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The Importance of Ontological Commitment and Linguistics in Relation to the Elucidation of Design Requirements

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ABSTRACT

One of the design process's earliest and most critical stages is establishing and determining requirements. Design requirements are often expressed through language, whether in written documents, diagrams, or verbal discussions in terms of the client's "wants" and "needs" or balancing what they can "afford." Designers use of quotes around "wants," "needs," and "afford" signals ambiguity or doubt in the meaning of the terms. The language used during early discourse is crucial for expressing and translating these ambiguous terms into specific unambiguous design requirements, which significantly shape and constrain possible solutions. In philosophy, this concept is known as ontological commitment. Embedded language in requirements documents, expressed through constraints, objectives, and functions, establish the ontological commitment to a specific solution space. Prior marine design research has focused on the wicked problem of requirements elucidation, with the goal visualizing potential solutions derived from language, and a more direct link to ontological commitment was developed by Andrews in the concept of style Duchateau (2016) van Ores (2011) Andrews (2012). However, the role and impact of linguistics in translating and interpreting uncertain or ambiguous terms into specific design requirements has been largely overlooked. This paper presents modern direct examples of ontological commitment from requirements development for the Littoral Combat Ship.

KEY WORDS

Design Requirements, Ontological Commitment, Naval Vessel Design, Linguistics, Early-Stage Concept Design

INTRODUCTION

The process of engineering design is a complex, highly entangled, and multifaceted endeavor, that commences with concept design and the establishment of design requirements. At this formative stage, the articulation of design needs, goals, and constraints are often conveyed through language, be it in written documents, visual diagrams, or verbal interactions. An intriguing phenomenon within this domain is the use of scare quotes by designers to underscore terms such as "wants," "needs," and "afford," signifying an element of doubt or ambiguity surrounding these crucial design aspects. Numerous examples of scare quotes can be found for in the design language for both military and commercial ships. A recent defense example can be seen through the development of the Landing Ship Medium. An article announced the "Draft Proposal for 'Affordable' Medium Landing Ship" Lagrone (2023). The scare quote around the word affordable signal the uncertainty with the cost of the vessel being designed. Further, some of the initial desired features for the ship state the want for

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“a “modest” suite of C4I equipment” or “a “Tier 2+” plus level of survivability” O’Rourke (2023). In both of these cases there is a level of ambiguity in how one would define modest or the level of survivability. These scare quotes, which typically serve to express uncertainty, are emblematic of the intricate interplay between language and the design process. One commercial example from the cruise ship industry can be seen through the idea used by Royal Caribbean of “above and beyond compliance” Royal Caribbean Group (2020). Primarily, this scare quote is concerning safety and environmental concerns, although they weren’t initially specified requirements at the onset of the design process in terms of what “above” compliance means in relation to additional capability needed. Throughout the design process ideas evolved into innovative concepts such as the Safety Command Center Royal Caribbean Group (2024). Initially undefined, this concept emerged and matured during the design process, guided by the philosophy of surpassing mere compliance to embrace a higher standard of safety. Additionally, one can argue that there is a large amount of uncertainty with what “above” compliance really means.

Language, with its capacity to express the nuanced aspects of “wants” and “needs,” plays a pivotal role in translating abstract desires into precise, unambiguous design requirements. The manner in which these requirements are framed through embedded language significantly influences and constrains the realm of possible design concepts and solutions, a concept analogous to the philosophical notion of ontological commitment. In philosophy, ontological commitment explores the connection between statements of existence and specific entities or types of entities, and in the context of design, the language embedded in requirements documents as well as design approaches, methods, processes, and tools establishes an ontological commitment to a predicated solution space Jubien (1998). The purpose of this paper is to present ontological principles within the framework of marine design, elucidating their impact on and ability to clarify design results.

Philosophy in Marine Design

Engineering, as a discipline, is often perceived as a realm of technical knowledge and practical applications. However, “overlying every technical or civil system is a social system that provides purpose, goals, and decision criteria” Miles and California Institute of Technology (1973). All engineering activities, including the language used in requirements or the logical reasoning behind decisions, are grounded in humanity based fields like cognitive psychology or philosophy. Looking back, Aristotle believed there were many reasons philosophy was practically important, “the analysis of foundational philosophical concepts cannot but influence science” Rovelli (2016) Andrews (2018b). Additionally, in his discussion on the philosophy of design, Galle argues that philosophy “serves the end of helping, guiding, suggesting how the [designer] comes to understand what he is doing, and not simply how he comes to do what he is doing.” This coming to understand what one is doing, rather than just understanding how to do it is an insight about design... [that] can only be pursued by philosophical means ” Galle (2002) Andrews (2018b). Philosophy enhances conceptual clarity in engineering. It helps engineers define and refine abstract concepts, such as efficiency, sustainability, affordability, and risk, to ensure that they are well-understood and can be effectively implemented in the design and evaluation of engineering systems.

