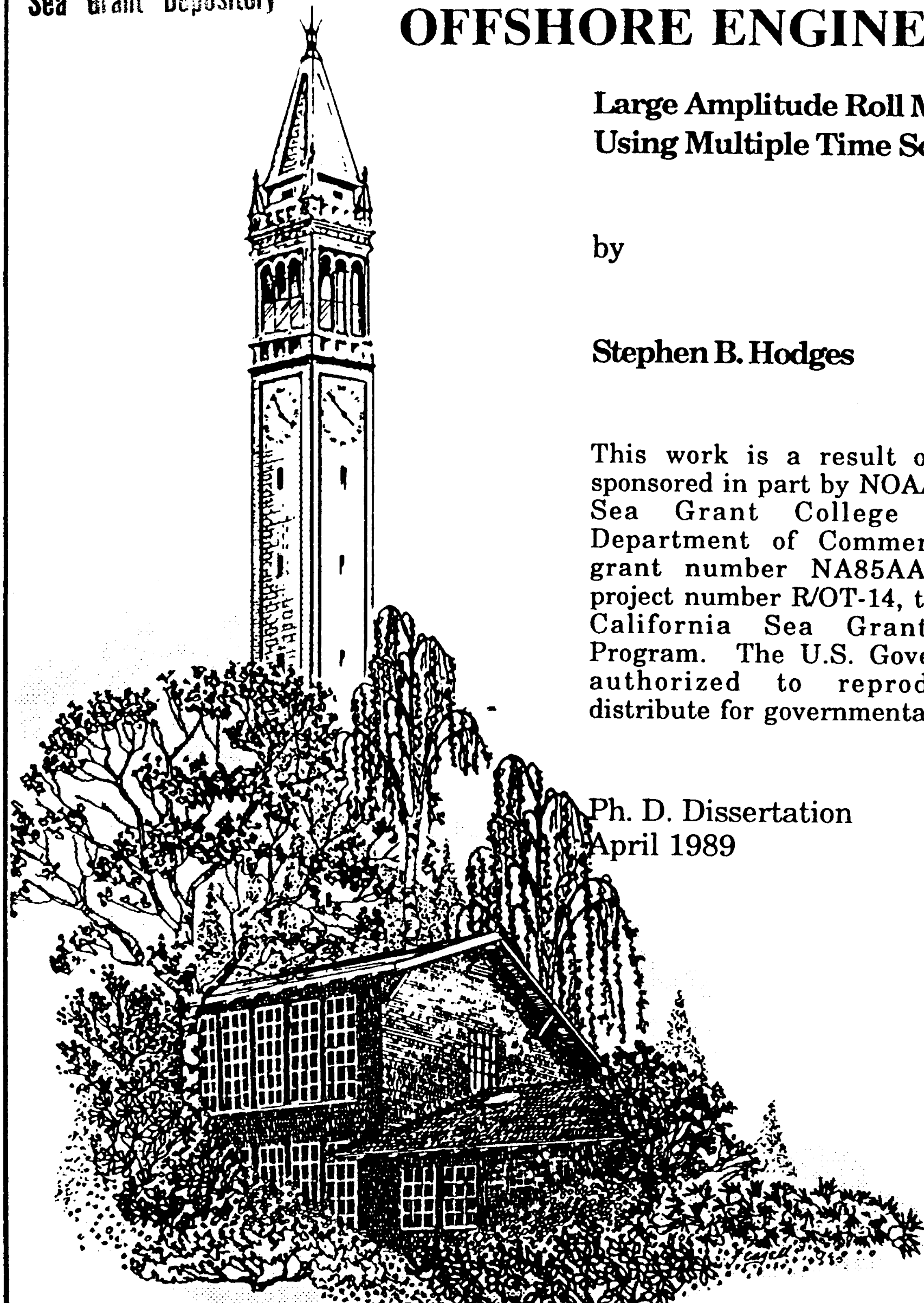
DEPARTMENT OF

NAVAL ARCHITECTURE & OFFSHORE ENGINEERING



Large Amplitude Roll Motions Using Multiple Time Scales

by

Stephen B. Hodges

This work is a result of research sponsored in part by NOAA, National Sea Grant College Program, Department of Commerce, under grant number NA85AA-D-SG140, project number R/OT-14, through the California Sea Grant College Program. The U.S. Government is authorized to reproduce and distribute for governmental purposes.

