NOTE: DOD-STD-1399/301 has been redesignated as an Interface Standard. The cover page has been changed for Administrative reasons. There are no other changes to this Document.

METRIC

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SECTION 301A
21 July 1986
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(See 6.4)

DEPARTMENT OF DEFENSE
INTERFACE STANDARD

INTERFACE STANDARD FOR SHIPBOARD SYSTEMS

SECTION 301A

SHIP MOTION AND ATTITUDE

(METRIC)

AMSC N/A FSC 1990

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DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND

Washington, DC 20362-5101

Interface Standard for Shipboard Systems, Ship Motion and Attitude (METRIC)

1. This Military Standard is approved for use within the Naval Sea Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Sea Systems Command, SEA 55Z3, Department of the Navy, Washington, DC 20362-5101 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FOREWORD

Purpose. The purpose of this standard is to define the standard interface requirements and constraints imposed by ship motion and attitude on the design of ship structure and systems/equipment to be installed therein.

Numerical quantities. Numerical quantities are expressed in metric (SI) units followed by U.S. customary units in parentheses. The SI equivalents of the U.S. customary units are approximated to a practical number of significant figures. Values stated in U.S. customary units are to be regarded as the current specified magnitude.

CONTENTS

CONTENTS - Continued

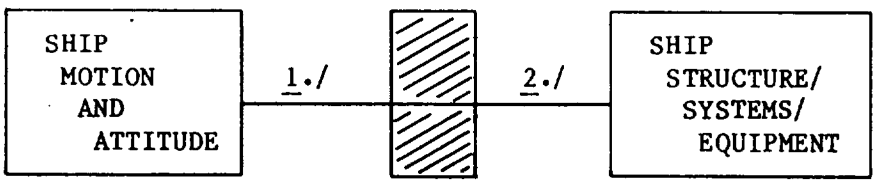
1. GENERAL, SCOPE, INTERFACE AND INVOCATION

1.1 General. This section is an integral part of DOD-STD-1399. When the interface between the ship motion and attitude and ship structure, systems and equipment is under consideration this section and the standard must be viewed as a single document. The policies and procedures established by DOD-STD-1399 are mandatory.

1.2 Scope. This section establishes interface requirements for ship structure, appurtenances, fittings, machinery, systems, and equipment which are affected by ship motions to ensure compatibility between such ship structure, and so forth, and the effects of ship motion and attitude.

1.3 Interface. The interface which is the concern of this section, and the basic characteristic and constraint categories involved at this interface, are shown symbolically on figure 1 (see definitions of DOD-STD-1399).

INTERFACE



BASIC CATEGORIES

1./ CHARACTERISTICS	2./ CONSTRAINTS
DYNAMIC	COMPATIBILITY
Roll	WEAPONS AND STORES HANDLING
Pitch	STOWAGE
Yaw	LUBRICATION
Surge	HYDRAULIC FLUID
Sway	SYSTEM ACCURACY
Heave	
STATIC	
Heel	
Trim	
List	

FIGURE 1. Interface flow chart.

The particular interface characteristics and constraints pertinent to this section are described in 5.2 and 5.3. Values for the characteristics are listed for conventional surface ships and are not applicable to multi-hulls, surface effects ships, and all craft supported principally by hydrodynamic lift.

1.4 Invocation. Specific ship motion conditions will be given in the ship design requirements document.

1.4.1 Information necessary for the use of this section includes required operational capabilities versus sea state. Ship system and equipment motion limits and calculation methods are presented in this section in table I and the appendix, respectively. Other motion limits or methods may be specified by the invoking document.

2. REFERENCED DOCUMENT

2.1 Government document.

2.1.1 Standard. Unless otherwise specified, the following standard of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation forms a part of this standard to the extent specified herein.

STANDARD

MILITARY
DOD-STD-1399 - Interface Standard for Shipboard Systems.

(Copies of standard required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.2 Order of precedence. In the event of a conflict between the text of this standard and the reference cited herein, the text of this standard shall take precedence.

