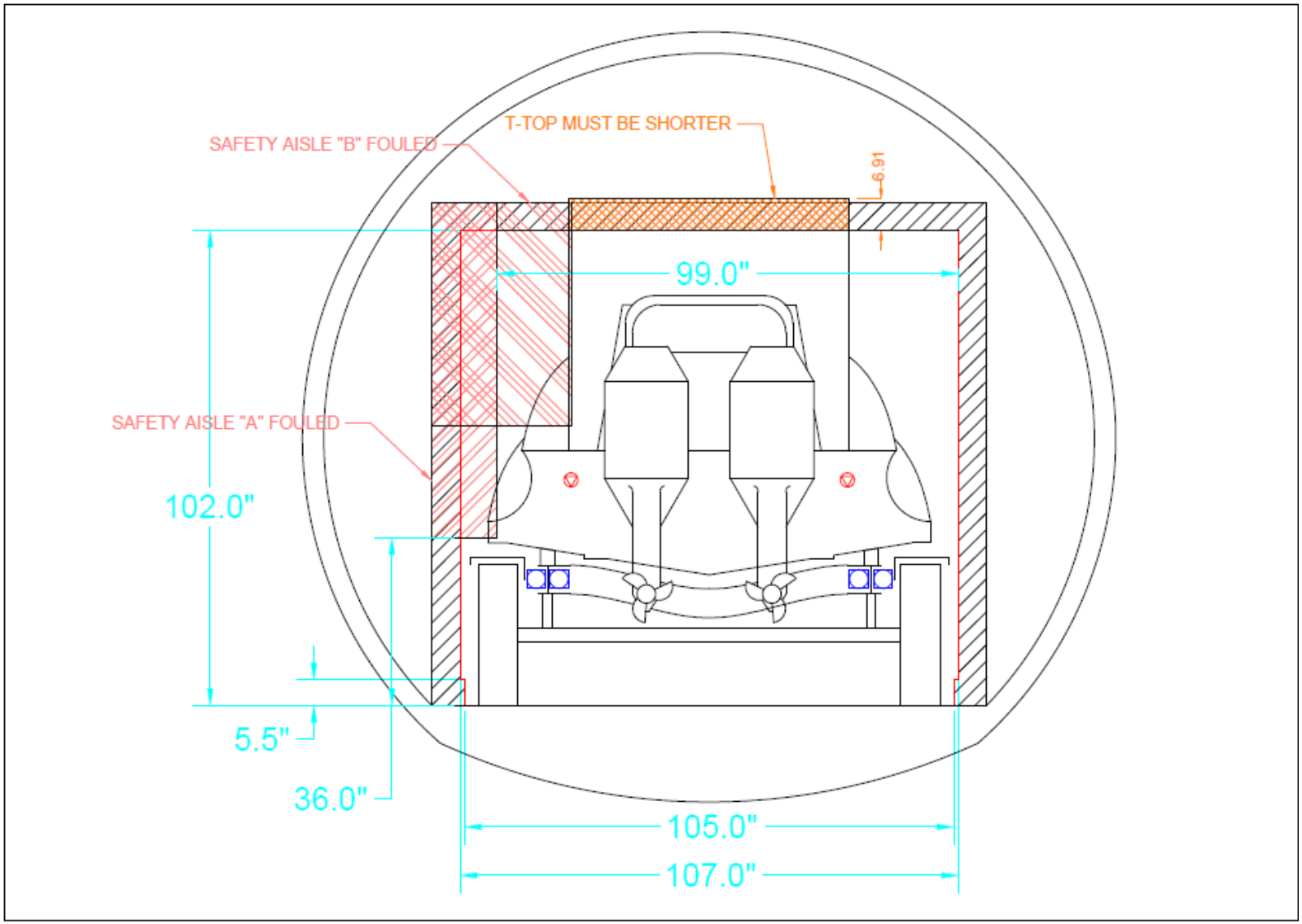
Max Anticipated Tongue Weight	1254
Manufacturers Max Tongue Weight	5000
Tare weight/weight of trailer empty	2000
Tongue Weight for Empty Trailer	575
How many inches do the axles travel in the upward direction before they bottom out on the axle stops?	6

