DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
1333 ISAAC HULL AVE SE
WASHINGTON NAVY YARD DC 20376-0001

IN REPLY TO

NAVSEAINST 9096.6B
Ser 05P/017
16 August 2001

NAVSEA INSTRUCTION 9096.6B

From: Commander, Naval Sea Systems Command

Subj: POLICY FOR WEIGHT AND VERTICAL CENTER OF GRAVITY ABOVE BOTTOM OF KEEL (KG) MARGINS FOR SURFACE SHIPS

Ref: (a) Dept of Defense Regulation No. 5000.2-R (R
(b) CNO memo Ser 00/6U300255 of 19 Aug 86 (NOTAL)
(c) OPNAVINST 9096.1
(d) NAVSEAINST 9096.3C (R

Encl: (1) NAVSEA Acquisition Weight and KG Margin Values
(2) NAVSEA Service Life Allowances for weight and KG for New Surface Ships (R

1. Purpose. To provide the policy for weight and vertical (R
center of gravity for acquisition margins and Service Life (R
Allowances for U. S. Navy Surface Ships. To revise the current (R
instruction and update the enclosures. The update includes the (R
results of a later statistical analysis that includes additional (R
ships, updates Service Life Allowance requirements for (R
amphibious ships, and includes acquisition reform terminology. (R
Parentheses and change symbols at the left or right indicate (R
where text has been changed. Square bracketed text reflects (R
acquisition reform terminology as defined in reference (a). (R

2. Cancellation. NAVSEAINST 9096.6A of 17 February 1987. (R

3. Applicability. This Instruction applies to NAVSEA managed ship projects undergoing design (including new and modified repeat designs), conversion or modernization or, on a case basis as designated by the Deputy Commander for Integrated Warfare Systems (SEA 05) where a major impact on mass properties of the ship is anticipated. It shall be effective for all of the above (R
design projects that have not passed Milestone I by the issue (R
date of this Instruction. (R

0693-LD-100-8198

4. Definitions

a. Mass properties. Mass properties are those physical characteristics which define the magnitude, location, and distribution of weight in the ship. They include weight, center of gravity location, weight moments, and moments of inertia. The term "mass" is more definitive than the somewhat ambiguous term "weight"; however, historical use and common practice will lead to the retention of the word "weight" for many years as applied to the control of mass properties aboard ships.

b. Weight estimate. A weight estimate is a prediction of the weight and location of the center of gravity of the ship at the time of delivery based on the definition of the design at the time the estimate is computed.

c. Acquisition margins. Acquisition margins are weight and KG allowances included in weight estimates to account for the inherent limits of precision and the undefined variations of component weight and center of gravity that take place during design development and the construction of ships. Specific margin values are developed for, and confined to, four accounts required
R) for weight control accountability. The structure of the margin
R) accounts adheres to acquisition reform design phases as well. The
R) margin accounts are:

R) (1) Preliminary and Contract Design [Phase I - Program
R) Definition and Risk Reduction]. This weight and KG margin
R) allocation accounts for increases associated with design
R) development occurring in these phases.

R) (2) Detail Design and Building [Phase II - Engineering
R) and Manufacturing Development]. This weight and KG allocation
R) accounts for contractor-responsible design changes to the current
R) weight/KG due to ship construction drawing development, growth of
R) contractor-furnished material, omissions, and errors in the
R) Accepted Weight Estimate, as well as differing shipbuilding
R) practices, omissions and errors in the ship construction drawings,
R) unknown mill tolerances, outfitting details, variations between
R) the actual ship and its curves of form and similar differences.

(3) Contract Modifications [Phase II - Engineering and
R) Manufacturing Development]. This weight and KG allowance is
R) included in the weight estimate to account for increases
R) associated with contract modifications issued during the Detail
R) Design and Building Phase.