3. DEFINITIONS

3.1 Ship angular motions.

3.1.1 Roll. Roll is the oscillatory motion of a ship about the longitudinal (x) axis.

3.1.2 Pitch. Pitch is the oscillatory motion of a ship about the transverse (y) axis.

3.1.3 Yaw. Yaw is the oscillatory motion of a ship about the vertical (z) axis.

NOTE: These oscillatory motions are characterized by their amplitudes and periods.

3.2 Snap roll. Snap roll is a unique motion experienced by submarines in response to asymmetric dynamic loads often experienced while executing high speed turns submerged.

3.3 Ship linear motions.

3.3.1 Surge. Surge is the fore and aft motion of a ship along the longitudinal (x) axis.

3.3.2 Sway. Sway is the lateral motion of a ship along the transverse (y) axis.

3.3.3 Heave. Heave is the up and down motion of a ship along the vertical (z) axis.

3.4 Ship attitude.

3.4.1 Heel. Heel (or list) is the inclination of a ship about the longitudinal (x) axis due to either lateral separation between the center of gravity and the center of buoyancy or steady externally imposed loads (that is, wind, control surface).

3.4.2 Trim. Trim is the inclination of a ship about the transverse (y) axis due to longitudinal separation of the center of gravity and the center of buoyancy.

3.4.3 Heel. Heel is the non-oscillating angular displacement of a ship about the longitudinal (x) axis caused by steady externally imposed loads (that is, wind, control surface).

3.5 Loading factor. The loading factor is a calculated number given in terms of gravitational and dynamic acceleration which, when multiplied by the mass of a structure or equipment, determines the design load (see 3.6) of such structure or equipment in the longitudinal (fore and aft), transverse (port and starboard), and vertical (up or down) directions as a result of the accelerations of gravity and ship motion. Loading factors are dependent upon the magnitude and frequency of ship motions, ship attitude, and location in the ship of the structure or equipment under consideration.

3.6 Design load. The design load is the force applied to structure or equipment at a given location in the ship. It is determined by multiplying the mass of the structure or equipment by the loading factor calculated for such location.

3.7 Sea state. Sea state is a measure of the severity of the sea condition (see 5.3.2). Sea conditions include wave height, period, energy distribution with wave frequency and direction. Statistics of occurrence of the sea state and sea conditions vary with location and time of year.

4. GENERAL REQUIREMENTS

4.1 Interface requirements and constraints. The specific interface requirements and constraints established herein are mandatory and shall be adhered to by Program Managers for ships, aircraft and equipment, contractors and all engaged in any aspects of total shipboard design including system or equipment design, production or installation (see requirements of DOD-STD-1399).

5. DETAILED REQUIREMENTS

5.1 Interface characteristics and constraints.

5.1.1 Ship motion - general considerations. Ship motion in a seaway includes roll, pitch, yaw, surge, sway and heave. Ship attitude caused by loading, wind, or control surface forces includes list, trim, and heel. Ship motion and ship attitude generate forces which are both static and dynamic in nature and which exert a cumulative effect. Dynamic effects vary depending upon the location in the ship and increase with distance from the ship motion axes. Static effects are uniform throughout the ship.

5.1.1.1 The forces described in 5.1.1 are caused by the sea state, wind, control surfaces, ship maneuvers, and ship loading, and produce effects whose magnitudes vary with the location on board ship. They must be considered in their combined "worst-case" value and applied to the design of ships so that ship structure, appurtenances, systems or equipment will perform in accordance with design requirements when exposed to such conditions, in addition to the other rigors of shipboard existence.

5.2 Interface characteristics. The interface characteristics of significance in the ship motion environment are given in 5.2.1 through 5.2.3. These forces are present on all ships and produce an effect on all ship structures, appurtenances, systems or equipment.

5.2.1 Dynamic motion forces. The more significant dynamic motion forces are those generated by roll, pitch, yaw, surge, and heave. Forces generated by sway are disregarded herein since they are normally of a lesser magnitude.

