Multi-objective Collaborative Optimization of Naval Fleets

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Many Naval concept studies for ship design focus on mission and operations performed by a single ship. Typically, design goals are established for things such as speed, range, and cost. However, they are merely proxies for the actual mission performance of the ship. Furthermore, in today's Navy, ships frequently operate interdependently as part of a larger battle or strike group and so ship designs should be evaluated as part of a super-system of multiple ships. Separately designing each ship typically results in duplication of effort as well as under-utilized and excess equipment and capability. This results in sub-optimal design of the super-system.

This thesis examines the performance based simultaneous design of several ships using the sea base concept as an example application of a network of ships working together to accomplish a mission: to assemble, deliver, sustain and reconstitute a joint force to and from a land objective from the sea. The number and characteristics of these ships determine the level of mission performance for the sea base.

To properly design any of these families of ships, the interrelationships must be included to avoid duplication of effort or under-utilization of resources. Using a low/medium fidelity simulation allows the combination of performance characteristics from different ship designs into a single Mission Performance Parameter (MPP) such as the time to deliver a brigade size force to their assigned objectives. This MPP also has the advantage of being something easily understood by the customer.

Optimizing a single ship is difficult to perform alone due to the large number of variables. Whereas designing multiple ships further complicates the optimization due to the addition of interfaces. Furthermore, designing a family of ships together ignores the fact that having been done separately, there are different algorithms and techniques that are preferentially used for each ship design. Thus, collaborative optimization, a multi-level optimization approach, was used to decompose the problem into individual ship designs directed where only system-level interfaces were altered by a super-system optimization algorithm.

By modifying the collaborative optimization scheme to include multiple objectives such as performance and cost, the methodology is able to develop a range of solutions which represent the tradeoff between these objectives.