Propulsion System Concept of Operations

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1. Introduction

The propulsion system concept of operations (PS-CONOPS) documents how the designer intends for the ship's propulsion system to be designed, operated during normal, nominal operations, operated during restorative operations, maintained, repaired, and upgraded. The scope of the PS-CONOPS includes the main propulsion systems, the auxiliary propulsion systems, steering systems, and maneuvering thruster systems. If the ship incorporates electric drive, the propulsion system includes all equipment from the interface with the ship's power system to the propeller. During the design process, the PS-CONOPS is a working document; the PS-CONOPS typically starts with only a few items, but rapidly includes additional items as the design evolves and matures; items are added as they become required to support design and analyses activities. The PS-CONOPS is the foundation, and single source of truth, for providing assumptions for the various calculations, analyses, and simulations performed on the propulsion system. When the ship becomes operational, the PS-CONOPS enables the crew to gain a full understanding of the ship's propulsion system design.

The PS-CONOPS complements other system concepts of operation. The Electric Power System Concept of Operations (EPS-CONOPS) for example, is required in addition to the PS-CONOPS to perform endurance fuel calculations.

2. PS-CONOPS uses

The primary uses of the PS-CONOPS are:

a. Serve as a single source of truth for design assumptions needed to support design and analysis activities (including simulations).
b. Define standard propulsion system line-ups.
c. Reflect knowledge gained from propulsion system studies.
d. Provide operators, designers, and maintainers with insight as to how the designers intended for the propulsion system to operate under different conditions.

Within a digital design environment, the PS-CONOPS is part of the digital thread; its evolution should be traceable over time. For some data elements, other documents or databases may serve as the single source of truth for the project; in these cases, the PS-CONOPS should link to the authoritative source of data.

As the PS-CONOPS evolves, the designer should evaluate the changes in the document and determine if analyses should be repeated to reflect the new information.

3. PS-CONOPS content

While a standard format for and contents of a PS-CONOPS do not exist, the following sections of a PS-CONOPS are recommended:

3.1. Overarching assumptions and requirements

Overarching assumptions and requirements include:

a. Margin and service life allowance policy
b. Ship service life
c. Redundancy requirements
d. Survivability requirements
e. Maneuvering requirements
f. Turning requirements
g. Crash stop / reversal requirements
h. Dynamic positioning requirements
i. Autopilot requirements
j. Propulsion system lineups for endurance calculations

These items should be defined and incorporated into the PS-CONOPS before they are needed for design and analysis.

3.2. Propulsion system machinery lineups

The EPS-CONOPS details the ship's operating conditions. For each of the operating conditions, the PS-CONOPS should contain a propulsion scheduling table. This table indicates for a given range of propulsion load, the online status of propulsion prime movers and propulsion motors, and for those propulsion prime movers and propulsion motors that are online, the method to determine how much mechanical power is provided by each propulsion prime mover and propulsion mover, and the amount of power consumed by each propulsor.

The propulsion scheduling table is required for many analyses such as endurance fuel calculations and annual fuel calculations.

Guidance for developing a propulsion scheduling table is provided in Doerry and Parsons (2023), and document D_00002. Guidance for optimizing the propulsion scheduling table for fuel efficiency is provided by Doerry (2022).

3.3. Nominal operations

The PS-CONOPS should describe how the propulsion system is intended to operate under normal conditions where equipment and software have not suffered failure or damage. Topics include:

a. For each of the operating conditions, what performance attributes should be optimized.
b. The process for transitioning between propulsion system lineups.
c. Limitations for the use of auxiliary propulsion motors and thrusters
d. Expected control modes (constant power, constant torque, or constant speed) and limitations on the use of control modes.
e. Limitations, if any, on operating in trail-shaft.
f. Uses of jacking gear and turning gear.
g. Shaft grounding system / cathodic protection system description
h. Operation of steering gear.

3.4. Restorative operations

The PS-CONOPS should describe the intended process for restoring propulsion system operation to nominal operations following failure or damage to equipment or software. Because of the large number of possible failures, the PS-CONOPS should describe the overall strategy at a relatively high level. Possible topics include:

a. Local control modes.

b. Use of clutches, shaft brakes, shaft seals, etc. in restorative operations.

c. Limitations on ship speed for different types of casualties and restorative methods.

d. Emergency steering procedures.

3.5. Propulsion system trade studies

The insights gained from analyses and trade-studies should be documented within the PS-CONOPS, or a link provided to such documentation within the digital thread. The goal for including this information is to ensure any insights gained are reflected in follow on analyses and design activities. Insights of particular interest are those that impact the operation of the propulsion system, and those that impact the modeling of the propulsion system.

3.6. Maintenance / repair strategy

The PS-CONOPS should document the maintenance and repair strategy the design is using to minimize loss of propulsion capability due to propulsion system equipment failures. The PS-CONOPS should include a description for how to remove rudders, shafting, propellers, and other major propulsion system equipment. Any special procedures required for shaft alignment should be described.

The maintenance and repair strategy should influence propulsion system design including the amount of redundancy provided. To preclude or minimize loss of propulsion capability, the system should be designed to minimize the number of single points of failure; single-points of failure that do exist should be very reliable. Maintenance activities should be designed to minimize failures, and repair strategies should be designed to minimize down time.

Planned maintenance that should be accomplished when the ship is in drydock should be listed along with the required periodicity.

3.7. Modernization strategy

The PS-CONOPS should document features, if any, within the propulsion system design that facilitate modernization of the ship.

4. PS-CONOPS development

The PS-CONOPS should be developed incrementally in a configuration managed environment. The contents of the PS-CONOPS should be developed in the order required to support ongoing analysis. In the earliest stages of design, information needed to support the endurance fuel calculations are typically required first. Some data elements may be delayed to preliminary design.

5. References

Doerry, Norbert, and Mark A. Parsons, "Modeling Shipboard Power Systems for Endurance and Annual Fuel Calculations," SNAME J Ship Prod Des (2023)

Doerry, Norbert, "Optimal Generator Set Loading for Energy Efficiency" ASNE Naval Engineers Journal, June 2022, Vol 134-2, pp. 101-111.

Doerry, Norbert, “Developing a propulsion scheduling table,” D_000002