5.2.1.1 Sea conditions. Sea conditions generate ship motions which produce dynamic forces. These dynamic forces depend on ship motion amplitudes and periods which depend upon the ship's responsiveness to the characteristics of the seaway. Loading factors are calculated for a number of sea states and are applied as dictated by the nature of the affected structure, system or equipment.

5.2.1.2 Loading factors. Dynamic motions shall either be selected from tables I through IV or independently computed for each individual ship type for sea conditions appropriate to each structure, system or equipment type. Loading factors shall then be computed depending upon location and equipment function, as specified in 5.3. The appendix describes the loading factors and gives examples of the application of the formulas for two selected ship types under storm conditions.

TABLE I. Data sources (list, trim and heel are not included in loading factors).

	Magnitude	Acceleration	Period
Roll	See table II	2/	1/
Pitch	See table II	2/	See table II
Yaw	2/	2/	2/
Surge	2/	See table II	2/
Heave	2/	See table II	3/
Sway	2/	2/	2/

1/ Shall be calculated.
2/ Not applicable.
3/ Approximately equal to pitch period, but not necessarily in phase.

TABLE II. Roll motion parameters for calculation of loading factors for conventional surface ships.1/

Sea state	Beam meters (feet)	Roll angle2/ degrees	Roll period
4	Less than 15 (50) 15-23 (50-75) 23-32 (75-105) Greater than 32 (105)	7 6 6 5	See note for determination of roll period3/
5	Less than 15 (50) 15-23 (50-75) 23-32 (75-105) Greater than 32 (105)	12 10 10 9	See note for determination of roll period3/
6	Less than 15 (50) 15-23 (50-75) 23-32 (75-105) Greater than 32 (105)	19 16 15 13	See note for determination of roll period3/
7	Less than 15 (50) 15-23 (50-75) 23-32 (75-105) Greater than 32 (105)	28 24 22 20	See note for determination of roll period3/
8	Less than 15 (50) 15-23 (50-75) 23-32 (75-105) Greater than 32 (105)	42 37 34 31	See note for determination of roll period3/

1/ Excludes multi-hulls, surface effect ships, and all craft supported principally by hydrodynamic lift.

2/ Roll angle is measured from vertical to starboard or port.

3/ Full roll period is to be calculated from:

$$Tr = (C \times B) / (\overline{GM})^{1/2}$$

Where:

- Tr - is the full roll period (seconds).
- C - is a roll constant based upon experimental results from similar ships - usual range 0.69 to 0.89 (sec/$\sqrt{m}$) (0.38 to 0.49 (sec/$\sqrt{ft}$)).
- B - is the maximum beam at or below the waterline (m or ft).
- $\overline{GM}$ - is the maximum metacentric height (m or ft).

TABLE III. Pitch motion parameters for calculation of loading factors for conventional surface ships.

Sea state	Length between perpendiculars (LBP) meters (feet)	Pitch angle* degrees	Pitch period seconds
4	Less than 46 (150)	2	3.5
	46-76 (150-250)	2	4
	76-107 (250-350)	1	5
	107-152 (350-500)	1	6
	152-213 (500-700)	1	7
	Greater than 213 (700)	1	8
5	Less than 46 (150)	3	3.5
	46-76 (150-250)	3	4
	76-107 (250-350)	2	5
	107-152 (350-500)	2	6
	152-213 (500-700)	2	7
	Greater than 213 (700)	1	8
6	Less than 46 (150)	5	3.5
	46-76 (150-250)	4	4
	76-107 (250-350)	4	5
	107-152 (350-500)	3	6
	152-213 (500-700)	3	7
	Greater than 213 (700)	2	8
7	Less than 46 (150)	7	3.5
	46-76 (150-250)	6	4
	76-107 (250-350)	6	5
	107-152 (350-500)	5	6
	152-213 (500-700)	4	7
	Greater than 213 (700)	3	8
8	Less than 46 (150)	11	3.5
	46-76 (150-250)	10	4
	76-107 (250-350)	9	5
	107-152 (350-500)	7	6
	152-213 (500-700)	6	7
	Greater than 213 (700)	5	8

*NOTE: Pitch angle is measured from horizontal to bow up or down.

