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February 23, 2024

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Chair John C. Velis
Joint Committee on Veterans and Federal Affairs
24 Beacon St., Room 513
Boston, MA 02133

Chair Gerald J. Cassidy
Joint Committee Veterans and Federal Affairs
24 Beacon St., Room 171
Boston, MA 02133

Dear Clerk Hurley, Clerk James, Chairs Rodrigues and Michlewitz, Chair Velis and Madaro, Chair Cassidy:

Subject to Section 2 of Chapter 28 of the Acts of 2023, the Department of Mental Health is pleased to submit a report on behalf of the Massachusetts Institute of Technology (MIT) outlining the feasibility of converting a decommissioned ship or other water-based vessel into a floating hospital for mental health, substance use treatment, and recovery services.

Special thanks to the Secretary of the Navy for endorsing this project and to the MIT's Naval Construction & Marine Engineering Program for their collaboration and research in producing this investigative report.

This project was modeled after Boston Medical Center's Brockton Behavioral Health Center Clinical Stabilization Services and can be used as a basis for both in-patient and out-patient treatment.

Thanks to their partnership, this study was completed at no cost to the Commonwealth.

Sincerely,

Brooke Doyle, M.Ed., LMHC
Commissioner

cc: Kate Walsh, Secretary, EOHHS

Feasibility Study

Cruise Ship Conversion

An investigation into the utility and feasability of converting a cruise ship into a mental health and rehabilitation facility

Project Team: Emily Curran
Adam Pressel
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Course: 2.704
February 5, 2024

Contents

List of Figures

List of Tables

1. Project Overview

1.1 Introduction

Boston, like many major metropolitan areas, is struggling with an opioid and public safety crisis. Specifically, in 2022, 352 overdose deaths were reported in Boston. A major contributor to this crisis is the lack of housing and medical facilities to support the most vulnerable population in the city [1]. The current demand for accessible mental health services far exceeds the available resources, and the city is facing a rising number of overdose deaths waiting for a solution. An article in the Boston Globe on 9 April 2023 cited a survey by the Massachusetts Health and Hospital Association and the Massachusetts Association of Behavioral Health Systems stating that the average wait time for patients requiring long-term inpatient care was 197 days [2]. Additionally, in the last year, the overcrowding of sheltering units has caused more than 1,200 people to be stuck in hospital beds with no place to be discharged [3]. These data points underscore the rapid need for innovative approaches to address the alarming imbalance between the growing demand for mental health and recovery support and the limited supply of resources.

Figure 1: Scrapped cruise ships at a ship breaking yard in Aliaga, Turkey. [4]

Following the 2020 coronavirus pandemic and the resulting reduction in the cruise industry, a large number of cruise ships became available for sale and alternative uses were explored. In 2022 alone, 18 cruise ships were scrapped, so much so that scrap yards are inundated with ships [5]. Figure 1 shows the scene in a single scrap yard [4]. There are more ships available than can be scrapped at once. As Boston is a coastal city, the prospect of capitalizing on an available cruise ship to repurpose it as a medical facility has been proposed as a potential course of action. This novel solution has the potential to provide community medical resources, despite the scarcity of land and buildings, while delivering in a much shorter time than a traditional brick and mortar facility.

An initial investigation into the possibility of converting a cruise ship to a mental health and substance rehabilitation facility revealed previous studies in similar areas of work, but no full-scale projects have been completed. Previous studies relevant to this work have examined the feasibility of converting a cruise ship to both a hospital ship and an affordable housing complex [6][7][8]. Elements of each of these studies were evaluated during this study.

The concept of providing Boston medical care via a converted ship is not an entirely novel idea. In the 1890s, Boston was home to the innovative Floating Children's Hospital, a ship dedicated to treating ill children, particularly from low-income families, and offering them the benefits of fresh sea air and isolation from city pollutants [9]. Although ship facilities were reestablished on land after a ship fire in 1927, the hospital remained an important facility serving Boston children more than 100 years later. This pioneering approach to the use of maritime resources for healthcare can inspire modern adaptations.

A Washington-based architecture firm proposed a cruise ship conversion to address the affordable housing crisis in Miami in 2022 [10]. Initial estimates put the cost per unit at $1,250 per month. A 2023 Massachusetts Institute of Technology (MIT) Naval Construction and Engineering (2N) team, Cruise Ship Conversion into Affordable Housing (CASH), built on this work to further explore the conversion of a cruise ship to an affordable housing complex. Their conversion design resulted in 246 housing units that could accommodate 350 people. The project team considered these results when first estimating the number of patients for whom a converted cruise ship may provide adequate treatment space. The 2023 CASH team projected that the rent of its 246 housing units to range from $475 per month to $3000 per month based on the size and amenities of the unit [6]. Cost estimates for these two projects did not readily translate into the cost of providing a medical facility; however, their cost metrics were used to develop the theoretical operating costs per patient of a ship-based facility.

A 2021 2N team also investigated the conversion from a cruise ship to a hospital ship. Their study aimed to look for options for potential replacements for the United States Navy (USN) hospital ships, as both current ships are expected to be decommissioned in the mid-2030s. Their study estimated a conversion cost of three to five billion dollars and accounted for unique elements of a hospital such as the services required and the hospital bed and wheel chair accommodations for ship transit [7]. This study and the available USN hospital ship maintenance availability data contributed to the conversion cost estimation for this project.

