**Naval Surface Warfare Center**

**Carderock Division**

West Bethesda, MD 20817-5700

**NSWCCD-80-TR-2016/020** **JULY 2016**

Naval Architecture and Engineering Department

Technical Report

# Estimating Weight and Moment for Ship Change Document Technical Assessment Team Reviews

by

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NSWCCD

NSWCCD-80-TR-2016/020

# REPORT DOCUMENTATION PAGE

*Form Approved*
*OMB No. 0704-0188*



| 1. REPORT DATE *(DD-MM-YYYY)* | 2. REPORT TYPE | 3. DATES COVERED *(From - To)* |
|---|---|---|
| 07-26-2016 | Technical Report | N/A |

**4. TITLE AND SUBTITLE**

ESTIMATING WEIGHT & MOMENTS for SCD Technical Assessment Team Reviews

**5a. CONTRACT NUMBER**
N/A

**5b. GRANT NUMBER**
N/A

**5c. PROGRAM ELEMENT NUMBER**
N/A

**6. AUTHOR(S)**
Adams, Christopher L.

**5d. PROJECT NUMBER**
N/A

**5e. TASK NUMBER**
N/A

**5f. WORK UNIT NUMBER**
N/A

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
NAVSEA Carderock
Naval Surface Warfare Center
Carderock Division (Code 8440)
9500 Macarthur Boulevard
West Bethesda, MD 20817-5700

**8. PERFORMING ORGANIZATION REPORT NUMBER**
NSWCCD-80-TR-2016/000

**9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)**
Naval Surface Warfare Center Carderock Division
Carderock Division (Code 8440)
9500 Macarthur Boulevard
West Bethesda, MD 20817-5700

**10. SPONSOR/MONITOR'S ACRONYM(S)**
PMS 312

**11. SPONSOR/MONITOR'S REPORT NUMBER(S)**
N/A

**12. DISTRIBUTION / AVAILABILITY STATEMENT**
DISTRIBUTION STATEMENT (A). Approved for public release: distribution unlimited.

**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**
The purpose of this document is to give general instructions to the SCD originators on how to prepare basic weight estimations for the Ship Change Document (SCD) Technical Assessment Team (TAT) review process.

**15. SUBJECT TERMS**
Weight and Moment, Weight Calculations

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT | b. ABSTRACT | c. THIS PAGE | | | Christopher Adams |
| Unclassified | Unclassified | Unclassified | See 12. | 20 | 19b. TELEPHONE NUMBER *(include area code)* 301-227-3868 |

**Standard Form 298 (Rev. 8-98)**
**Prescribed by ANSI Std. Z39.18**

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ADMINSTRATIVE INFORMATION

This guidance was created at the Naval Surface Warfare Center, Carderock Division (NSWCCD), West Bethesda, MD by the Naval Architecture and Engineering Department (Code 80) in the Naval Architecture and Engineering Division (Code 8440). This guidance was developed in FY16 and was tasked by the In-Service Aircraft Carrier Program Office (PMS 312).

## SUMMARY

While developing an Ship Change Document (SCD) for review and approval, the SCD Originator is responsible for developing and providing an estimated weight and moment for the impact of the SCD. While not required for Phase II reviews, it is useful to have, can later be refined for Phase III reviews. Weight and moment information is required for Phase III reviews and approvals. This information is used as a placeholder in helping predict the future weight and stability condition of the fleet.

The purpose of this document is to provide SCD originators the ability to do weight and moment estimates for SCDs. This includes determining weight values, centers, moments, and the correct way to fill out the SCD Technical Assessment Team (TAT) form on the Navy Data Environment (NDE).

This document is NOT intended to be used for detailed weight and moment calculations for approving SCDs in Phase IV or beyond.

# INTRODUCTION

## 1.1 Definitions:

*Aft:* The direction towards the stern. See Figure 1 & 2.

*Bow:* The front of a ship. See Figure 1 & 2.

*Centerline:* A vertical plane through the center of the hull. See Figure 2.