TABLE IV. Heave and surge motion parameters for calculation of loading factors for conventional surface ships.

Sea state	LBP meters (feet)	Heave acceleration (g)	Surge acceleration (g)
4	Less than 46 (150)	0.10	0.06
	46-76 (150-250)	.10	.05
	76-107 (250-350)	.10	.05
	107-152 (350-500)	.08	.04
	152-213 (500-700)	.06	.04
	Greater than 213 (700)	.04	.02
5	Less than 46 (150)	0.17	0.10
	46-76 (150-250)	.17	.10
	76-107 (250-350)	.17	.10
	107-152 (350-500)	.14	.05
	152-213 (500-700)	.10	.05
	Greater than 213 (700)	.07	.05
6	Less than 46 (150)	0.27	0.15
	46-76 (150-250)	.27	.15
	76-107 (250-350)	.27	.15
	107-152 (350-500)	.21	.10
	152-213 (500-700)	.16	.10
	Greater than 213 (700)	.11	.05
7	Less than 46 (150)	0.4	0.25
	46-76 (150-250)	.4	.20
	76-107 (250-350)	.4	.20
	107-152 (350-500)	.3	.15
	152-213 (500-700)	.2	.15
	Greater than 213 (700)	.2	.10
8	Less than 46 (150)	0.6	0.35
	46-76 (150-250)	.6	.30
	76-107 (250-350)	.6	.30
	107-152 (350-500)	.5	.25
	152-213 (500-700)	.4	.25
	Greater than 213 (700)	.2	.10

5.2.2 Static forces. Significant static forces are those generated by ship attitude - permanent list and trim. Forces generated by heel are included in the determination of effects of maximum list.

5.2.3 Limiting values - roll, pitch, list, heel and trim. Overall design limits of roll, pitch, list, heel and trim are given in table V. It is not statistically likely that the motions given in table V will be exceeded. No design limits are placed on certain less significant parameters of ship motion attitude such as yaw, heave, and surge. Limiting motion values are useful in designing structure, systems or equipment when the intent is to maintain satisfactory lubrication and avoid the loss of oil from machinery or hydraulic systems. Either more or less stringent limiting values may be invoked by governing documents and shall be used when available.

TABLE V. Design limits for ship motion.

	Surface ships1/	Submarines	
		Surfaced	Submerged
	Degrees	Degrees	Degrees
Roll2/	45 30 (for CV types)	60 (below 10 kts) 30 (above 10 kts)	3/30
Pitch2/	10	10	3/7.5
Heel, list	15	15	15
Trim	5	7	30

1/ Excludes multi-hulls, surface-effect ships, and all craft supported principally by hydrodynamic lift.
2/ Roll is measured from vertical to starboard or port. Pitch is measured from horizontal to bow up or down.
3/ Snap roll and pitch due to control surface action must be calculated separately for certain submarine classes if their design will permit snap roll or extreme pitch angles to occur.

5.3 Interface constraints. The interface characteristics of ship motion forces impose certain constraints on the design of ship structure, systems and equipment which will be subject to such forces. These constraints are described in 5.3.1 through 5.3.4.

5.3.1 Compatibility. The design and installation of ship structure, systems and equipment which are subject to ship motion forces shall be compatible with the interface characteristics given in 5.2.

5.3.2 Survival sea conditions. Loading factors calculated for survival conditions specified in ship requirements documents shall be applied to the design of the following:

(a) Masts, superstructure, other structure, fittings and equipment intended to survive the effect of severe ship motion forces.
(b) The securing features of stowed equipment intended to prevent damage or dislodgement of such items.
(c) Certain structure in the unloaded condition (see 5.3.3) which is intended to carry working loads only under less than specified survival sea conditions.
(d) The holding features of weapons and ammunition handling equipment intended to prevent uncontrolled movement when carrying full load under lesser conditions.

The ship requirements documents which invoke this section specify survival sea conditions which are more severe than those in which various ship subsystems are operational. Different sea conditions may be specified for different performance levels, as follows:

(a) Limited operation and capability of continuing its mission without returning to port for repairs after sea subsides.
(b) Survivability without serious damage to mission essential subsystems.