Andrews’ exploration of Style in many works largely aims to introduce philosophy into the domain of ship design and requirements elucidation Andrews (2018a). Andrews states that “the style to be adopted in a specific design option is seen to be the key design decision for that option and so is the first design decision...” Andrews (2018b). Additionally, Andrews argues that “style can make a substantial difference to the final outcome of a design, so their relative impact ought, in the case of a complex ship, to emerge from a proper dialogue between designer and client ...” Andrews (2018a). Keane and Tibbits similarly argue that “the way ahead for a successful ship design starts with establishing the initial design philosophy...” Keane and Tibbits (2013). A design philosophy sets the tone for an entire program, such as “Design/Build” for the U.S. Navy’s Virginia class attack submarine, which signaled major changes to organizations, contracts, and processes relative to past Navy programs.

The setting of a design philosophy or Style is an ontological commitment, in how ontological commitment directly establishes relations to a predicated solution space. A direct justification of the need for Style in design lies within the concepts of ontology. The intent of this paper is to introduce ontological concepts in the context of marine design, and how they can influence and explain design outcomes.

IMPORTANT PHILOSOPHICAL AND ONTOLOGICAL CONCEPTS IN ENGINEERING DESIGN

The following section introduces and defines multiple philosophical and ontological concepts that are relevant to engineering design and in elucidating design requirements. The case study presented later in this manuscript largely utilizes and investigates the concepts of a universe of discourse, an ontological anchor, and ontological conflict (anguish). However, the other concepts introduced below are to help provide a more compressive understanding.

The Notion of a Universe of Discourse

A universe of discourse establishes the scope or domain of a statement or argument, indicating what is relevant and applicable to the discussion at hand. A universe of discourse is implied or defined, clarifying the boundaries of the discussion and ensuring that statements or arguments are meaningful within the specified context. Certain types of objects or concepts will be included, while others will be excluded. The universe of discourse is particularly important in relation to the elucidation of design requirements as this is a key point in the design process when domains to be included in a design are set and ranges on design variables are specified. Returning to Style, selecting a certain Style directly influences the universe of discourse of a design. For example when designing a container ship one may consider the styles of robustness, commercial quality, operational serviceability, or producability, but would probably not include lethality. On the other hand if one were designing a naval vessel by nature one would need to include lethality, while excluding commercially unique concepts. In general terms, a universe of discourse is an inclusive class of entities that is implied or defined relative to a statement or theory.

The Notion of Ontological Commitment

Ontological commitment is defined "to be a relation that holds between persons or existence assertions, on the one hand, and specific entities or kinds of entities, on the other" Jubien (1998). This implies that "assertions of the existence of specific entities or kinds of entities are the intuitive source of the notion of an ontological commitment" Jubien (1998). In more basic terms, the concept of ontological commitment represents the acknowledgment that one assigns value to something through inference of belief within an existing domain or context, and the ontological commitment is only valid when it is connected to some conception of past existence. There are many examples that exist of ontological commitments. For example, some of the ontological commitments of physics include atoms, quarks, and space-time. To further this example, physics theory is ontologically committed to the concept of electrons. This means that the truth of physics requires that electrons exist and behave in certain ways.