*Compartment Number:* Often referred to as a 'TAC' number, every space in a ship is assigned one. It identifies the deck and longitudinal location, the side of the ship, and the purpose of the space.

*Frame:* The "ribs" of a ship's hull. They are typically evenly spaced and can be used for identifying locations along the longitudinal length of a ship.

*Forward:* The direction towards the bow.

*List:* Angle due to asymmetric moment such as caused by shifted weights or damage about the longitudinal axis.

*Midship:* The longitudinal middle of the ship between the forward and aft perpendicular. See Figure 1.

*Port:* When looking forward, the left side of the ship. See Figure 2.

*Starboard:* When looking forward, the right side of a ship. See Figure 2. The island is on this side of the ship for aircraft carriers and certain amphibious assault ships.

*Stern:* The back of a ship.

*Long Ton:* Also known as Long Ton is equal to 2,240 pounds.

*Tonne:* Tonne is a metric ton, equal to 2,205 pounds or 1,000 kgs.

*Trim:* Longitudinal angle due to forces caused by shifted weights or changing liquid loads.

## 1.2 Abbreviations:

*AP:* After Perpendicular – Intersection of the Full Load waterline and the centerline of the hull aft.

*FP:* Forward Perpendicular – Intersection of the Full Load waterline and the stem.

*KG:* Vertical Center of Gravity to the Keel – Not to be confused with VCG this is the vertical center of gravity including the thickness of the keel.

*LBP:* Length Between Perpendiculars – The distance between the AP and FP. See Figure 1.

*LCG:* Longitudinal Center of Gravity – The center of gravity measured along the ship's length. Zero reference is typically midship, but can be measured from other known reference points such as the AP and FP.

*LMOM:* Longitudinal Moment – The product of the weight of an item multiplied by its LCG.

*LOA:* Length Overall – The extreme length of a ship. See Figure 1.

*NDE:* Navy Data Environment – A centralized database and web-based application used to manage Navy modernization, maintenance, logistics, workload, and performance. This is where SCDs are submitted for review and stored.

*SCD:* Ship Change Document – Document that summarizes a proposed alteration to a ship or class.

*TAT:* Technical Assessment Team – The team that reviews and approves SCD to advance to the next development phase.

*TCG:* Transverse Center of Gravity – The center of gravity measured to the port or starboard from the ship's centerline.

*TMOM:* Transverse Moment – The product of the weight of an item multiplied by its TCG.

*VCG:* Vertical Center of Gravity – The center of gravity typically measured from the baseline of the ship.

*VMOM:* Vertical Moment – The product of the weight of an item multiplied by its VCG.

*WL:* Waterline – A line that runs between the forward and aft drafts that represents the intersection of the above water portion of the ship and the below water portion.