Ph. D. Dissertation
April 1989

UNIVERSITY OF CALIFORNIA, BERKELEY, CA 94720

(415) 642-5464

Large Amplitude Roll Motions Using Multiple Time Scales

By

Stephen Bradford Hodges

B.S. (Northwestern University) 1983
M.S. (University of California) 1985

DISSERTATION

Submitted in partial satisfaction of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

ENGINEERING
NAVAL ARCHITECTURE

in the

GRADUATE DIVISION

of the

UNIVERSITY OF CALIFORNIA at BERKELEY

Approved:

William C. Webster .... April 28, 1989
Chair .... Date

J R Paulling .... April 28, 1989

J A Berger 4/27/89

****

Large Amplitude Roll Motions Using Multiple Time Scales

by

Stephen B. Hodges

ABSTRACT

In this work, a mathematical model is developed to predict large-amplitude roll motions of a ship with low initial stability in a narrow-banded seastate. The condition of low stability implies that the natural roll frequency is low compared to the frequencies contained in the incident waves. Experimental studies of such vessels indicate that large amplitude roll motions can be excited by nonlinear interactions between closely spaced frequency components in the incident waves which yield second-order moments at frequencies near the low natural roll frequency. The experimental results also suggest that if the difference between the wave frequencies and the roll frequency is large enough then the roll motion appears to be made up of two distinct components: one small in amplitude and near the wave frequencies, and the other large in amplitude and at a much lower frequency.

The model developed in this work exploits this apparent distinction between the wave-frequency and low-frequency responses. The problem is solved using a multiple time-scale perturbation involving two perturbation parameters: one related to the smallness of the waves and the high-frequency motions, and the other related to the ratio of the natural roll frequency to the wave frequencies. The resulting first-order equations are similar to a linear small-motions theory except that the body geometry is allowed to vary with the slow time scale. The second-order equation for the slow, large-amplitude roll motion is formed by retaining only the terms that have slow time-scale components. The separation into the two time-scales

is crucial because it allows the low and high frequency (slow and fast) components to be decoupled in a mathematically consistent fashion.

The theoretical model was tested for a body subjected to regular wave groups and the character resulting slow-roll motions were quite reasonable. Although the two-dimensional model cannot be directly compared with experimental results, the character of the motions compares favorably.

William C. Webster
Committee Chairman

Acknowledgements:

The completion of this dissertation marks not only the completion of my doctoral degree, but it is the culmination of some twenty-odd years of formal education. Although I have learned a great deal from classes and books, there is an important, intangible element to the education process that is strongly dependent on the people one encounters. I have been fortunate enough to have had associations with a number of outstanding people, both here at Berkeley and previously, who have had a great influence on my studies and this dissertation. Although names and faces often blur with passing years, there are a few that stand out, and in the following paragraphs, I would like to express my sincere appreciation to those people who have taught, supported, encouraged and inspired me.

This work is a result of research sponsored in part by NOAA, National Sea Grant College Program, Department of Commerce, under grant number NA85AA-D-SG140, project number R/OT-14, through the California Sea Grant College Program. The U.S. Government is authorized to reproduce and distribute for governmental purposes. This support has been greatly appreciated.

I would like to express my sincere thanks to the members of my thesis committee: Professors William C. Webster, J. Randolph Paulling and Stanley A. Berger for their guidance and advice throughout this work. It has been a pleasure working with them.

Since I arrived in Berkeley, Professor Webster has been an invaluable source of encouragement and support in the capacity of teacher, thesis advisor, mentor and friend. Throughout my stay here, he has been instrumental in helping me to obtain financial support, as well as providing, often much needed, guidance and advice. He has always shown a great deal of confidence in me which I believe has allowed me to progress in new directions where I would not have otherwise gone. As my thesis advisor, he provided me with many challenging ideas, but always allowed me a great deal of latitude in learning from my own mistakes. I think that this not only enhanced the outcome of this thesis, but also made me a wiser man for my troubles. For all of this, I wish to express my heartfelt