USAF Air Transport Data Sheet (2 of 2)



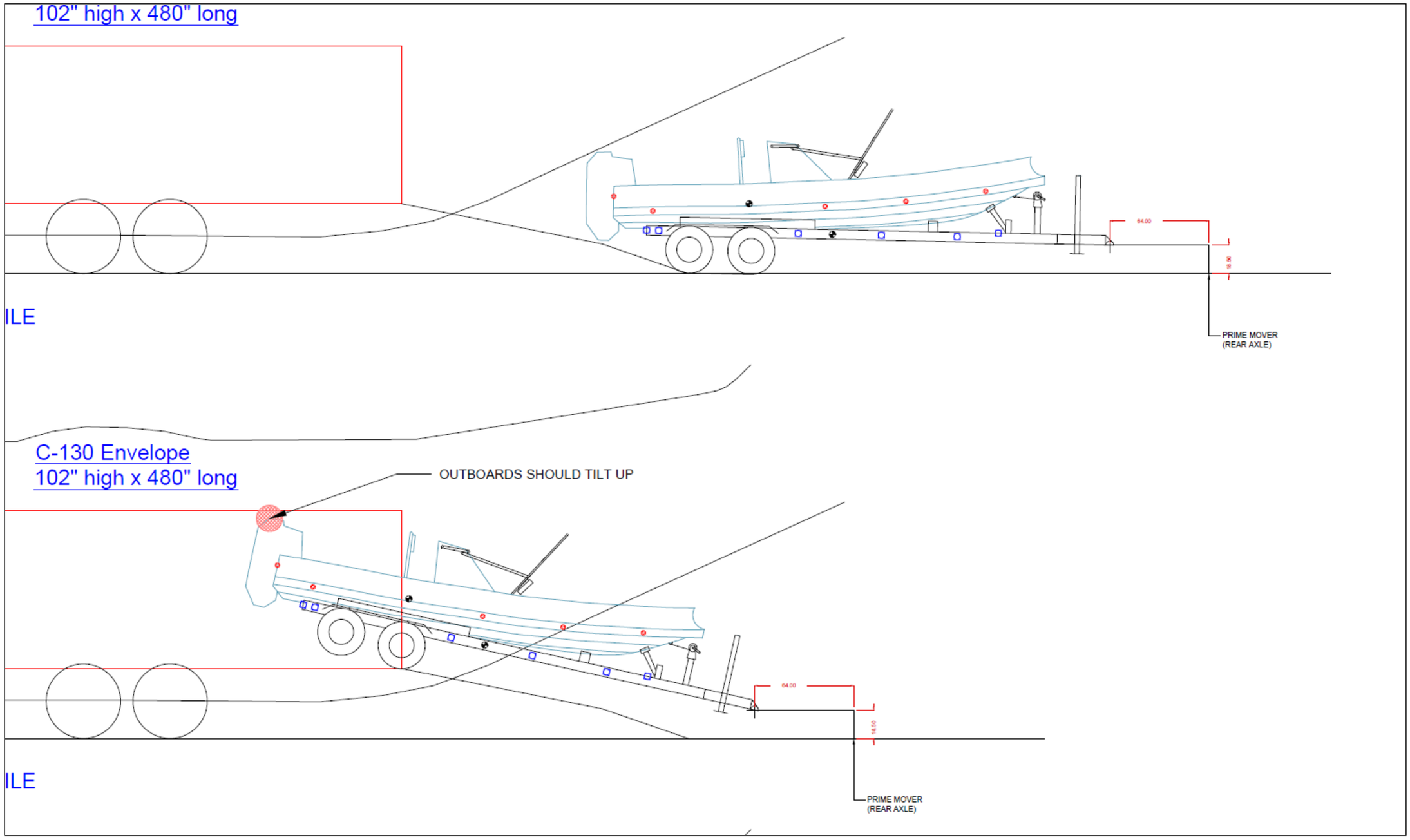
Example ATTLA Air Certification Data Sheet Dimensions

Sketch is for illustration purposes only. No preference for configuration, arrangement, or analysis method should be inferred from this example.