Another way to think about ontological commitment is through the idea that ontological commitment reveals the "demands imposed on the world" Rayo (2007). Explicit and implicit ontological commitment are two of the more recent concepts that have been introduced. The concepts are directly a byproduct from the modern efforts to try to quantify all entities involved in a commitment and were originally present by Peacock and Krämer and expanded upon by Österblom Peacock (2011) Krämer (2014) Österblom (2017). Explicit ontological commitments are defined by the entities that are claimed to exist that are directly stated in the statement of a theory or statement Peacock (2011) Österblom (2017). In other more simple terms "a theory is explicitly ontologically committed [to an entity] if it contains some sentence that means there are X" Krämer (2014) Österblom (2017). Explicit ontological commitment is a pretty clear notion and really covers any direct statement of existence. In common language, explicit commitment refer to relations, statements, or entities that are clearly stated and actually understood by individuals. To cover the commitments that are not directly stated or directly related to a theory or statement there is implicit ontological commitment. Implicit ontological commitment are defined by two criteria. The first of the criteria for determine implicit ontological commitments is "the theory could not be true unless X existed," and the second is "the theory is committed to X and not explicitly committed to X" Peacock (2011) Österblom (2017). In more common language implicit commitments refer to relations, statements, or entities that either classify as believed to be understood or that fall into the category of unknown-unknowns. In relation to the case study presented later in this manuscript, this work does not directly attempt to use ontological commitment from philosophy but is inspired and investigates commitments relative to design requirements and decisions.

The Notion of Ontological Cost

Ontological cost was introduced by Peacock and furthered by Österblom and it is meant to look at the preconditions of an ontological commitment and reckon what cost is imposed by making that commitment Österblom (2017) Peacock (2011). The "ontological cost of a theory is to ask what is given that it must be true. It is to ask what entities or kinds of entities are needed or required for the truth of the theory" Österblom (2017). In other words this is essentially to ask what explicit and implicit commitments are needed to make a given ontological commitment. In relation to the case study presented later in this manuscript, ontological cost can be physically interpreted and measured by the cost implications of a specific design requirement, ontological commitment, or design change or decision.

The Notion of an Ontological Anchor

A novel, critical concept to introduce that is directly related to the concept of ontological commitment is the concept of an ontological anchor. The term ontological anchor is not defined in the field of philosophy, but is rather inspired from philosophy. The term was coined in a conversation with a retired U.S. Navy Captain. The term ontological anchor refers to a stronger concept than ontological commitment. An ontological anchor refers to the fastening of one's view of the universe of discourse or belief system to a specific assertion or assertions. While at first ontological commitment and ontological anchors may seem the same, there are some important subtle differences. An important note on ontological commitment is that in evaluating relations the universe of discourse and truth are static. There is also a dependence that the universe of discourse and truth statement need to be aligned in ontological commitment. In this context a truth statement is defined by a proposition or sentence that is considered to accurately represent reality. It is a statement that is true or perceived true, meaning it corresponds to the facts or the way things really are or how things are perceived. However, with an ontological anchor, truth is independent of the universe of discourse. Thus, the largest and most important difference between ontological commitment versus ontological anchors is truth versus untruth. Ontological anchors hold in situations with false truth statements as one either creates a universe of discourse to justify the incorrect truth statement or ignores the universe of discourse all together. Organizational bias can be seen as a strong example of an ontological anchor. Ontological anchors can also be supported from concepts from organizational theory. Two concepts from organizational theory that help support the concept of an ontological anchor are the anchoring effect and the concept of strategic misrepresentation. The idea of the anchoring effect is that "an individual's judgements or decisions are influenced by a reference point or "anchor" which can be completely irrelevant" Wikipedia (2023). Strategic misrepresentation is the concept that "decisions are based solely on the optimism of benefits and projected accordingly to management or leadership" The Strategy Institute (2023). In both of these theories the root influence or reference represent an ontological anchor.

Cognitive dissonance theory suggests that individuals experience discomfort or tension when holding conflicting beliefs, attitudes, or values. When someone is presented with information that contradicts their existing beliefs, they may experience cognitive dissonance and attempt to resolve it by reinforcing their existing beliefs rather than changing them Festinger (1957). Thus, direct truth or facts cannot be used since the individual is anchored to a universe of discourse that justifies their views. In more common language the ontological anchor occurs when people or designers know what they are doing is bad or incorrect, but they proceed to do it anyway even though they know better.

To introduce an analogy as an example of an ontological anchor one can consider a game of Sudoku. In Sudoku a number of the squares depending on the difficulty are already filled in with numbers. These numbers can be considered one's ontological anchors. When playing Sudoku one must account for the pre-filled in numbers in their solution and if the pre-filled in numbers are moved or changed, the predicated solution changes or may become infeasible. This same behavior can be seen with design and complex engineering problems.