Table VI presents the sea state definitions.

TABLE VI. Sea states.

Sea state number	Significant wave height	
	Meters	Feet
0-1	0.0 - 0.1	0.0 - 0.3
2	0.1 - 0.5	0.3 - 1.6
3	0.5 - 1.25	1.6 - 4.1
4	1.25 - 2.5	4.1 - 8.2
5	2.5 - 4.0	8.2 - 13.1
6	4.0 - 6.0	13.1 - 19.7
7	6.0 - 9.0	19.7 - 29.5
8	9.0 - 14.0	29.5 - 45.5
>8	>14.0	>45.5

5.3.3 Moderate sea conditions. Loading factors calculated for other sea conditions shall be applied to the design of structure, systems or equipment required to be operational under those conditions. Normally these sea conditions will be specified in the Required Operational Capabilities (ROCs) of the governing document which dictate missions to be performed in various sea states. The designer shall indentify the structure, system or equipment that is to be operated in each mission and shall develop and apply loading factors to that item in accordance with the sea states called out in the ROCs. Such equipment shall be designed to permit satisfactory operation (that is, at rated load and rated speed).

5.3.4 Motion limits. Unless otherwise specified in the governing document, structure, systems and equipment shall be designed to operate satisfactorily under the conditions given in 5.2.3.

5.3.4.1 Where required by the type of equipment, the design shall provide for the maintenance of satisfactory lubrication under the operational conditions specified.

5.3.4.2 For hydraulic or other fluid operated systems, the design of such systems shall provide that under the specified operational conditions fluid pressure and flow necessary for continuous operation shall be maintained and loss of fluid from such systems shall be prevented.

5.3.4.3 Where required for proper performance of certain systems, (that is, weapons control, surveillance, navigation system) the design shall provide for the maintenance of the required accuracy under the specified operational conditions.

6. NOTES

6.1 Deviations. In achieving the purpose of this section it is recognized that there must be some flexibility of application. During the early stages of ship design, it may become apparent that significant advantages can be achieved by deviating from the characteristics specified herein. In such instances, the deviation provisions in DOD-STD-1399 should be complied with. Request for deviation should be submitted to the Naval Sea Systems Command (NAVSEA) with copies to the Hull Form and Hydrodynamics Performance Division.

6.2 International standardization agreements. Certain provisions of this standard are the subject of international standardization agreement STANAG 4154 and STANAG 4194. When amendment, revision, or cancellation of this standard is proposed which will modify the international agreement concerned, the preparing activity will take appropriate action through international standardization channels including departmental standardization offices to change the agreement or make other appropriate accommodations.

6.3 Subject term (key word) listing.

Calculation methods, ship system interface
Design limits, ship motion
Dynamic motions
Equipment motion limits
Interface characteristics, categories
Interface standard, shipboard systems
Loading factors, definition and application
Ship motion and attitude, constraints and effects

6.4 Changes from previous issue. Asterisks are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Review activities:
AS, EC, OS, YD, MC

User activity:
CG

Preparing activity:
Navy - SH
(Project 1990-N047)

APPENDIX

LOADING FACTORS

(The material in this appendix is provided for information and guidance to assist the designer in complying with the requirements of this standard. While it is expected that this material will apply in most cases, it is recognized that exceptional cases may require deviation from this approach.)

10. GENERAL

10.1 Scope. The coverage of this section concerns ship motions and the force generated by such motions. These forces must be translated into their effect on ship structure, equipment, and so forth, in order to be applied by the ship and equipment designers. This is accomplished by the calculation of loading factors using the empirical formulas given in 40.5. Specific cases may require more in-depth computation of ship motions to obtain more accurate loading factors.

20. REFERENCED DOCUMENTS

Not applicable.

30. DEFINITIONS

Not applicable.

40. GENERAL REQUIREMENTS

40.1 To calculate loading factors, certain data is required. Some of this data is relatively constant for ranges of ship dimensions; the remainder must be calculated for the particular ship type. Data sources for the various parameters are given in tables I, III, and IV.

