INTERNATIONAL

SOCIETY OF ALLIED WEIGHTS ENGINEERS, INC.

Serving the Aerospace - Shipbuilding - Land Vehicle and Allied Industries

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Standard Coordinate Systems for Reporting Mass Properties of Marine Vehicles

Revision Letter 1.1

Prepared by
Government - Industry Workshop
Society of Allied Weight Engineers, Inc.

Change Record

Issue No.	Date	Description	Entered by
-	June 5, 1996	Initial issue	
1.1	Nov 8, 2009	Changed RP title from "…Surface Ships and Submarines" to "…Marine Vehicles" Added definitions for: roll, pitch, yaw, left and right hand rules, and forward and aft perpendiculars. Modified definitions for: Referenced origin, Longitudinal lever, Transverse lever, and Vertical lever. Updated Referenced Origin and made it Section 3.0 Deleted Figure 2 (coordinate system for submarines) and revised figures 1 through 3. Incorporated RP 14 European Standard Axes into Section 4.2. Added Standard Axes for Unique Marine Vehicles as Section 4.3. Combined Center of Gravity section with Reference Origin section. Removed Section 4 Weight Moment of Inertia / Gyradius for incorporation into a future RP. Moved Section 3.3.2 Calculation to Section 5.0 Added Section 6.0 Standard Coordinate System For Weight Moment Of Inertia/Gyradius Added Reference Modified format to suit G/I format	J. Capin

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1 Scope

The scope of this Recommended Practice is to establish acceptable three-coordinate reference systems for marine vehicles. Each coordinate system will include a defined origin, specified axes of rotation, and a sign convention in order to establish uniformity in mass property data collection and reporting. The use of a standard coordinate system will minimize the possibility of error due to differences in coordinate systems used by suppliers, designers, builders, regulatory bodies, or owners. These coordinate systems will be used in the determination of centers-of-gravity. They will also be used to determine weight moments of inertia as they relate to the three rotational degrees of freedom: roll, pitch and yaw.

2 Reference Documents

This recommended practice shall be used in conjunction with the following publications. When the following specifications are superseded by an approved revision, the revision shall apply.

1) SAWE RP 12. 2002. Weight Control Technical Requirements for Surface Ships. SAWE Recommended Practice

3 Definitions, Abbreviations, Acronyms

The definitions used in this recommended practice are found in Table 1 below.

Table 1. Example of definitions and abbreviations table.

Term	Symbol	Definition
Aft Perpendicular	AP	Is generally a vertical datum line passing through the ship's rudder stock or at the aft end of the rudder post. For submarines this is normally the after end of the propeller.
Center of Gravity	CG	The center through which all weights which make up the ship and its contents may be assumed to act. This center has the conventional meaning used in mechanics when it applies to a ship (i.e., It is the point at which the sum of the moments of all the weights in the ship, with reference to any axis through this point, is equal to zero).
Forward Perpendicular	FP	Is a vertical datum line passing through the intersection of the ship's stem (or bow) with the waterline (usually the design waterline). For submarines this is normally the very forward-most point of the hull.
Gyradius		The square root of the quotient of the ship's weight moment of inertia about the roll, pitch, and yaw axes, respectively, divided by the ship's displacement.
Left Hand Rule		A common mnemonic used to represent a coordinate system. If you extend your thumb, index finger, and middle finger of the left hand and you point your index finger in the direction of the x axis and point your middle finger in the direction of the y axis, then your thumb will point in the direction of the z axis.

Longitudinal Lever	The perpendicular distance from a transverse vertical plane through the referenced origin of the ship to the center of gravity of an item.
Moment	The product of an item's weight times the perpendicular distance of the item's center of gravity about the referenced axis.
Pitch	A rotation about the transverse axis (y).
Pitch Inertia	The inertia about the transverse axis (y) through the ship's center-of gravity.
Referenced Origin	The location of the intersection of the x, y and z axis referenced to the marine vehicle.
Right Hand Rule	A common mnemonic used to represent a coordinate system. If you extend your thumb, index finger, and middle finger of the right hand and you point your index finger in the direction of the x axis and point your middle finger in the direction of the y axis, then your thumb will point in the direction of the z axis.
Roll	A rotation about the longitudinal axis (x).
Roll Inertia	The inertia about the longitudinal axis (x) through the ship's center-of gravity.
Transverse Lever	The perpendicular distance from the vertical centerline plane of the ship to the center of gravity of an item.
Vertical Lever	The perpendicular distance from a horizontal plane through the vertical reference of the ship to the center of gravity of an item.
Yaw	rotation about the vertical axis (z).
Yaw Inertia	The inertia about the vertical axis (z) through the ship's center of gravity.