Two interesting examples of ontological anchors during design are illustrated through the SR-71 Blackbird Program. With the SR-71, the U.S. Air Force insisted on having its insignia painted on the wings and fuselage, "even though no one would ever see it at eighty-five thousand feet" Rich and Janos (1994). This anchor of needing insignia painted even on a spy aircraft caused for major ontological costs, actual costs, and development. They even had to use pink paint instead of white to try to limit detection Rich and Janos (1994). Another example of an ontological anchor during the program was how the U.S. Air Force also mandated the aircraft could pass a dust test for low altitude flight over the desert even though the aircraft would be flying at altitudes of over 16 miles Rich and Janos (1994). These can be seen as ontological anchors as they directly show the fastening of the U.S. Air Force's view on the design of an aircraft.

The Notion of Ontological Conflict (Anguish)

Ontological conflict (anguish) is an important concept to define prior to delving into the presented case study. Ontological conflict or anguish is not defined in the field of philosophy, but is rather inspired from philosophy. In philosophy the existential concept of anguish, as articulated by philosophers like Jean-Paul Sartre and Søren Kierkegaard, plays a significant role in the context of decision-making. This concept is rooted in the idea that human existence is characterized by a fundamental sense of anxiety and anguish, which arises from our freedom and responsibility to make choices. Existential anguish, also known as existential dread or anxiety, is considered a fundamental aspect of the human condition. It emerges from the realization that human beings are free to make choices, and with this freedom comes the burden of responsibility for those choices. The act of making choices in this context becomes a source of anguish. When individuals confront a decision, they experience existential anguish as they grapple with the uncertainty of outcomes and the weight of their choices. This anguish is not merely a psychological condition but an inherent part of the human experience. This can directly apply to the decision making one faces as a designer or an engineer. In relation to ontological commitment, when a design decision is made that causes for a misalignment of "truth," universe of discourse, or another ontological commitment, there exits ontological conflict (anguish) associated with the decision. This will be shown later in the investigated case study. Practical examples of ontological anguish can be seen through computation fluid dynamics (CFD) replacing towing tanks or one's struggle in developing new methods that disprove prior methods.

The Philosophical Concept of Discourse Ontology

In philosophy, discourse ontology refers to the study or analysis of existence and reality as expressed through language and discourse. It involves examining how our understanding of being and the nature of reality is shaped, conveyed, and constructed through language and communication. Discourse ontology explores the relationship between language and our understanding of reality. It considers how language structures and influences our perception of being and existence. Tombras defines discourse ontology formally as "an ontology—in so far as it concerns being, i.e. the open space where a world can present itself as intelligible to the human being—with the designation "discourse" denoting the source of this intelligibility" Tombras (2019). One should note that by combining discourse ontologies one is able to form a universe of discourse. This process involves bringing together various discourses or ways of talking about existence to create a broader and more inclusive context for investigation and inquiry.

Introducing Philosophy to Engineering Design

Navigating the intricate realm of design requires a nuanced understanding of its complexities and entanglements. Entanglement in this case refers to the concept that one cannot look at certain aspects or concepts in isolation but rather as a whole in terms of both macroscopic and microscopic impacts. As begins the elucidation process of defining requirements and initiating the design process, the philosophical and ontological concepts introduced above each wield a substantial influence on the process. Among these, the notions of universe of discourse, ontological commitment, ontological cost, ontological anchor, ontological anguish, and discourse ontology play a profound role in shaping the trajectory of design endeavors. By delving into real-world examples, one can unravel the intricate interplay of these ontological considerations and appreciate their substantial impact on engineering design. To underscore their significance, it is insightful to examine the challenges encountered by naval vessel design programs, as they represent long duration design projects, and many have significant amounts of publicly available information. The following sections will look at public information from the Littoral Combat Ship (LCS) program to illustrate philosophical and ontological aspects in design and the elucidation of design requirements.

AN INTRODUCTION TO U.S. NAVY SURFACE SHIP DESIGN

The design of U.S. Navy ships involves several key entities including the Office of the Chief of Naval Operations (OPNAV), Naval Sea Systems Command (NAVSEA), Program Executive Office Ships (PEO Ships), and shipbuilders. For ship design, OPNAV establishes strategic and operational requirements and is responsible for resource allocation. PEO Ships manages the design, construction, and delivery of ships, ensuring that ships meet operational, schedule, and budget requirements. PEO Ships is affiliated with NAVSEA, and NAVSEA engineering directorates are the principal authority for design and engineering. NAVSEA defines and manages technical requirements including adherence to safety, environmental, and performance standards. Shipbuilders and industry play a pivotal role in the actualization of naval ship designs, translating design specifications into detailed designs and ultimately construction and delivery. The process for the acquisition of a ship is complicated and bureaucratic, involving the development of binding design requirements, specifications, and contract documents.