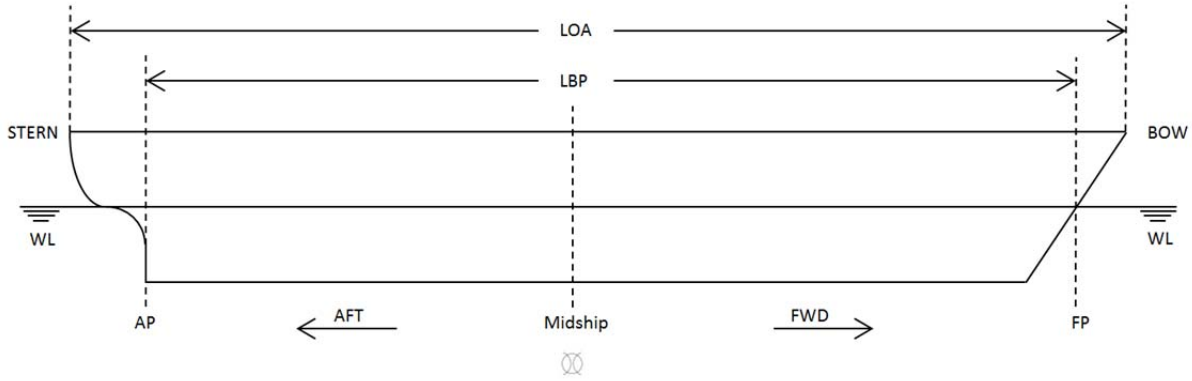


**Figure 1: Typical Profile View**

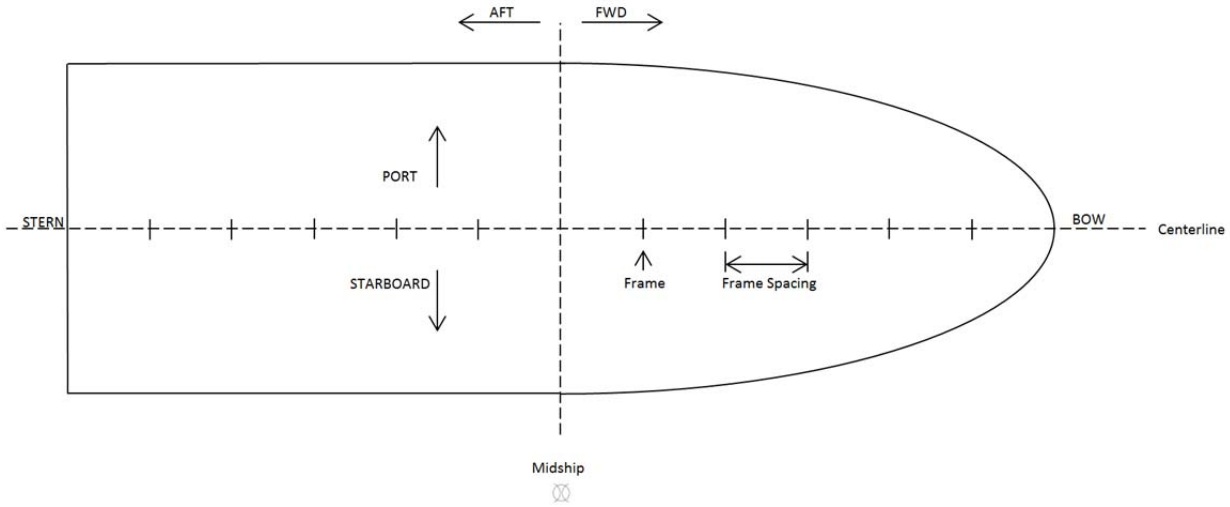


**Figure 2: Typical Plan View**

## 1.3 Loading Conditions

The Light Ship (Condition A) loading condition is defined via Naval Ship's Technical Manual (NSTM) Chapter 096, Weight and Stability, as follows:

> *"Light Ship (Condition A):* Ship complete, ready for service in every respect, including permanent ballast (solid and liquid), on-board repair parts, and liquid in machinery at operating levels, without any items of variable load. This condition represents the ship under wartime conditions, with ultimate armament but peacetime boat allowance aboard."

NSTM 096 defines the Full Load (Condition D) loading condition as follows:

> *"Full Load (Condition D):* Ship complete, ready for service in every respect. It is Condition A (light ship) plus the following variable loads: authorized complement of officers, men, and passengers, and their effects; full allowances of ammunition in magazines and ready service spaces; full allowance of aircraft and vehicles (fueled weight without weapons or pilots/crew/drivers, with full allowance of repair parts and stores); full supply of provisions and stores for the periods specified in the design characteristics; fuel and lube oil tanks are 95% full or in case of compensating tanks 95% fuel and 5% water, potable and reserve feed water tanks are 100% full; anti-roll tank to operating levels; all other liquids in tanks to required capacity in accordance and characteristics and exiting liquid loading instructions. The ammunition, stores, fuel, and other liquids referred to above are for the ship's own use; cargo (liquid and solid) is included in amounts normally carried or to the specified portion of the full capacity of the assigned spaces. This condition applies to weight estimating, weight reporting, and inclining experiment reports."