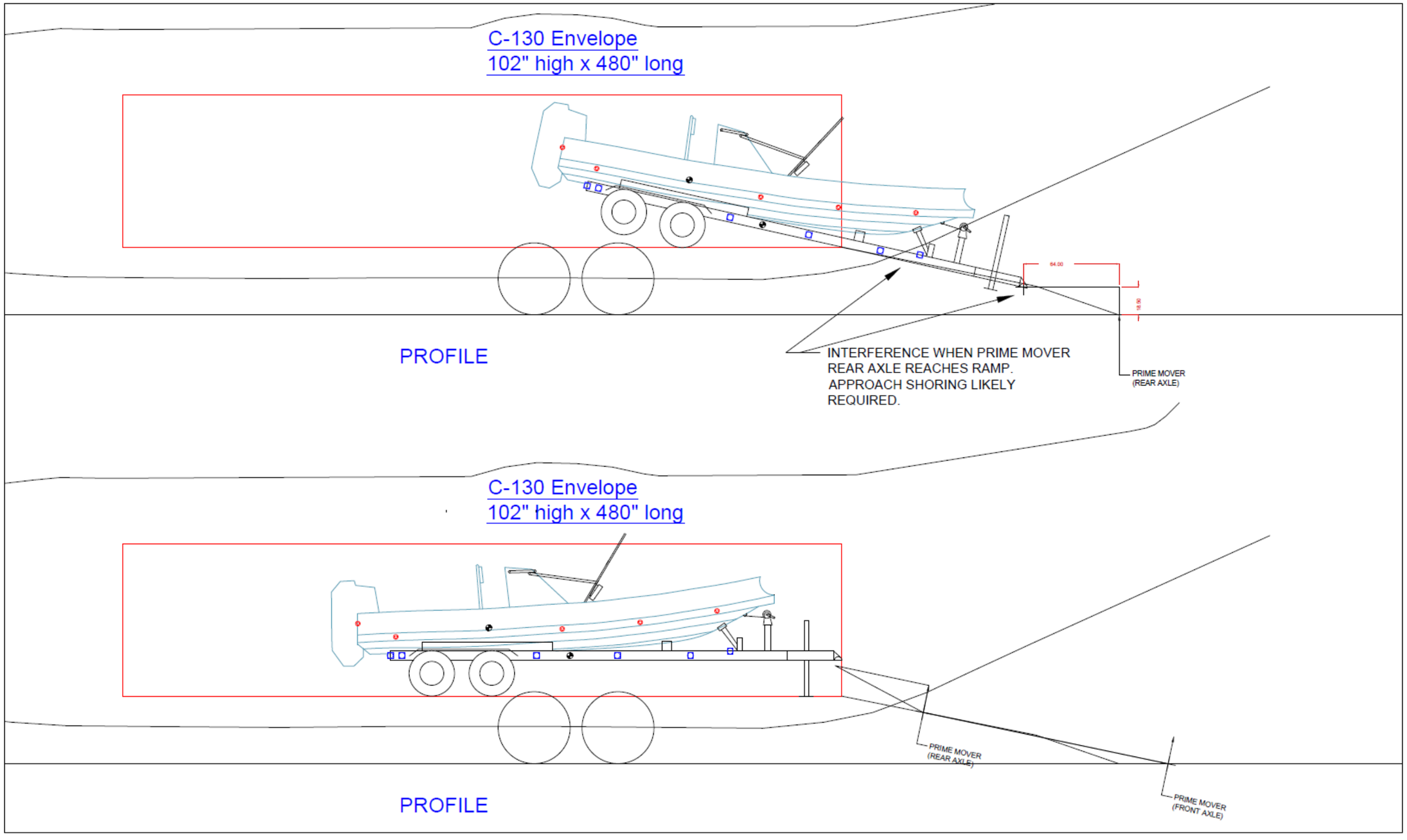
Load Plan - Compartment Cross-Section Check

Sketch is for illustration purposes only. No preference for configuration, arrangement, or analysis method should be inferred from this example.