4 General Requirements

There are several origin conventions in use for marine vehicles and this recommended practice defines the preferred conventions. The particular coordinate system chosen shall define the origin for reporting all centers-of-gravity and weight moments of inertia. Regardless of which standard coordinate system is employed, there are several basic rules that should be followed:

- Avoid changing coordinate systems during the course of a program.
- Clearly communicate to all parties involved the specific system used.
- Clearly identify the coordinate system and axes of rotation to be used.
- Use simple diagrams describing the coordinate system to minimize the possibility of confusion
- Ensure that all computer software programs communicate and incorporate mass property data correctly (e.g. the software used by a vendor may report data in a different convention and could cause errors if incorporated directly into software used by the shipyard).

4.1 Referenced Origin

The referenced origin as illustrated in Figure 1 is a point located within a three axes coordinate system from which distances are measured in order to define the location of the marine vehicle's center of gravity. The distance measured vertically along the z axis from the referenced origin to the ship center of gravity is referred to as the Vertical Center of Gravity (VCG). The distance measured longitudinally along the x axis from the referenced origin to the ship center of gravity is referred to as the Longitudinal Center of Gravity (LCG). The distance measured transversely along the y axis from the referenced origin to the ship center of gravity is referred to as the Transverse Center of Gravity (TCG). The locations for preferred reference origins are defined in sections 4.1 and 4.2.

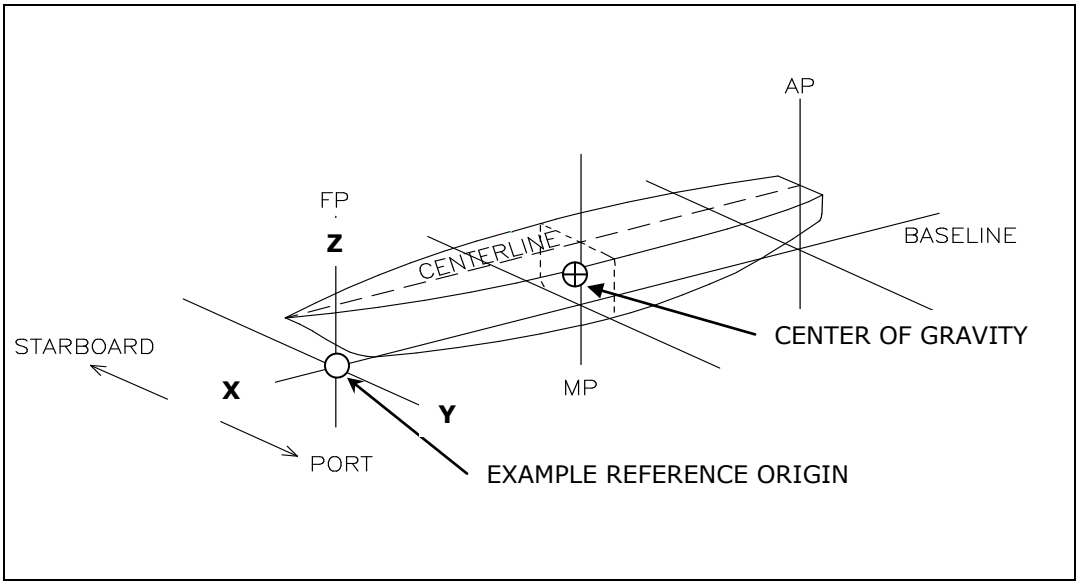

Figure 1 Referenced Origins

4.2 Standard Coordinate Systems

4.2.1 Forward Standard Coordinate Systems – Station 0 at FP

The forward standard coordinate system is a left hand rule system for marine vehicles as shown in Figure 2. This coordinate system is used with framing conventions originating at the forward perpendicular (FP) and ending at the stern. The x-axis is oriented at the baseline along the centerline of the ship. Longitudinal dimensions are measured along or parallel to this axis with the origin at the forward perpendicular. Locations aft of the origin are positive. The y-axis runs transversely port and starboard. Transverse dimensions are measured along or parallel to this axis with the origin on centerline. Locations to port are positive. The z axis runs vertically and dimensions are measured along or parallel to this axis. Locations above the baseline are positive.