## 1.4 Sign Convention

Sign convention is important when tracking the locations of items to be installed, removed, and/or relocated as part of an SCD. This document makes no effort to standardize the sign convention. However, the sign convention that is adopted must be consistent throughout the SCD development to prevent confusion. For example, if it is decided that forward of midship is negative, aft of midship is positive, starboard is negative and port is positive for items being installed, then it must be the same for all remaining items associated with the SCD.

The Estimated Weight and Moment section of the SCD TAT form only allows positive numerical values. The submitter is required to specify whether it is forward or aft of midship and port or starboard of centerline. Since calculations are required, a consistent sign convention is needed (See section 3.4.3). If an origin has not been established it is recommended using the SCD TAT origin with a consistent sign convention orientation. If an origin with orientation has already been established it may require conversion in order to fill out the TAT tab.

# ESTIMATING WEIGHT and CENTERS:

## 2.1 Estimate Weight

The estimated weight associated with an SCD needs to identify every aspect involved with the change. These aspects include all the weight associated with equipment that is being ripped out, installed, and/or relocated. In addition, weight estimates should include installs and rip outs needed for the execution of the SCD including, but not limited to, cable runs, support racks, and foundations. These are considered changes to the ship's Light Ship (Condition A) loadout.

Installs are considered positive weight additions, while rip outs are considered negative weight removals. Relocations are net zero weight impacts but may have a moment impact. In order to capture the moment changes, separate removal and installation calculations need to be performed. If items are being relocated in relatively small space, calculations may not be necessary.

Weight estimates should be made to the nearest pound and indicated as such in the body of the SCD. This is because weight entered in pounds in NDE is automatically converted to long tons in the Weight and Moment Section. When the net weight is less than 11 pounds it appears as 0.00 long tons in NDE.

Some frequently asked questions for estimating weight and centers for an SCD can be found in Appendix A.

### *2.1.1 Changes to Loading Conditions*

Changes to the ship's Full Load (Condition D) that are the result of an SCD must also be taken into account. An example of a change to the full load condition would be installation of a new gun mount on the ship which would result in changes in the ship's ammunition loadout, or new equipment that will require spares onboard that the ship previously did not carry.

## 2.2 Estimate Centers

In addition to weight, the vertical, longitudinal, and transverse centers of gravity need to be determined. These are the lever arms used for generating the moments for each weight item. These are not necessarily easy to figure out since the ship's reference points for vertical, longitudinal, and transverse are rarely in the compartment that an SCD impacts.

### *2.2.1 Vertical Center of Gravity (VCG)*

The vertical center of gravity (VCG) of each item that is being installed, removed, and/or relocated needs to be identified. In the case of relocations, the VCG of the old and new locations will need to be identified. See Figure 3.