THE LITTORAL COMBAT SHIP (LCS) AS A CASE STUDY

One of the U.S. Navy's more recent ship design programs was the development of the Littoral Combat Ship (LCS). The design of LCS proves to be an insightful study as there is an atypically large volume of publicly available literature showing a change in perception of the design. Perception has ranged from being what the Navy needed as a "streetfighter" during concept development, to derision as "The Navy's Very Expensive Mistake" when several ships in the class were decommissioned early Barbaro and Lipton (2023). This case study looks to explain that change in perception through a philosophical and ontological analysis of the design challenges and requirements development.

It is the authors' premise that top level truth statement(s) for an organization must hold true for a design to be successful, acting as ontological anchors. These anchors can be considered a Style, or design philosophy. If the motives or narrative for a design or design decision are in line with the ontological anchors, the process can move ahead smoothly. However, if entities are working toward false anchors or the design becomes misaligned with the true ontological anchors, this will result in design churn or re-work until the design either aligns or fails. Recognizing and accounting for the discourses, ontological commitments, and ontological anchors is critical for a successful design program. In the case of LCS, the change in perception about the program may be explained using the premise that a global universe of discourse with shared ontological anchors did not exist. Once the true anchors became clear and were commonly held, the pull toward alignment came in the form of changes to the program.

Three aspects of the LCS program will be presented as two cases: changes in vessel rules during the bidding and design process, changes in the evaluation of survivability over the design process, and changes in vessel lethality over the design process and introduction to the fleet.

Case 1: The Ontological Anchors of a Commercial Parent, Commercial Rules, and Survivability

The LCS program was originally conceived as part of a surface combatant family of ships. LCS was envisioned to be the small and low cost ship that could be built in larger numbers, in part relying on the broader force network for effectiveness and survivability Work (2014). Attempting to meet affordability targets meant designing LCS to a commercial parent, with reduced survivability, and to commercial standards. Each of these ontological anchors is examined in turn.

The first ontological anchor was to use a commercial parent hull form and industry partnered vessel rules. Based on the initial stipulations for LCS, industry designs were based on high speed ferries. "The philosophy of the two industry design teams was to leverage technical advances and risk-reducing lessons learned in these high-speed commercial ferry designs, while integrating features and design approaches that are unique to a U.S. Navy Combatant" Keane and Tibbits (2013) However, "the incorrect framing assumption was that these commercial vessels were appropriate parents upon which to base an appreciably different warship" Keane and Tibbits (2013). While at the time this may have seemed like a good idea, this represents a major ontological commitment. By using commercial ferry designs as a parent hull, the industry design teams greatly predicated, influenced, and committed the universe of discourse for the design and translation of requirements for LCS. During this process however, "grumblings from the surface warfare community, which was highly skeptical of warship based on commercially derived designs," started to cause a shift in requirements Work (2014). This shift is an example of ontological conflict resulting from a false ontological anchor. In this case, the design started to be pulled away from the false ontological anchor (commercial parent) and begin aligning with the underlying true ontological anchor (warship).

The next ontological anchor is that industry partnered rules were sufficient for a warship. When initially setting out the bid for LCS, "the Navy initially asked for ship designs using American Bureau of Shipping (ABS) High Speed Naval Craft Rules, which were essentially commercial standards" Work (2014). In 2003, a partnership was developed between the U.S. Navy and ABS. The partnership was intended to help develop the Naval Vessel Rules (NVR), a set of rules meant to update military general specifications and develop rules in collaboration with industry. LCS was the first vessel where NVR would be implemented. It should be noted that the "implementation of new Naval Vessel Rules (design guidelines) further complicated the Navy's concurrent design-build strategy for LCS. These rules required program officials to redesign major elements of each LCS design to meet enhanced survivability requirements, even after construction had begun on the first ship" United States Government Accountability Office (2007). The switch from ABS High Speed Naval Craft Rules to the NVR occurred after the contract for the vessel was awarded.