(4) Government-Furnished Material [Phase II - (R
Engineering and Manufacturing Development]. This weight and KG (R
allowance is included in the weight estimate to account for (R
increases caused by the growth in Government-furnished material (R
during the Detail Design and Building Phase. (R

These accounts are briefly defined in Enclosure (1). Accounts 3
and 4 can be considered as subsets of account 2, and account 4 (R
may not apply to all designs. (R

d. Service Life Allowances. Weight and KG allowances
included in design to accommodate changes due to both authorized
(e.g. ship alterations), and unplanned growth (e.g. accumulating
of paint and deck covering, personal belongings, unauthorized (R
changes, etc.) during the ship's operational lifetime which (R
increase displacement and impact stability. (R

5. Discussion

a. Acquisition weight and KG margins are essential (R
elements of ship design practice at NAVSEA since this practice
utilizes the concept of a predicted baseline weight estimate that (R
reflects the displacement, KG, trim and list of the ship at
delivery. These margins are an essential element to mitigate the (R
risk of delivering a ship that does not meet required mass (R
properties characteristics. The margin allocation process takes (R
the following into account: (R

(1) Historical patterns of refinement and growth as
reflected in weight estimates during the progress of a design and
during shipbuilding are reasonably well established and are
subject to statistical analysis.

(2) Each ship design requires a systematic and (R
structured approach which gives individual consideration to its (R
unique features, unknowns, indeterminates, and complexities. (R

(3) Injudicious application of margins, whether
excessive or insufficient, can result in unrealistic projections
of ship displacement and KG at delivery which generally either
increase shipbuilding costs related to ship size or result in
expensive corrective measures.

R) (4) Acquisition strategy and policies can deviate
R) substantially from previous practices and design requirements,
R) impacting necessary margins.

R) b. Service Life Allowances (SLAs) also are required for
R) weight and KG since experience has shown that the displacement and KG of a naval ship tend to increase during commissioned service. These allowances are intended to provide for reasonable growth during the ship's service life without unacceptable compromise of the principal naval architectural characteristics, notably those
R) characteristics relating to the specific performance of hull
R) strength, reserve buoyancy, and stability. These SLAs must be
R) incorporated in the early stage of design and construction in
R) order to be available at delivery.

R) 6. Policy. Acquisition margins and SLAs shall be applied as specified herein:

R) a. Acquisition Margin. Acquisition margins shall be
R) included in all weight estimates. The margins shall be tailored
R) using a systematic and structured approach to the specifics of the
R) design and shall reflect aspects such as the uniqueness of the design and the degree of definition of developmental systems incorporated. Acquisition margin values should be developed according to the guidance of enclosure (1).

R) b. Service Life Allowances

(1) SLAs shall be included in all designs in
R) accordance with enclosure (2), such that, when delivered each naval surface ship shall be capable of accommodating the anticipated growth of weight and KG during its service life
R) without compromise of the hull strength, reserve buoyancy, and
R) stability characteristics established for the class. Performance
R) characteristics which must be satisfied at the end of a new
R) ship's service life shall be identified by dialogue with the
R) OPNAV sponsor and shall be highlighted in the Operational
R) Requirements Document (ORD). Other performance characteristics,
R) normally including speed and endurance, which are satisfied at
R) delivery, are permitted to degrade as service life growth occurs.
R) However, predictions for these characteristics, both at delivery
R) and at the end of the predicted service life shall be prepared
R) and reported in Preliminary and Contract Design [Program
R) Definition and Risk Reduction] Reports. Basic SLAs were
R) established by reference (b) for new construction ships.

Enclosure (2) reflects these values by ship types with an (R
additional subset. For any deviation from the values of (R
enclosure (2), the concurrence of the CNO with the selected (R
values shall be obtained via the OPNAV sponsor in accordance with (R
reference (c). (R

(2) SLAs for major modernizations and conversions shall be assessed on a case basis. A study taking into account the age of the ship, the remaining service life, the available weight and KG growth potential, etc., shall be performed to determine a specific recommendation for the modernization / conversion. These values, with supporting rationale, shall be (R
highlighted in appropriate OPNAV sponsor presentations.

(3) SLAs are generally depleted during the service life of a ship. Depletion of the SLAs and the status of each ship with respect to its naval architectural limits shall be monitored throughout the ship's active service. Compensation (R
requirements for weight and/or moment for any alteration which (R
unacceptably degrades the remaining stability or reserve buoyancy allowances shall be identified in accordance with reference (d).