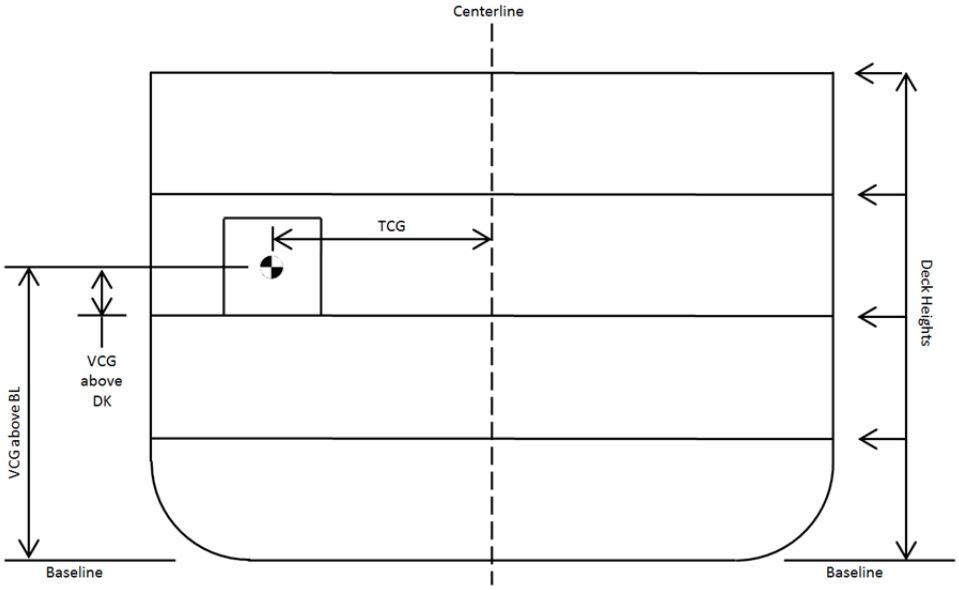


**Figure 3: VCG Example**

The VCG is reference to the baseline. To find the VCG to the baseline, measure the VCG for each item above the deck where it is situated. After that is found, consult the deck height information for the class of ship that is affected. Using the deck height information and the measurement from the deck, the VCG referenced the baseline can be found. See Equation 1.

*VCG above the Deck + deck height at location = VCG above the Baseline* (Equation 1)

Deck height information can be found in the ship's Booklet of General Arrangement, Compartment & Access, Inboard/Outboard Profile, and/or contacting the appropriate Naval Surface Warfare Center, Carderock Division (NSWCCD) Code 8440 engineer listed in Appendix B.

#### *2.2.1.1 Note about Keel Thickness:*

The KG includes the keel thickness in the VCG calculations. The keel thickness needs to be included in any VCG calculations. The thickness is simply added to the VCG above the baseline value. Exact keel thickness varies from ship to ship, it can be found on the ship's docking drawing or by contacting the appropriate engineer listed in Appendix B. It should be noted in the Description of Change section whether or not the keel thickness was taken into account in the VCG calculations.

### *2.2.2 Longitudinal Center of Gravity (LCG)*

The longitudinal center of gravity (LCG) of each item that is being installed, removed, and/or relocated needs to be identified. In the case of relocations, the LCG of the old and new locations will need to be identified.

The LCG is referenced to midship. Typically, forward is negative and aft is positive (See Section 1.4, Sign Convention). To approximate the LCG, identify the frame where the item is located. Typically, but not always, the forward bulkhead of a space is on a frame. The middle portion of

the ship's TAC number identifies the frame that the compartment starts. Once the frame is identified, consult the appropriate lever arm sheet.

The lever arms provide the longitudinal distance from midship to each frame. The lever arms are class specific documents that present the frame distance from midship in a table format. Some ships have large frame spacing; in those situations, approximating to the half frame is acceptable.

