I. INTRODUCTION

Submarine periscope depth operations are conducted in order to accomplish specific tasks and perform them in minimum time and with the least amount of noise. Accurate submarine maneuvering predictions are essential both for design to assess alternatives based on their maneuvering performance, and for operation, to provide optimal and safe submerged operating envelopes. Submarines are subject to several exciting forces and moments at periscope depth beneath a seaway. These forces and moments induce an oscillatory motion at the wave frequencies and second-order drifting motions at very low frequencies well outside the wave spectrum of the seaway, which are referred to as free surface suction effects. It is difficult in practice to control these low frequency motions and may result in a rise to unsatisfactory depth keeping. Standard ways of computing free surface effects rely on combinations of potential flow and semi-empirical coefficient based models. Rankine type sources are distributed along the hull of the ship, which satisfy the free surface boundary condition. Source strength can be computed by satisfying the exact body boundary condition, that no fluid can pass through the hull surface. Discretization of the hull form into a finite set of Hess-Smith type quadrilateral panels allows formulation of algebraic system of equations to be solved for the unknown singularity strengths [Ref. 1]. Combination of forces and moments generated in this way with deep water force predictions can then be utilized to simulate the motion of the boat under waves. These forces and moments are slowly varying in time and as a result they can be controlled by either the operators or automatic control systems. In this work a potential flow, strip theory solver program is utilized to determine vehicle motions in the proximity of a free surface in deep water, based on the work by Beck and Troesch [Ref. 2].

Tactical assessment is possible by adopting a number of criteria, each pertaining to different operational hazards. These criteria can be divided into two main categories, such as subtle and catastrophic failures. In the study, we have considered two criteria which are periscope submergence and sail broaching. Periscope submergence is a subtle failure and sail broaching is a catastrophic failure.

Subtle failures are the events which will occur in all types of periscope depth operations, such as , propeller emergence, mast emergence, periscope submergence, mast submergence. The frequency of these events imposes operability limits for a certain sea-state, although single occurrence of them does not constitute failure of operations. Periscope submergence impairs visual information. The dominant criterion is the number of occurrences per unit time.

Catastrophic failures are the ones which will probably result in either cancel of operations, failure to complete mission or submarine detection, such as sail broaching, loss of depth control deep. Since a single event occurrence is identified as a catastrophic failure, the primary analytical criterion is the expected duration between two consecutive events, instead of being the number of events per time. Broaching is defined as the loss of depth control shallow to a sufficient extent and duration. It is assumed that the submarine detection will occur with probability of one each time a broaching occurs.

In Chapter II of the thesis, evaluation of the response is described, beginning with the definition of submarine geometry. A typical hull consists of three sections, the entrance (bow) the shape of a parabolic body of revolution, the parallel middle body of a cylindrical shape, and the run (stern) the shape of an ellipsoid of revolution (Jackson,1992) [Ref. 3]. The parameters and all the coefficients are explained and formulated. Chapter III shows the resulting operability indexes of a submarine for different sea-states and wave heading angles and deep water operations for periscope submergence, sail broaching and combined criteria. These results are obtained from the limited diameter and limited length cases, different shape factors and speed/operating depth combinations. Conclusions from the study and recommendations for further studies are presented in Chapter IV.