7. Responsibilities. Implementing the foregoing policy, the following responsibilities are assigned:

a. The Deputy Commander for Integrated Warfare Systems (SEA 05) shall: (R

(1) Develop/approve and assign weight and KG acquisition margins and SLAs for each ship design, modernization, (R
or conversion in accordance with this Instruction. (R
(R

(2) Develop/approve and maintain procedures for assigning acquisition margins and allowances, and for ensuring (R
that these margins and allowances are not compromised during ship design and construction. (R

(3) Develop/approve and implement procedures to monitor growth during ship service and to prevent compromise of (R
specific performance characteristics, hull strength, reserve (R
buoyancy and stability. (R

(4) For nuclear powered ships, coordinate the above actions with SEA 08.

R) b. For ship acquisition programs the cognizant Platform
R) Directorates shall submit for review by the OPNAV sponsor and approval by the CNO any deviation to the SLAs specified in this Instruction.

G. R. YOUNG
Deputy Commander for
Integrated Warfare Systems

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NAVSEA ACQUISITION WEIGHT AND KG MARGIN VALUES (*

1. Ship design practice utilizes the concept of a predicted displacement and KG at delivery. To accomplish this, the amount of margin to be provided must be determined and included in feasibility [Concept Exploration] studies, both for new designs and for feasibility studies of conversions or modernizations. While feasibility studies only require a single overall margin allocation for weight and one for KG, as acquisition programs develop they require more definitive weight and KG margins allocations for each phase of the design to account for increases associated with design development and building during those phases. This enclosure provides guidance for total margins at the feasibility stage, and secondly for separate margin accounts later in the acquisition phase.

2. The data in the margin range tables in this enclosure is derived from historical growth results. The ship database from which these ranges have been derived includes only lead ships of the class or follow ships built by a different yard. In addition, they reflect normal design development with growth due to many indeterminate influences. Excluded are ship designs which had their normal design development disrupted or basic characteristics altered by outside influences. In the tables, the lower range (mean) represents a 50% chance that the selected margin will be exceeded, and conversely, the higher range (mean plus one standard deviation) represents a 16% chance that the selected margin will be exceeded.

3. The margins selection process should be tailored to the specifics of the proposed design and reflect aspects such as the uniqueness of the design, the degree of definition of developmental systems incorporated, the acquisition process, and shipbuilding methods and practices. These considerations must be addressed through a structured and systematic approach, which characterizes the design uncertainty[1].

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[1] A sample method is presented in "Weight and KG Margin Analysis of Naval Surface Ships", Society of Allied Weight Engineers, Inc., Paper No. 2356, dated 19 May 1997.

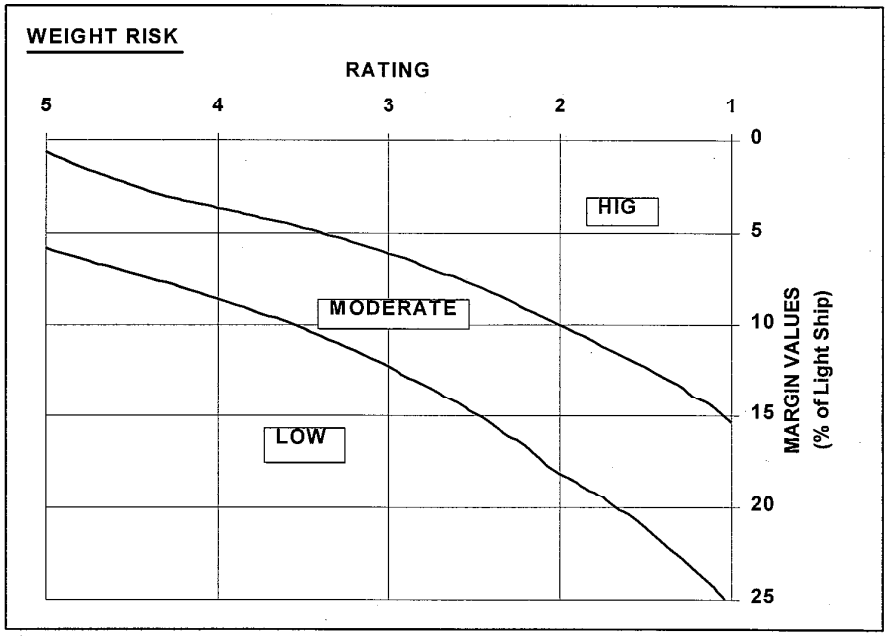
4. Margins that result from a systematic and structured approach would be expected to fall within the mean and mean plus one standard deviation guidance values shown in the tables below. In special cases, rational deviations from the guidance values of enclosure (1) may be considered. For example, design studies reflecting radical hull forms, exotic hull materials, or major subsystems that are in the early development stages may entail larger margin allocations. Conversely, incorporating identical items from previous designs may allow smaller margin allocations.