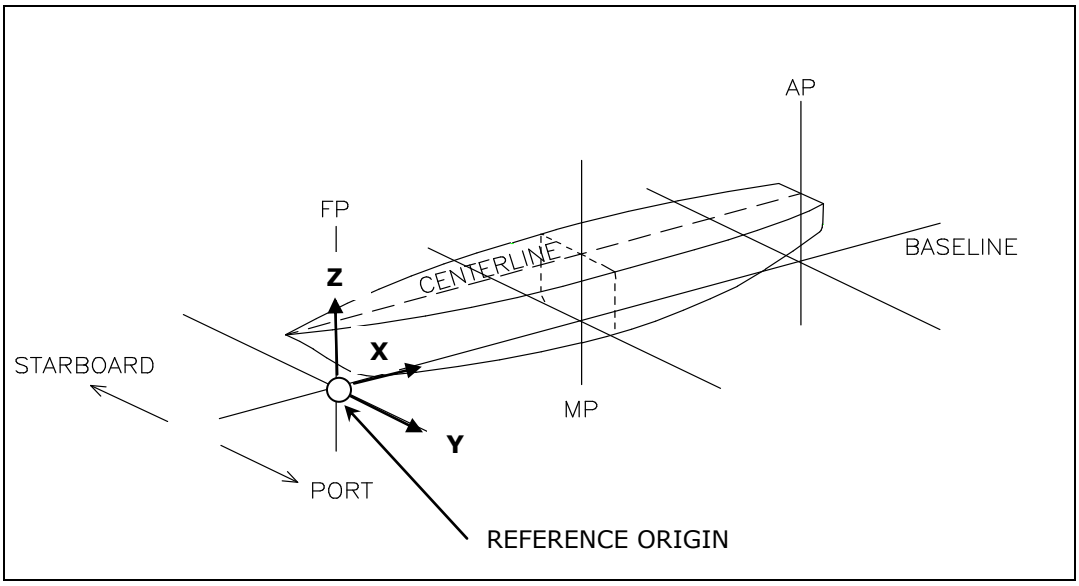

Figure 2 View of Ship with Forward Standard Coordinate System

4.2.2 Aft Standard Coordinate System – Station 0 at AP

The aft standard coordinate system is a right hand rule system for marine vehicles as shown in Figure 3. This coordinate system is used with framing conventions that originate at the aft perpendicular (AP) and end at the bow. The x-axis is oriented at the baseline along the centerline of the ship. Longitudinal dimensions are measured along or parallel to this axis with the origin at the aft perpendicular. Locations forward of the origin are positive. The y-axis runs transversely port and starboard. Transverse dimensions are measured along or parallel to this axis with the origin on centerline. Locations to port are positive. The z axis runs vertically and dimensions are measured along or parallel to this axis. Locations above the baseline are positive.