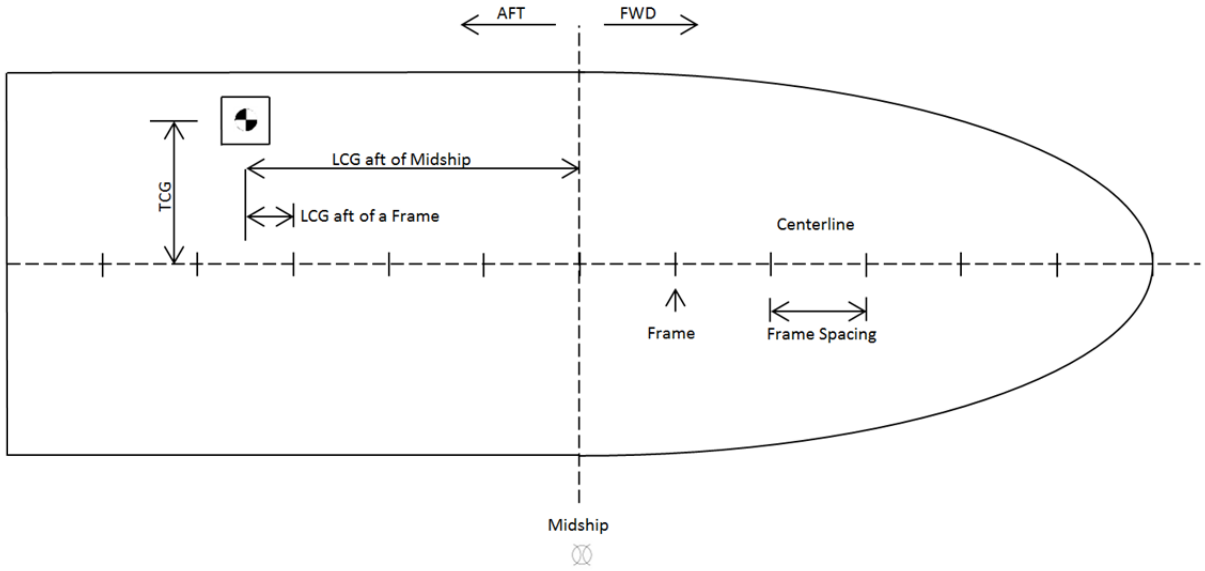


**Figure 4: LCG Example**

Another way to determine the LCG for an item is to measure the distance it is from a known frame location. Note whether the distance being measured is forward or aft of the reference frame. The distance measured from the reference frame is either added or subtracted from the frame's lever arm depending on its relation to midship. A good frame to reference can be the forward bulkhead.

A trick to determining whether to add or subtract the distance from a known frame reference is, "like directions add, different subtract." For example, if the frame is aft of midship and the distance measured is aft of that frame, then the total distance, is the summation of those distances. Alternatively, if the distance measured is aft of a frame forward of midship, the distance is subtracted from the frame's lever arm.

### *2.2.3 Transverse Center of Gravity (TCG)*

The transverse center of gravity (TCG) of each item that is being installed, removed, and/or relocated needs to be identified. In the case of relocations, the TCG of the old and the new locations will need to be identified. TCG is referenced in both Figures 3 and 4.

Measurements for the TCG are taken in reference to the centerline of the ship. For ships with islands, such as aircraft carriers and some amphibious assault ships, consideration must be given to ensure that the TCG is not accidently measured to the centerline of the island instead of the centerline of the ship.

# SECTION 3 Calculating Total Impact

## 3.1 Calculating Moments

Once the weight and associated centers have been identified, a composite center needs to be generated for input into the SCD form, generated via NDE. This is done by calculating and summing the three respective moments: vertical, longitudinal, and transverse.

Equations 2 through Equation 4 are used to generate moments for each item associated with the SCD. For items that are being relocated, there will be two separate sets of centers and moments, one for the removal, and another for the installation.

*Weight of Item * VCG = Vertical Moment (VMOM)* (Equation 2)

*Weight of Item * LCG = Longitudinal Moment (LMOM)* (Equation 3)

*Weight of Item * TCG = Transverse Moment (TMOM)* (Equation 4)

## 3.2 Composite Center

After each moment is generated, all resultant vertical moments need to be added together. The same is done for the longitudinal moments and the transverse moments. The resultant sums are the total moment impact of the SCD.

When the total moments are each divided by the total weight impact, the result is the mathematical center of the SCD. These values are inputs into the Estimated Weight and Moment Section of the SCD form (See Section 3.4.3).

## 3.3 Moment and Center Calculation Example

To better explain sections 3.1 and 3.2, below is an example showing the weight, moment and final center calculations. This is done using a spreadsheet format shown in Table 1. If a spreadsheet is used for doing the weight and moment calculations it should be attached to the SCD.

This example assumes all weights are in long tons. Item 2 is an example of a relocation. The coordinate system used, indicates distances aft of midship are positive and distances on the port side of centerline are positive.

The total VCG, LCG, and TCG were calculated by dividing the VMOM, LMOM, and TMOM by the total weight, respectively.

