Technical Report Documentation Page

1. Report No.	2. Government Accession Number	3. Recipient's Catalog No.
CG-D-06-99	AD-A 363933	

4. Title and Subtitle	5. Report Date
Modeling of Leeway Drift	September 1998
	6. Performing Organization Code Project No. 1012.3.16 / UDI 76
7. Author(s) Eric Anderson, Anatoly Odulo and Malcolm Spaulding	8. Performing Organization Report No. R&DC 06/98

9. Performing Organization Name and Address		10. Work Unit No. (TRAIS)
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12. Sponsoring Agency Name and Address	13. Type of Report & Period Covered
U.S. Department of Transportation United States Coast Guard Operations (G-O) Washington, DC 20593-0001	Final Report, Nov 97 – April 98
	14. Sponsoring Agency Code Commandant (G-OPR) U.S. Guard Headquarters Washington, DC 20593-0001

15. Supplementary Notes

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16. Abstract (MAXIMUM 200 WORDS)

This document reviews the existing state of practice in the computation of leeway drift. Five documents were specified for review. One document was found to be unavailable. All four remaining documents used essentially the same governing equations for the body motion. These equations are well known and widely used. After definition of terms, the generalized analysis of the force balance of a drifting object in the open ocean is presented. Comparisons of the generalized presentation with two of the referenced papers are made to show the parallelism of approach. An idealized measurement program is defined to parallel the theoretical formulation. A set of sensitivity analyses to test the relative contribution of the various terms and parameters in the model analysis is presented. Recommendations for future work, both in the laboratory and the field, are presented.

17. Key Words	18. Distribution Statement
drift model, leeway, life raft drift, search and rescue, ship drift, person-in-water drift, mathematical drift model	This document is available to the U.S. public through t National Technical Information Service, Springfield, VA 22161.

19. Security Class (This Report)	20. Security Class (This Page)	21. No of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED		

EXECUTIVE SUMMARY

This report was prepared for the USCG R&D Center as an overview of the current state of practice for modeling leeway drift as it applies to search and rescue (SAR) mission planning. The intent of this effort was to make an initial assessment of what would be required to develop a math model of leeway. Such a model could be used in combination with field experiments to provide accurate prediction of wind-driven search object motion for mission planners. It was expected that this approach to leeway prediction would be more economical and efficient than field experiments alone, resulting in the ability to provide leeway data on the many classes of search objects more economically. While the mathematical modeling approach may indeed provide some economies over a purely empirical approach, the report documents that math models will still need empirically-derived inputs to be accurate. The value of this study is in documenting what will need to be done in order to develop a reliable math model. The study is one piece of ongoing R&D Center efforts to better-define object movement due to leeway, and in turn feed new generation search planning tools with the objective of reducing size and search mission costs through better movement prediction.

This report is a companion for Allen and Plourde, 1998, "Review of Leeway Field Experiments and Implementation," and reviews four documents that model leeway dynamics. The four documents use essentially the same force balance solution to the drifting body problem. The four reports include two documents by Su (Su (1986) and Su et al. (1997)) which were prepared for the USCG R&D Center. Both of these documents contain a development of the theoretical background of the leeway dynamics problem and the equations governing the wind and water forces on a leeway object. Su et al. (1997) restates the theoretical presentation and includes laboratory results for air and water drag coefficients. Su's field experiments suffered from short duration and a lack of real time ocean current data collection. A third paper, Richardson (1997), that focuses on the leeway of ships under power, has limited application to the SAR problem. The fourth report, Hodgins and Mak (1995), develops force balance equations and includes an experimental program to obtain air and water drag coefficients for two specific life rafts. Hodgins and Mak addressed issues of model scaling effects and boundary layer effects.

In this presentation, the common approach to the development of the physics of the leeway problem is restated. Essential force terms acting on the leeway object are defined. The assumptions and simplifications used in the formulation of the leeway problem in physical terms are presented. The problem is restated with reference to the papers of Su (1986) and Hodgins and Mak (1995) to show the parallelism of their approaches.

The resistance of floating objects to changes in velocity, inertial force and added mass is presented and discussed for objects with a range of masses. For light bodies the inertial force is shown to be small and the object therefore responds rapidly to changing environmental forcing. Eliminating the inertial force for low mass SAR type objects simplifies the force balance equation. The forces associated with wind, wave, and water drag are each addressed in separate sections. A method for the parameterization of drag coefficients for water and air is discussed. Building on the work of Su (1986) and Hodgins and Mak (1995) an expression for the calculation of the body velocity is derived.

The authors suggest an “ideal” measurement program based on a set of sensitivity studies to test the relative contribution of model terms and parameters. Each parameter for each of the individual terms in the force balance equation is presented, classified and discussed. Parameters are classified by a matrix of air, wave, and water measurements and by the method of measurement (wind tunnel, tow tank, field experiment). Specific approaches to the laboratory collection of data to calculate wave forces and equilibrium drift angle and forces are presented. The direct method now in use by the U.S. Coast Guard R&D Center to measure leeway, which utilizes instrumented drift objects, is confirmed as a viable approach compatible with modeling efforts. The collection of simultaneous, independent fixed-frame surface current measurements during field experiments is suggested in the report.

The present state of leeway modeling is well developed from a theoretical point of view. Forces due to the action of wind, currents, and waves are adequately described. The governing physical equations, however, contain characteristics of the drift object and environment that are best presented as parameters within the equations. These parameters are often not well quantified. Because of this lack of understanding of the parameters relating to drag, lift, and torque, it is often difficult to accurately predict the direction of leeway drift even when the distance of the drift is of the correct magnitude. The Coast Guard will benefit by adopting a parametric approach to the classification of wind and water drag coefficients. This will allow the adjustment of generalized leeway equations for specific objects to better predict their movement through the water. Also, the collection of field data in extreme cases of wind-, wave-, and current-only forcing would benefit sensitivity testing of model parameters. Classes of leeway objects should be grouped, and parameters governing their drift should be quantified by experiment. Data from these experiments can be used to validate a dynamical model of leeway, and the model can then be used to interpolate results for non-tested drift objects.