40.2 Data which is relatively constant for ranges of ship dimensions is given in table II.

40.3 Loading factors are calculated in the longitudinal (x), transverse (y), and vertical (z) directions at X, Y, or Z distances in feet from the ship's center of gravity. The design loads are obtained by multiplying the mass of the structure or equipment by the appropriate loading factor for each location.

40.3.1 In addition to the generation of design loads on structure, systems and equipment by ship motions, the detailed motion of a ship in a seaway may, in certain operational circumstances, be of major concern (for example, the optical landing system of a carrier). In such cases precise calculations of ship motion are required independent of the procedures used in this document.

40.5 Loading factors, in the x, y and z direction, are the sum of a number of terms as shown in the formulas given in 40.5.1. These terms are contributed by roll, pitch, yaw, heave, and surge accelerations. The components of the gravitational acceleration on the equipment are also included.

40.5.1 The formulas for computing the loading factor in the x, y, or z directions are as follows:

$$A_x = g\sin\theta + s + \frac{4\pi^2}{T_p^{\,2}}\,\theta^2 X + \frac{4\pi^2}{T_p^{\,2}}\,\theta Z$$

$$A_y = g\sin\phi + \frac{1}{2}\cdot\frac{4\pi^2}{T_p^{\,2}}\,\theta X + \frac{4\pi^2}{T_r^{\,2}}\,\phi^2 Y + \frac{4\pi^2}{T_r^{\,2}}\,\phi Z$$

$$A_z = g \pm \left(h + \frac{4\pi^2}{T_p^{\,2}}\,\theta X + \frac{4\pi^2}{T_r^{\,2}}\,\phi Y\right)$$

(In the factor A_z, the plus sign relates to downward force, and the minus sign relates to upward force.)

Where:
- θ = Maximum pitch angle (radians) (Note: Values from table III are multiplied by 0.01745 to convert degrees to radians).
- ϕ = Maximum roll angle (radians) (Note: Values from table II are multiplied by 0.01745 to convert degrees to radians).
- $A_{(\ )}$ = Loading factor in x, y, or z direction.
- T_p = Pitch period (seconds).
- T_r = Roll period (seconds).
- h = Heave acceleration (in m/sec^2 or ft/sec^2) (Note: Values from table IV are multiplied by 9.807 to convert g's to m/sec^2 or by 32.15 to convert g's to ft/sec^2).
- s = Surge acceleration (in m/sec^2 or ft/sec^2) (Note: Values from table IV are multiplied by 9.807 to convert g's to m/sec^2 or by 32.15 to convert g's to ft/sec^2).
- X = Longitudinal distance from center of gravity (in meters or feet).
- Y = Transverse distance from center of gravity (in meters or feet).
- Z = Vertical distance above center of gravity (in meters or feet).
- g = Acceleration due to gravity (9.807 m/sec^2 or 32.15 ft/sec^2).

These formulas are then applied to the calculation of loading factors by inserting the applicable maximum angles of ship attitude, their periods, and the location on the ship. Examples of the application of these formulas to the design requirements of two typical ship types for sea state 7 are as follows. For calculations of other sea conditions see 5.2.1.2:

<u>Example A:</u>	<u>A typical destroyer</u>	
	Beam (B)	15.2m (50 feet)
	Length (LBP)	152.4m (500 feet)
	Draft	6.1m (20 feet)
	Displacement	7,100 tonnes (7,000 tons)
	GM	1.52m (5 feet)
	Roll constant (C)	0.82 (0.45)
From table II, III and IV:	Roll period (T_r)	10 seconds
	Pitch period (T_p)	7 seconds
	Maximum roll angle	24 degrees
	Maximum pitch angle	4 degrees
	Heave acceleration (h)	0.2g
	Surge acceleration (s)	0.15g

$$A_x = 0.6841 + 1.470 + 0.003925\ X + 0.05624\ Z \quad m/sec^2$$
$$(2.243 + 4.823 + 0.003925\ X + 0.05624\ Z) \quad ft/sec^2$$

$$A_y = 3.989 + 0.02812\ X + 0.006924\ Y + 0.1653\ Z \quad m/sec^2$$
$$(13.08 + 0.02812\ X + 0.006924\ Y + 0.1653\ Z) \quad ft/sec^2$$

$$A_z = 9.807 \pm (1.960 + 0.05624\ X + 0.1653\ Y) \quad m/sec^2$$
$$(32.15 \pm (6.430 + 0.05624\ X + 0.1653\ Y)) \quad ft/sec^2$$