**Table 1: Sample Weight and Moment Calculations**

| Item # | Weight (LT) | VCG (FT) | VMOM (VCG*WGT) FT-TON | LCG (FT) +AFT | LMOM (LCG*WGT) FT-TON | TCG (FT) +PORT | TMOM (VCG*WGT) FT-TON |
|---|---|---|---|---|---|---|---|
| 1 (Install) | 6.00 | 43.00 | 258 | 69.00 | 414 | -8.00 | -48 |
| 2 (Removal) | - 2.20 | 32.00 | -70 | - 48.00 | 106 | 37.00 | -81 |
| 2 (Install) | 2.20 | 66.00 | 145 | - 55.00 | -121 | 45.00 | 99 |
| 3 (Removal) | - 1.00 | 7.00 | -7 | 75.00 | -75 | - 23.00 | 23 |
| TOTAL | 5.00 | 65.20 | 326 | 64.72 | 324 | -1.50 | -7 |

NOTE: Values are truncated to the 2nd decimal places for weight, VCG, LCG, and TCG. Values are truncated to whole numbers for moments.

## 3.4 SCD TAT Form

The SCD TAT form that is filled out when submitting SCDs for reviews has several sections pertaining to weight and moment. This section will specifically go over Description of Change, Distributive Systems/Other Impacts, and Estimated Weight and Moment.

### *3.4.1 Description of Change*

The Description of Change section is the best place to provide clarification to anything provided later in the SCD TAT form. It can explain differences in installation locations, weight, etc. between ships in the same class and/or assumptions made for doing the weight and moment calculations. The weight in terms of pounds can be placed in this section. The breakdown between lightship and load items should also be shown in this section.

The Description of Change is limited to 4,000 characters. In the event that there insufficient space for all the necessary information in the Description of Change section, it is acceptable to attach a word document as a reference. This must be noted in the Description of Change section.

### *3.4.2 Distributive Systems/ Other Impacts*

Distributive Systems/Other Impacts is the first part of the TAT form that indicates the impact of the SCD on a ship's weight and moment. The exact portion that applies to Weight and Moment is shown in Table 2. There is a box that must be checked if there is a net weight and moment impact. A net impact is anything that is not zero in terms of weight or moments. The net change box needs to indicate whether there is an increase or a decrease in weight. It is vital to fill out the Distributive System/ Other Impacts correctly since the Estimated Weight and Moment Section cannot indicate whether the install is an increase or a decrease. In the Explanation or Added/Removed block the preparer can specify the exact weight that is being added or removed.

**Table 2: Distributive Systems/Other Impacts Example**

| | **Distributive System / Other Impacts** | **Net Change** | **Explanation or Added/Removed** |
|---|---|---|---|
| ☐ | Weight & Moment Change (Net Change required if checked) | | |

### *3.4.3 Estimated Weight and Moment*

The Estimated Weight and Moment section is where most information generated during the weight and moment calculations is recorded. This includes both lightship and full load weight changes.

The information generated from Table 1 would be entered into the Estimated Weight and Moment section of the SCD form. This is shown as an example in Table 3. Ship class and Stability Status are dependent on the ship where an install is taking place. A more detailed explanation of Stability Status can be found in Appendix C. Please contact the appropriate NSWCCD Code 8440 engineer for the latest Stability Status.

Currently only English units can be used in the Estimated Weight and Moment section. If the ship that an SCD impacts is in metric units it needs to be converted to English units before being placed in the Estimated Weight and Moment section. It is recommended that the metric values be included in Description of Change section to ensure clarity.

The breakdown between lightship and load items should be shown in the Description of Change section.

**Table 3: Sample SCD Input Using Table 1 Info**

| Class | Weight (LT) | TCG (Ft) | Port or Starboard | VCG (Ft) | LCG (Ft) | Forward or AFT | Stability Status |
|---|---|---|---|---|---|---|---|
| XXX | 5.0 | 1.5 | Starboard | 65.20 | 64.72 | Aft | XXX |

## APPENDIX A: Frequently Asked Questions

- *What if I don't have the lever arms or deck heights for the ship I am working on?*
  Deck height information can be found on ship's Booklet of General Arrangement, Compartment & Access, and/or Inboard/outboard drawings. Lever arm information can be determined by the same drawings or the ship's docking drawing. If more information is needed contact the point of contact for the class in question listed in Appendix B.