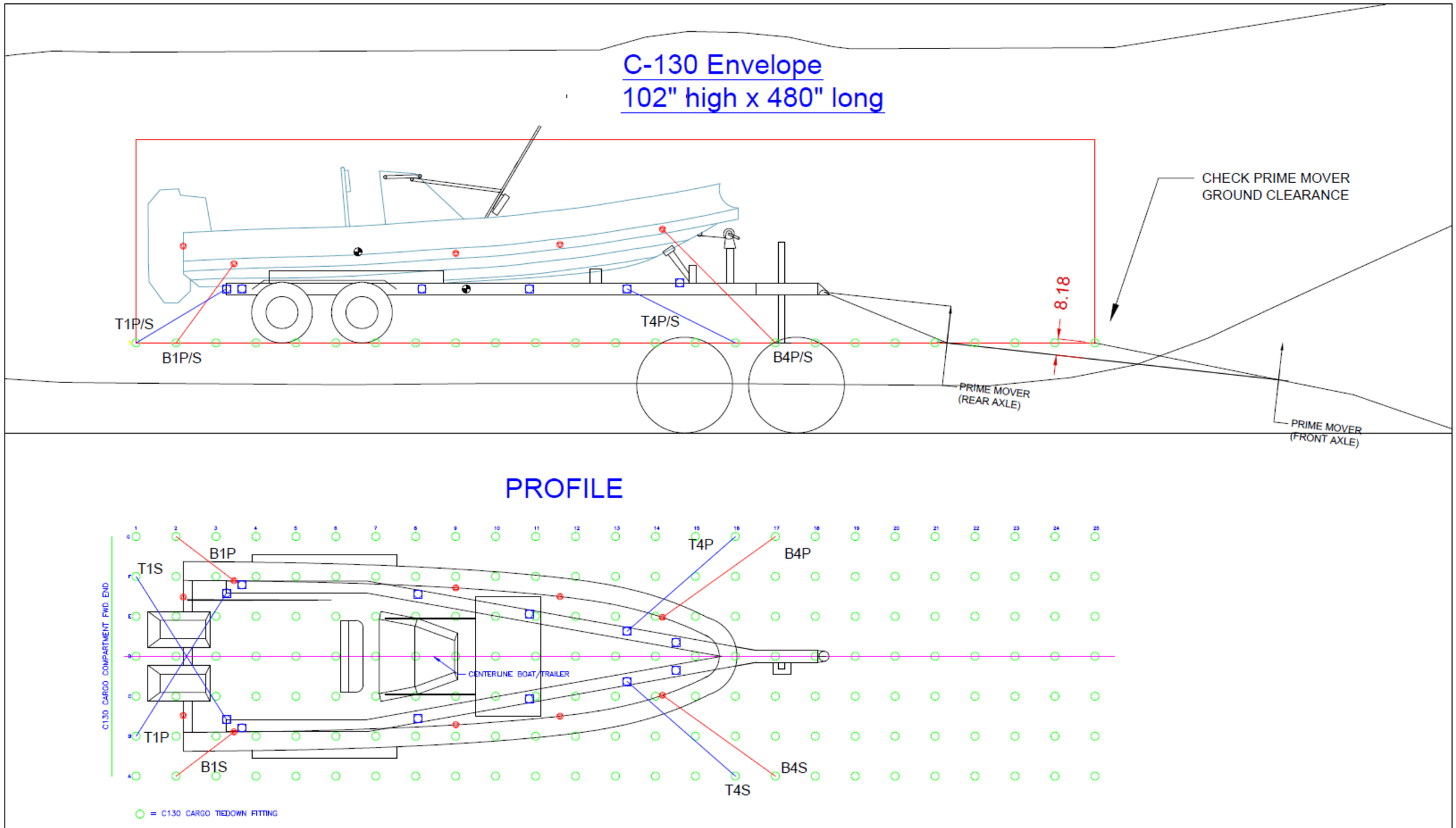


Load Plan - Craft Critical Points

Sketch is for illustration purposes only. No preference for configuration, arrangement, or analysis method should be inferred from this example.