Example B: A typical aircraft carrier

	Beam (B)	38.1m (125 feet)
	Length (LBP)	304.8m (1,000 feet)
	Draft	10.67m (35 feet)
	Displacement	71,000 tonnes (70,000 tons)
	GM	3.05m (10 feet)
	Roll constant (C)	0.725 (0.40)
From table II, III and IV:	Roll period (T_r)	15.8 seconds
	Pitch period (T_p)	8 seconds
	Maximum roll angle	20 degrees
	Maximum pitch angle	3 degrees
	Heave acceleration (h)	0.2g
	Surge acceleration (s)	0.1g

$$A_x = 0.5133 + 0.9807 + 0.001690\ X + 0.03229\ Z \quad m/sec^2$$
$$(1.683 + 3.215 + 0.001690\ X + 0.03229\ Z) \quad ft/sec^2$$

$$A_y = 3.354 + 0.01615\ X + 0.01926\ Y + 0.05519\ Z \quad m/sec^2$$
$$(11.00 + 0.01615\ X + 0.01926\ Y + 0.05519\ Z) \quad ft/sec^2$$

$$A_z = 9.807 \pm (1.961 + 0.03229\ X + 0.05519\ Y) \quad m/sec^2$$
$$(32.15 \pm (6.430 + 0.03229\ X + 0.05519\ Y)) \quad ft/sec^2$$

40.5.2 To obtain the component of the design load, ($F_{(i)}$), in the x, y and z directions for any particular ship, multiply the loading factors $A_{(i)}$ for the selected location in the ship by the mass of the structure or equipment:

$$F_{(i)} = W/g \cdot A_{(i)}$$

Where: $F_{(i)}$ = Design load at specified location in x, y, or z direction (newtons or pounds)

W = Weight of structure or equipment (newtons or pounds)

$\frac{W}{g}$ = Mass of structure or equipment (kilograms or pounds $\cdot$ sec^2/ft)

$A_{(i)}$ = Loading factor in x, y, or z direction

g = Acceleration due to gravity (9.807 m/sec^2 or 32.15 ft/sec^2)

The load equation may also be rewritten, for example:

$$F_x = W/g \cdot A_x$$

$$F_y = W/g \cdot A_y$$

$$F_z = W/g \cdot A_z$$

And the magnitude of the total force acting on the structure or equipment is given by:

$$F = (F_x{}^2 + F_y{}^2 + F_z{}^2)^{1/2}$$

For a piece of equipment of a given weight at a given location, the distances X, Y, and Z are inserted into the bad factor equations. Then the load factors and the equipment weight are inserted into the load equations to obtain the design load. Continuing the examples begun above:

Example A: A typical destroyer

Equipment	Weight (W)	2224 newtons (500 pounds)
	Longitudinal location (X)	27.48 m (90.15 feet)
	Transverse location (Y)	5.03 m (16.50 feet)
	Vertical location (Z)	15.84 m (52.00 feet)

and with values inserted for X, Y and Z the load factors are:

$$A_x = 0.6841 + 1.470 + 0.1078 + 0.8908 = 3.153 \text{ m/sec}^2$$
$$(2.243 + 4.823 + 0.3538 + 2.924 = 10.34) \text{ ft/sec}^2$$

$$A_y = 3.989 + 0.7727 + 0.03483 + 2.618 = 7.415 \text{ m/sec}^2$$
$$(13.08 + 2.535 + 0.1142 + 8.596 = 24.32) \text{ ft/sec}^2$$

$$A_z = 9.807 \pm (1.960 + 1.545 + 0.8315) = 9.807 \pm 4.336 \text{ m/sec}^2$$
$$(32.15 \pm (6.430 + 5.070 + 2.727) = 32.15 \pm 14.23 \text{ ft/sec}^2$$