- *What if I am unable to provide exact location of an installation or removal of equipment associated with the SCD I am developing?*
  For SCD phase I-III development, using the center of the space that is impacted is acceptable. The VCG can be estimated at the deck overhead to provide the most conservative estimate. If the space in question is large (such as aircraft hangers, engineering machinery spaces, etc.) localizing the area is also acceptable.

- *I only have the weight of the equipment being installed but no additional weight information.*
  Provide the weight information that is available but emphasize in the Description of Change the assumptions that were made for the weight estimate.

- *I don't have a precise VCG data for the equipment being installed.*
  The VCG can be estimated at the deck overhead to provide the most conservative estimate until better information becomes available.

- *The ship that I am working on uses metric units.*
  Unfortunately at this time the SCD TAT form on NDE only accepts English units. Convert the information to English units for the sake of filling out the Weight and Moment Section but place the metric unit data in the description of change section.

- *What items are frequently forgotten or underestimated when estimating weight?*
  Items that are frequently forgotten or underestimated can include but are NOT limited to the following:
  - Wiring (cable weight, length etc.)
  - Structure (Foundation installs & removals, braces, brackets etc.)
  - Piping
  - Liquids (lubrication, water, etc.)
  - Insulation
  - Support equipment
  - COSAL
  - Other changes to the full load

## APPENDIX B: Code 8440 Contact Information

The NSWCCD Code 8440 Weight and Stability branch reviews SCDs for completion and impact on US Navy Ship. NSWCCD Code 8440 does not generate weight and moment estimates for SCDs. The table below provides the contact information for questions on specific ship classes.

| Name | Ship Classes | Phone | E-Mail |
|---|---|---|---|
| C. Adams | CVN 68<br>CVN 78 | (301) 227-3868 | christopher.l.adams7@navy.mil |
| J. Griffin | LCC 19<br>LHA 6<br>LHD 1<br>LSD 41/49 | (301) 227-0056 | james.a.griffin@nacy.mil |
| M. Kipp | CG 47<br>DDG 51<br>DDG 1000 | (301) 227-1714 | michael.a.kipp@navy.mil |
| L. Moraski | LCS 1 | (301) 227-0060 | lauren.moraski@navy.mil |
| J. Rosborough (Supervisor) | All Ships | (301) 227-5392 | john.rosborough@navy.mil |
| A. Senuta | LCS 2 | (301) 873-7196 | vytenis.senuta@navy.mil |
| E. Shanahan | LPD 17<br>MCM 1 | (301) 227-0542 | edward.shanahan@navy.mil |

NSWCCD Code 8440 Fax: (301) 227-0071

# APPENDIX C: Stability Status

Ships are assigned a Stability Status based on their growth potential as measured by the difference between the current Full Load displacement and center of gravity (KG) versus the limiting displacement and KG. These differences are commonly referred to as the displacement service life allowance and the KG service life allowance. The two service life allowances are considered separately, and depending on whether the service life allowances are adequate or deficient, the combination of the two factors determines the appropriate status. It is important to remember that the service life allowances must be considered adequate for the expected remainder of a ships service life in order for it to be "not critical".

Ships are generally assigned to a status on a class wide basis, i.e., when several ships in a class are determined to be critical. It is assumed that they reflect the imminent condition of all ships in the class.

Further information regarding Weight and KG service life allowances can be found in NAVSEAINST 9096.6.

Ships, which consume most of their service life allowances early in life, will be put into a critical status if the rate of consumption is too high. If a class has managed to reduce an initially high rate of consumption to a moderate level it may be allowed to revert to a less critical status.

| Stability Status | Definition |
|---|---|
| 1 | No displacement/stability problems |
| 2 | Deficient in both service life allowances |
| 3 | Deficient in KG service life allowance |
| 4 | Deficient in displacement service life allowance |

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