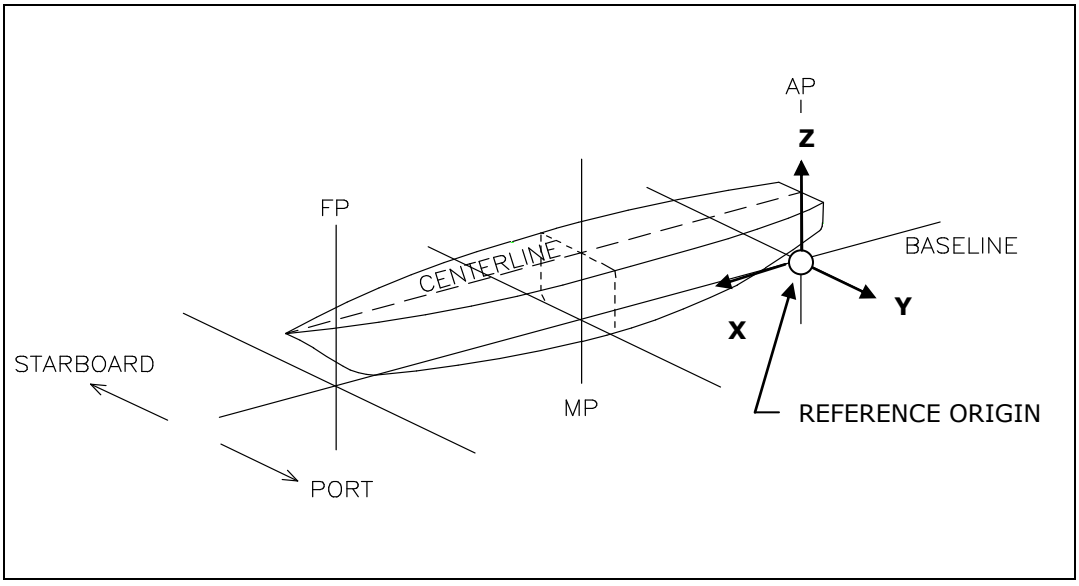

Figure 3 View of Ship with Aft Standard Coordinate System

4.3 Calculation

The weight estimate for a ship at any stage in the design is composed of a finite number of items. The weight of each of these items is included in the estimate along with the location of the item's center of gravity (CG). This is given as the vertical (z), longitudinal (x) and transverse (y) distance of the center of gravity from the defined referenced origin. This data is sufficient to calculate the total weight and center of gravity of the ship by simply adding the weights and moments of the item's center of gravity about the referenced origin.

4.4 Standard Coordinate System for Weight Moment of Inertia/gyradius

The weight moment of inertia of marine vehicle is calculated relative to a reference origin about the longitudinal x axis for roll, transverse y axis for pitch, and vertical z axis for yaw. The reference origin is located at the marine vehicle's center of gravity. The three rotational axes for motions are shown in Figure 4. A bow up rotation is positive for pitch, a bow to port rotation is positive for yaw, and a port side up rotation is positive for roll. Both Cimino and Redmond (1991) and Cimino and Tellet (2007) contain the guidelines for calculating the moments of inertia and the gyradii.

Care should be taken when computer systems have the capability to integrate component inertias to ensure the axes the computer uses are consistent with the intended coordinate system.

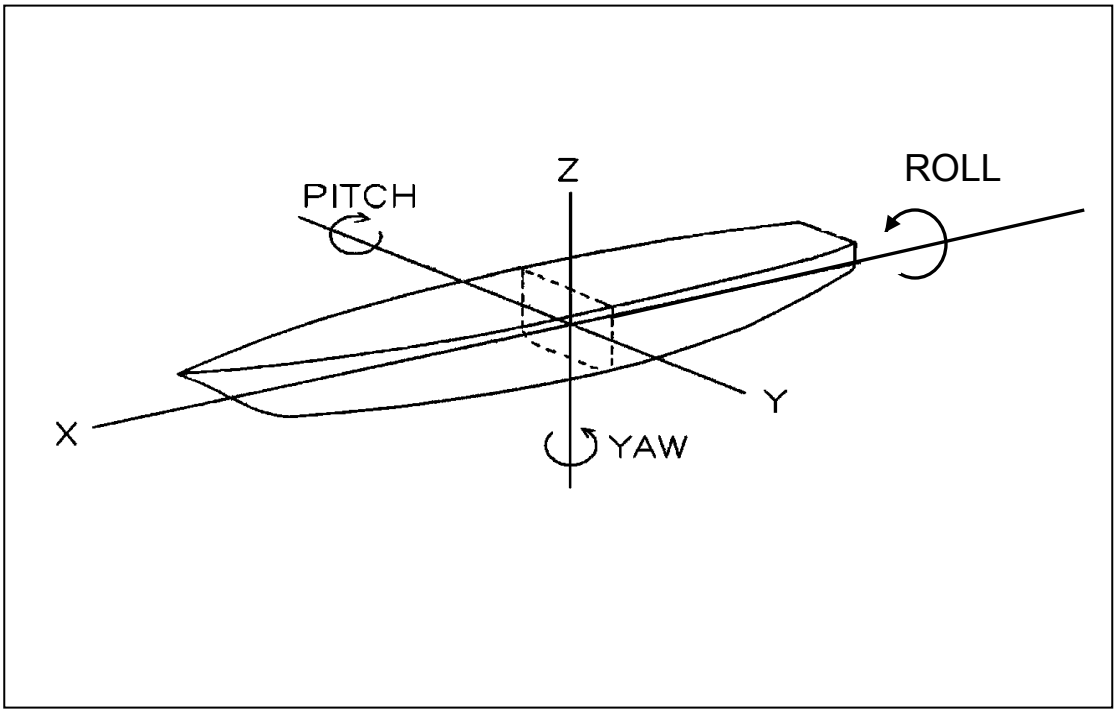

Figure 4 Three Rotational Motions of a ship

5 References

Cimino, D., and Redmond, M. 1991. Naval ships' weight moment of inertia – A comparitive analysis, SAWE Paper No. 2013. San Diego.

Cimino, D., Tellet, D., eds. 2007. *Marine Vehicle Weight Engineering*, SAWE Inc