Then the components of design load are:

$$F_x = (2224/9.807) \cdot 3.153 = 715.0 \text{ newtons}$$
$$((500/32.15) \cdot 10.34 = 160.8) \text{ pounds}$$

$$F_y = (2224/9.807) \cdot 7.415 = 1682 \text{ newtons}$$
$$((500/32.15) \cdot 24.32 = 378.2) \text{ pounds}$$

$$F_{z_{max}} = (2224/9.807) \cdot (9.807 + 4.336) = 3207 \text{ newtons}$$
$$((500/32.15) \cdot (32.15 + 14.23) = 721.3) \text{ pounds}$$

And the magnitude of the force is

$$F = ((715.0)^2 + (1682)^2 + (3207)^2)^{1/2} = 3691 \quad \text{newtons}$$
$$(((160.8)^2 + (378.2)^2 + (721.3)^2)^{1/2} = 830.2) \quad \text{pounds}$$

Example B: A typical aircraft carrier

Equipment	Weight (W)	2224 newtons (500 pounds)
	Longitudinal location (X)	82.37 m (270.25 feet)
	Transverse location (Y)	16.61 m (54.50 feet)
	Vertical location (Z)	14.77 m (48.45 feet)

and with values inserted for X, Y and Z the load factors are:

$$A_x = 0.5133 + 0.9807 + 0.1329 + 0.4769 = 2.110 \quad \text{m/sec}^2$$
$$(1.683 + 3.215 + 0.4567 + 1.564 = 6.919) \quad \text{ft/sec}^2$$

$$A_y = 3.354 + 1.330 + 0.3199 + 0.8152 = 5.819 \quad \text{m/sec}^2$$
$$(11.00 + 4.365 + 1.050 + 2.674 = 19.09) \quad \text{ft/sec}^2$$

$$A_z = 9.807 \pm (1.961 + 2.660 + 0.8151) = 9.807 \pm 5.436 \quad \text{m/sec}^2$$
$$(32.15 \pm (6.430 + 8.726 + 2.674) = 32.15 \pm 17.83 \quad \text{ft/sec}^2$$

Then the components of the design load are

$$F_x = (2224/9.807) \cdot 2.110 = 478.5 \quad \text{newtons}$$
$$((500/32.15) \cdot 6.919 = 107.6) \quad \text{pounds}$$

$$F_y = (2224/9.807) \cdot 5.819 = 1320 \quad \text{newtons}$$
$$((500/32.15) \cdot 19.09 = 296.9) \quad \text{pounds}$$

$$F_{z_{max}} = (2224/9.807) \cdot (9.807 + 5.436) = 3457 \quad \text{newtons}$$
$$((500/32.15) \cdot (32.15 + 17.83) = 777.3) \quad \text{pounds}$$

And the magnitude of the total force is

$$F = ((478.5)^2 + (1320)^2 + (3457)^2)^{1/2} = 3731 \quad \text{newtons}$$
$$(((107.6)^2 + (296.9)^2 + (777.3)^2)^{1/2} = 839.0) \quad \text{pounds}$$

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE
DOD-STD-1399(NAVY) SECTION 301A	Interface Standard for Shipboard Systems Section 301A, Ship Motion and Attitude (Metric)

3a. NAME OF SUBMITTING ORGANIZATION	4. TYPE OF ORGANIZATION *(Mark one)*
	☐ VENDOR ☐ USER ☐ MANUFACTURER ☐ OTHER *(Specify)*: ______
b. ADDRESS *(Street, City, State, ZIP Code)*	

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional	b. WORK TELEPHONE NUMBER *(Include Area Code)* – Optional
c. MAILING ADDRESS *(Street, City, State, ZIP Code)* – Optional	8. DATE OF SUBMISSION *(YYMMDD)*

DD FORM 1426 82 MAR

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