5. For the first stage of margin selection at the feasibility stage [prior to Milestone I], Table 1 provides the range of total margin values. As discussed previously, these values provide a historical comparison to assess the margins developed using a systematic approach. Tables 2 through 4 provide associated risk. Once the appropriate total margin values have been selected, a level-of-confidence (or risk) may be associated by using Table 2. Table 3 provides a summary of the design characterization ratings, which along with the selected margin will give an associated risk. Table 4 relates the three general levels of risk (i.e., low, moderate and high) to the necessary programmatic risk consequences. The selection of margin values with high risk must be fully justified and appropriate risk mitigation planned. The selection of low risk margin values should also be justified, as it could result in extra cost to the acquisition program.

TABLE 1 ACQUISITION MARGIN VALUE RANGES FOR FESIBILITY [CONCEPT EXPLORATION] AND OTHER SPECIAL STUDIES

	Percentage of Displacement of the Light Ship Condition	
	Mean	Mean + One Standard Deviation
Total Acquisition Weight Margin	6.0	17.5
	Percentage of KG of the Light Ship Condition	
	Mean	Mean + One Standard Deviation
Total Acquisition KG Margin	4.8	14.5

TABLE 2 WEIGHT AND KG RISK ASSESSMENT



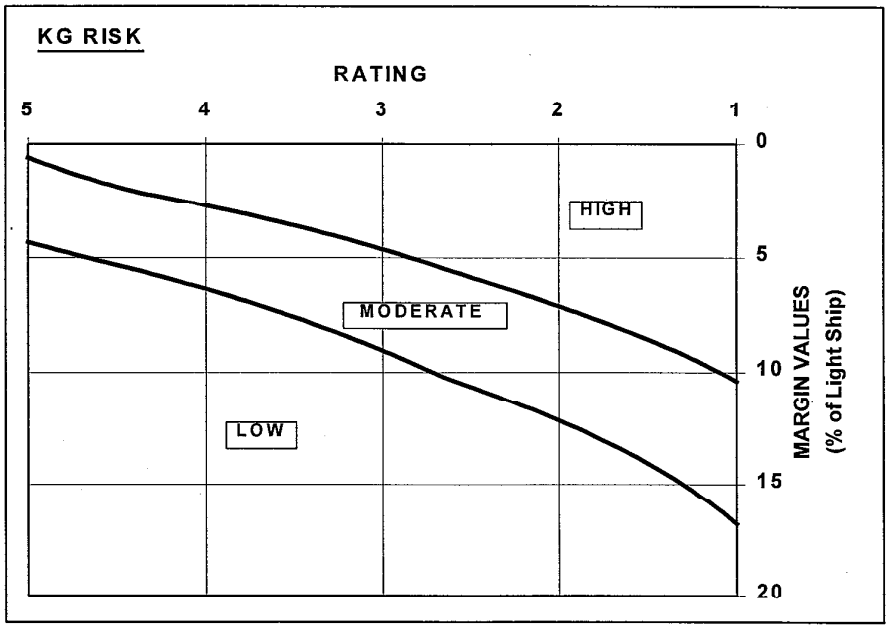


TABLE 3 DESIGN CHARACTERIZATION RATINGS

RATING	DESIGN CHARACTERIZATION
1	Developmental design/High level of uncertainty
2	New concept design/Some significant level of uncertainty
3	Similar design with major changes/Some level of uncertainty
4	Similar design with minor changes/Low level of uncertainty
5	Follow design with minor changes/Almost no uncertainty

TABLE 4 RISK CONSEQUENCES

RISK ASSESSMENT	RISK CONSEQUENCES
HIGH	Design might not meet safety limits (subdivision, strength, service life allowances), might involve redesigns and schedule impacts. Extreme weight control measures will be required.
MODERATE	Risk can be controlled by an effective weight control program that would involve incentives, Not-to-Exceed values, and other risk mitigation measures.
LOW	Safe design with very little uncertainty and applying standard weight control and reporting procedures.