Load Plan - Prime Mover Critical Points
Sketch is for illustration purposes only. No preference for configuration, arrangement, or analysis method should be inferred from this example.



Craft Loaded and Tie-Down Arrangement
Sketch is for illustration purposes only. No preference for configuration, arrangement, or analysis method should be inferred from this example.

TITLE: Transportability Guidance Example
PREPARED: M. Rugnetta

Drawing SAMPLE
DATE: 6-Oct-09

IAT - Craft Only

CARGO WEIGHT 4,200 lb

Tie-Down Strap/Chain Rating (WLL) 10000 lb

	DIMENSION				Vector			AVAILABLE RESTRAINT (lb) FROM MOVING… **(CRAFT CENTERED FRAME OF REF.)**				
STRAP #	FORE/AFT EFFECTIVE LENGTH (D)	LATERAL EFFECTIVE LENGTH (E)	VERTICAL EFFECTIVE LENGTH (B)	TIEDOWN STRAP LENGTH (A)	X	Y	Z	FORWARD	AFT	LATERAL (PORT)	LATERAL (STBD)	VERTICAL
B1S	29.02	22.14	39.61	53.9	-1.0	-1.0	1.0		5387.4		4110.0	7354.1
				0.0								
				0.0								
B4S	56.48	40.50	56.92	89.8	1.0	-1.0	1.0	6286.8			4508.1	6336.6
B1P	29.02	22.14	39.61	53.9	-1.0	1.0	1.0		5387.4	4110.0		7354.1
				0.0								
				0.0								
B4P	56.48	40.50	56.92	89.8	1.0	1.0	1.0	6286.8		4508.1		6336.6
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
REQUIRED RESTRAINT (lb-f)								12,600	6,300	6,300	6,300	8,400
LOAD FACTOR								3	1.5	1.5	1.5	2
TOTAL RESTRAINT (lb-f) PROVIDED								***12,574***	**10,775**	**8,618**	**8,618**	**27,382**
Actual Load Factor Provided								2.99	2.57	2.05	2.05	6.52

Internal Air Transport (Craft-only Weight) Restraint Calculation Example

No preference for analysis method should be inferred from this example.

TITLE: Transportability Guidance Example
PREPARED: M. Rugnetta

Drawing SAMPLE
DATE: 6-Oct-09

IAT - Trailer Only

CARGO WEIGHT 2,000 lb

Tie-Down Strap/Chain Rating (WLL) 10000 lb

	DIMENSION				Vector			AVAILABLE RESTRAINT (lb) FROM MOVING… **(CRAFT CENTERED FRAME OF REF.)**				
STRAP #	FORE/AFT EFFECTIVE LENGTH (D)	LATERAL EFFECTIVE LENGTH (E)	VERTICAL EFFECTIVE LENGTH (B)	TIEDOWN STRAP LENGTH (A)	X	Y	Z	FORWARD	AFT	LATERAL (PORT)	LATERAL (STBD)	VERTICAL
T1S	45.30	71.73	27.12	89.1	-1.0	1.0	1.0		5085.7	8053.8		3044.8
T2S				0.0								
T3S				0.0								
T4S	54.25	47.46	27.12	77.0	1.0	-1.0	1.0	7044.5			6162.4	3521.3
T1P	45.30	71.73	27.12	89.1	-1.0	-1.0	1.0		5085.7		8053.8	3044.8
T2S				0.0								
T3S				0.0								
T4P	54.25	47.46	27.12	77.0	1.0	1.0	1.0	7044.5		6162.4		3521.3
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
				0.0								
REQUIRED RESTRAINT (lb-f)								6,000	3,000	3,000	3,000	4,000
LOAD FACTOR								3	1.5	1.5	1.5	2
TOTAL RESTRAINT (lb-f) PROVIDED								**14,089**	**10,171**	**14,216**	**14,216**	**13,132**
Actual Load Factor Provided								7.04	5.09	7.11	7.11	6.57

Internal Air Transport (Trailer-only Weight) Restraint Calculation Example

No preference for analysis method should be inferred from this example.

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