In testimony before Congress at the time, NAVSEA stated the partnership with ABS was "to write a new set of rules to take the best of the old and some of the good commercial practice from ABS and blend them together in a set of Naval Vessel Rules for the ship. A problem is that we did that throughout–concurrently throughout the time when the bidders were bidding on the ship and the ship that we bid and the ship that we costed out is not the same ship that we are buying today because of the parallel development of those rules" U.S. Government Printing Office (2007). The development of the rules in parallel with the design of the ship caused for numerous late stage design changes. This can directly be seen through how NAVSEA stated in the testimony that "the ship that was bid did not include many of the provisions of the Naval Vessel Rules because it was based on a commercial design and in getting the ship design from the commercial design to meet the rules that we need to keep our sailors safe" U.S. Government Printing Office (2007). The ontological anguish of this can also be seen on the shipbuilder side from the same hearing from testimony by the president of Lockheed Martin at the time, "we bid, as [NAVSEA] said, a commercial ship. ABS class ship was our bid. The Navy decided, for good reasons, to make this ship a surface combatant which would be very survivable, which it is. And that caused a lot of change" U.S. Government Printing Office (2007).

The final anchor, alluded to above, was the acceptability of a less survivable warship. At the outset, LCS was designed to a "Level 1+ survivability standard, which is greater than the Level I standard to which the Navy's current patrol craft and mine warfare ships were designed, but less than the Level II standard to which the Navy's current Oliver Hazard Perry (FFG-7) class frigates were designed" O'Rourke (2012). However, hitting this requirement with a commercial parent and commercial based standards proved a challenge, "...designers simply did not believe they could hit the LCS cost targets... Consequently, early program documents established "crew survivability" as the minimal design standard" Work (2014). Even then, this meant changes relative to commercial rules, including shock hardening of systems, additional water-tight compartmentalization, and redundant firefighting systems. The yards selected for the ship did not initially have the capability needed to build the ship to the increased level of survivability, and it had to be built up. Even with all of the design churn, the Director, Operational Test and Evaluation did not expect LCS "...to be survivable in a hostile combat environment. This assessment is based primarily on a review of LCS design requirements, which do not require the inclusion of the survivability features necessary to conduct sustained operations in its expected combat environment" O'Rourke (2012).

The public record and abundance of published opinions about LCS survivability are evidence the ontological anchor was false Lagrone (2013) Hilger (2016). Remembering that an ontological anchor is the fastening of one's view of the universe of discourse to a specific assertion, the LCS survivability anchor was false because the assertion that Level 1+ survivability was sufficient was based on a false perception of the Navy's universe of discourse on survivability. The true universe of discourse was around traditional warship surivivability. This is evidenced by the 2014 Secretary of Defense directive for the Navy to submit more frigate like survivable alternatives to LCS.

Case 2: The Ontological Anchor of Lethality

The LCS was designed to be lethal against asymmetric near coastal threats, emphasizing prosecution of small boats, mine warfare, and littoral anti-submarine warfare, enabling other forces to focus on primary missions Defense Acquisition Management Information Retrieval (2004). This ontological anchor for lethality was fastened to a universe of discourse in the context of a "...a new security agenda that addresses contemporary threats such as the proliferation of nuclear, chemical and biological weapons, terrorism, and international crime" The White House (2000). Over the course of the program the universe of discourse shifted, "inter-state strategic competition, not terrorism, is now the primary concern in U.S. national security, " but the original ontological anchor for lethality had already been actualized via design, construction, and delivery of ships and was still reflected in program reports U.S. Department of Defense (2018) Defense Acquisition Management Information Retrieval (2018). The ontological anchor for lethality was true for the original universe of discourse, but became a false anchor as the universe of discourse shifted. Attempts to align the two did occur. Efforts to change the ontological anchor to align with the shifting universe of discourse started in 2014 when the Secretary of Defense directed the Navy to "...submit alternative proposals to identify and procure a more lethal and survivable small surface combatant, with capabilities generally consistent with those of a frigate" U.S. Department of Defense (2014). Attempts to change the universe of discourse to better align with original anchor also occurred, "to compensate for any gaps in the ship's survivability and lethality capabilities, the Navy continues to redefine the concept of operations (CONOPS) for LCS" United States Government Accountability Office (2015) .