6. Secondly, for acquisition programs following Preliminary Design [Milestone I] approval, appropriate weight and KG margin values need to be selected within the ranges shown in Table 5. The margin selection should be tailored to the specifics of each design by a characterization method applied to each design phase separately to produce specific weight and KG margin values for each design phase. At this point, the characterization approach becomes more detailed and it involves programmatic as well as technical aspects. Typical programmatic considerations are: applicable design phases and their length; imposition of an Accepted Weight Estimate, Not-to-Exceed values; liquidated damages, or conversely, performance incentives for weight and KG. Typical technical considerations involve: overall maturity of the design; evaluation of each system in terms of developmental

versus traditional; available weight and KG estimating methods; a weighting method that relates each system to the overall design, shipbuilders' weight control plan and practices, and others. Design margins are generally allocated into the following accounts:

a. Preliminary/Contract Design Allocation
b. Detail Design Allocation
c. Contract Modification Allocation
d. Government-Furnished Material Allocation

TABLE 5 VALUE RANGES FOR SHIP DESIGN ACQUISTION PHASES

Weight Margin	Percentage of Displacement of the Light Ship Condition	
	Mean	Mean + One Standard Deviation
Preliminary and Contract Design [Program Definition/Risk Reduction]	0.8	4.4
Detail Design and Building [Engineering/Manufacturing Development]	4.5	9.8
Contract Modification	0.4	2.1
Government-Furnished Material	0.2	0.7

KG Margin	Percentage of KG of the Light Ship Condition	
	Mean	Mean + One Standard Deviation
Preliminary and Contract Design [Program Definition/Risk Reduction]	2.7	6.1
Detail Design and Building [Engineering/Manufacturing Development]	1.7	5.1
Contract Modification	0.3	1.9
Government-Furnished Material	0.1	0.4

NAVSEA SERVICE LIFE ALLOWANCES FOR WEIGHT AND KG FOR NEW SURFACE SHIPS (*

1. The weight and KG values in Table 1 are based on historical growth data for the ship types noted. These are the minimum values that must be provided in new construction ships. As the values in Table 1 are based on a service life of 20 years (30 years for carriers and large deck amphibious warfare ships), an increased SLA may be required for ships with longer projected service lives. The increase in SLAs should be evaluated on a case basis until there is data to update Table 1.

TABLE 1 SERVICE LIFE ALLOWANCE VALUES

Ship Type	Weight[a] Percent(%)	KG[b] Meters(Feet)
Combatants	10.0	0.30 (1.0)
Carriers	7.5	0.76 (2.5)
Amphibious Warfare Ships types		
- Large deck	7.5	0.76 (2.5)
- Other	5.0	0.30 (1.0)
Auxiliary Ship types	5.0	0.15 (0.5)
Special Ships and Craft	5.0	0.15 (0.5)

a. Weight percentage based on the predicated full load departure displacement at delivery.

b. KG values based on the predicted full load departure KG at delivery.

2. For ships designed to carry dry cargo, i.e., auxiliary and amphibious ships, the full load departure condition will include the notional dry cargo load as defined by the ORD. For ships designed to carry liquid cargo the cargo tanks shall be considered filled to 95% of the total net volume of each tank designed to carry petroleum products and 100% of the total net volume of each tank designed to carry cargo, potable water, or cargo reserve feed water.

3. For SWATH or other unique hull form designs, the minimum SLAs for weight and KG shall also be based on Table 1 for the applicable ship type. In addition, an analysis shall be conducted to determine the center of anticipated SLA growth for KG to validate the values in Table 1. The results of this analysis shall be highlighted to the OPNAV Sponsor along with the rationale for values used.