The misalignment over time between anchor (lethality) and universe of discourse (threat) has ultimately resulted in early decommissioning of several ships, and cancellation of key portions of the program, including the Anti-Submarine Warfare (ASW) mission package. The explanation was that "those requirements for that ASW package for LCS were developed back in 2008 against a diesel [submarine] threat in the littorals. And then our minds shifted to we'll be using these things in the deep blue ocean" Ong (2022). However, what is intuitive retrospectively (significant changes in requirements means rework and consequent cost and schedule impacts) can be difficult to see in the present. Ontological and philosophical concepts provide a more general, structured and rigorous way to identify and understand as a designer what one is doing, rather than just understanding how to do it.

DISCUSSION

One of the most important concepts that can be gleaned from the presented case study is that requirements elucidation is really just working to resolve one's ontological anchor (true or perceived). Work to resolve the ontological anchor is supported by low fidelity engineering, for example, concept design activities. Once the ontological anchor or anchors are resolved, the process moves into the design phase where the anchors are considered to be set. To implement the anchor, one conducts design activities so that design knowledge can be generated over time. If an anchor changes, an anchor is found to be false, or a new anchor emerges, this causes for design rework or for the design to fail.

In regards to the LCS program, this can be clearly seen through how in the Work report it is stated that "perhaps the most serious objection to LCS is that the Navy charged into series production without having a clear idea of how the ship would be used" Work (2014). This sentiment is directly connected to the idea of not properly resolving one's ontological anchor.

One of the reasons for the larger amount of rework and failures seen with naval design is the time scale. The duration of Navy design programs are very long, some upwards of 20 years. Given the long time scale of naval design, the probability of an ontological anchor or universe of discourse changing is very high. This means if the anchor changes the prior engineering work may no longer supports the new anchor. The high probability of an ontological anchor changing can also be partially attributed to changes in personnel over the course of a design program or evolving threats.

The case on survivability hints that even if entities try to do things differently, an organization will be pulled toward its cultural anchors. Cultural and societal based ontological anchors can be enduring, whereas anchors based on an individual's vision are comparably unstable and short. Thus, in an organization with long-time scale projects and staff turnover, things are likely to revert to more enduring cultural or societal anchors. This could directly be seen with LCS in how the initial vision for a commercially based less survivable ship was pulled toward the more culturally accepted idea of a frigate. The pull away from anchors for commercial parents, standards, and reduced lethality and survivability toward more traditional anchors is not unique in warship design.

CONCLUSIONS

In conclusion, the elucidation of requirements is foundational in the early stages of the engineering design process. In the realm of design, language serves as a crucial medium for articulating desires and necessities, which then transform into explicit and unambiguous design requirements. This transformation, facilitated by embedded language in various design documents and tools, contributes significantly to shaping and constraining potential solutions, encapsulated in the philosophical concept of ontological commitment.

However, the translation of uncertain or ambiguous language into concrete design requirements has been overlooked from a linguistic standpoint. The true implications of design requirements and their ontological commitments and anchors, often only become fully apparent later in the design process. The real-world examples presented from the Littoral Combat Ship program underscore the tangible impact of ontological and philosophical concepts in the requirements process. These examples serve as a modern lens through which to examine how language, through the articulation of requirements, shapes and guides the trajectory of design solutions. As the design process evolves, it becomes increasingly evident that the linguistic choices made in the early stages exert a profound influence on the ontological commitments and anchors that underpin the final design outcomes. While the presented case may seem specific the concepts and method introduced are largely and generally applicable to marine design and other design disciplines.

A few important concepts can be taken from the case study presented in this manuscript. One important realization is that universe of discourse and truth statements can be relative to an individual or group. This is akin to the idea that "beauty is in the eyes of the beholder." This concept does not work in naval design. Given this, in design it is important to try to find a universe of discourse that is generally global and robust. The other critical realization is that requirements elucidation is really just working to resolve and properly account for one's ontological anchor. This is critical to try to get right from the early stage of the design process to try to prevent design churn, re-work, or failure.

Looking to the future, concurrent engineering approaches may address the challenges facing current and future design programs, based on the presented theory. Concurrent engineering approaches, including close interaction between stakeholder organizations, may be able to avoid silo effects and better identify enduring ontological anchors and form a global universe of discourse. In any event, ontological anchors and commitments will need to be accounted for and properly resolved.

CONTRIBUTION STATEMENT

CWA: Conceptualization; investigation, methodology; writing – original draft. **MCP:** conceptualization; methodology; writing – review and editing **DJS:** conceptualization; supervision; writing – review and editing.

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