Although the idea of a dedicated and afloat public mental health treatment facility is not common, the concept of providing afloat medical care in a crisis is not new. The USN has used ships to provide emergency care when needed in times of natural disasters and the resulting humanitarian crises, such as in New Orleans after Hurricane Katrina (2005), Haiti after a devastating earthquake (2010), and New York City during the COVID-19 pandemic (2020). These examples show the potential benefits of an afloat medical treatment facility of any kind. They provide a unique medical surge capacity that can be relocated as needed. Further research of these examples, along with the consultation of subject matter experts, provided a starting point to study the validity of converting a cruise ship to a mental health and substance use rehabilitation facility.

1.2 Study Objectives

The objective of this conversion project is to determine the feasibility of converting a cruise ship to a floating medical facility that supports mental health services and substance rehabilitation treatment for the Commonwealth of Massachusetts. The project team identified potential areas of insight that required additional analysis due to their impact on the success of the conversion design. These items are outlined below.

Key Insights

Cost. Determine the cost of purchasing a ship of adequate tonnage, personnel capacity, and of a sufficient material condition. Model and estimate the overall cost of conversion and overhaul. Provide a gross estimate for continued operations following conversion. Contrast with the nominal costs of running a conventional land-based facility, as well as the current city costs incurred due to a lack of facilities.

Arrangements. Determine what major spaces and equipment can/need to be removed and what needs to be retained to support this conversion and maximize the treatment and living space on board. What changes are required for the topside arrangement to support egress and medical evacuation capability? Additionally, what significant medical equipment and spaces will be required on board? How can passageways, corridors, rooms, and ship ladders be adapted to accommodate disabled personnel or the movement of hospital beds and stretchers? Evaluate potential changes to hydrostatic stability and strength to the aforementioned changes.

Habitability. Determine the major design decisions and considerations necessary to convert existing hotel-style rooms into Massachusetts-regulation-compliant treatment rooms and living spaces for long-term patients. This will require a particular emphasis on safety and the requirements of the Massachusetts Department of Public Health (DPH), Department of Mental Health (DMH), and the Bureau of Substance Addiction Services (BSAS).

Concept of Operations. Determine how this type of facility can support both short-term and long-term treatment. Determine whether this requires housing facilities for staff in addition to patients. Evaluate the engineering requirements generated from housing full-time occupants with medical services. Consider the hotel services required for medical patients compared to cruise ship guests.

Support Systems. Determine what in-port infrastructure needs to be implemented or upgraded (with respect to shore power, potable water, garbage disposal, etc.) to support long-term docking of this type of vessel. What additional pier services are required for a medical facility? What will these additional services cost?

Seaworthiness. What ship features needed to be retained and/or upgraded to support long-term mooring and short-notice sortie in case of extreme weather conditions? What impact to seakeeping, speed, and stability does the conversion have?

1.3 Customer Requirements

The primary requirement from the project sponsor was that the facility provide mental health and rehabilitation treatment and lodging for 200 to 500 patients in or near Boston, Massachusetts. The sponsor placed significant emphasis on minimizing the conversion cost and schedule.

The project team further developed the customer requirements by reviewing the licensing requirements of DMH, DPH, BSAS, consulting subject matter experts, and reviewing hospital ship requirements. The expanded requirements are that the ship supports medical care for mental health and substance recovery treatment, is able to remain pier side in or near Boston, is relocatable, and requires less time and money to complete than a land-based facility. Further analysis of these baseline requirements yielded derived requirements which are listed below along with the primary requirements.

1. The study will investigate the creation of a floating hospital for mental health, substance abuse treatment, recovery services, and state-mandated commitments for 200 to 500 patients.
   - 1.1 The facilities must be compliant with DMH, DPH, and BSAS licensing and operational standards.
   - 1.2 The vessel must support adequate staffing facilities for offices and berthing for in-port and short-duration at sea operations.
   - 1.3 The vessel must be comparable to facilities built on land for the same patient population.
2. The ship must be able to operate pier side in or near Boston indefinitely.
   - 2.1 The ship must be within draft/size restrictions associated with Boston and its surrounding waters.
   - 2.2 The vessel must be compatible with pier services available or be self-sufficient in the case of missing services.
   - 2.3 This ship must be retrofitted with hotel services requisite of a dedicated medical facility vice a recreational cruise ship.
3. The design shall retain onboard auxiliary electrical power and distribution in case of loss of normal shore power and in order to provide power during transit.
   - 3.1 Any additions or modifications made to the purchased ship design must fit within the installed electrical capacity.
   - 3.2 The ship must maintain organic service generators and a dedicated fuel system.
4. The converted cruise ship must be relocatable to support any sortie requirements or any required movement along the eastern United States.
   - 4.1 The ship must maintain adequate stability to withstand at-sea transit.

4.2 The ship must retain systems involved with light/sound requirements for at-sea transit.

4.3 The ship must be self-propelled.

4.4 The ship must be built with fixtures, and services that are easily secured for sea prior to ship's movement.

5. The cost must be comparable to a similarly sized land-based facility.

5.1 The lifecycle average annual cost comparison is specific to the city of Boston for this project.

5.2 The conversion should take less time than that of building an equivalent land-base facility.

1.4 Major Assumptions

The following assumptions served as the starting point for the design decision, concept exploration, and concept development phases of the project. They were informed by research conducted at the beginning of the conversion study and were influenced by feedback received from subject matter experts, the project sponsor, and the course instructors.

Capital Cost Funding. The venture has the full backing and approval of the city and state governments such that required funding would be provided to finance all initial capital fixed costs. This includes the cost of purchase and overhaul of the vessel, the initial cost of the refurbishment and modification of the pier, and the cost of any initial upgrades to the utility infrastructure of the pier to support the converted cruise ship.

Regulatory Approval. Any and all requirements and regulations that would need to be waived, modified or approved by state mental health and public health organizations, the United States Coast Guard (USCG), professional societies, and any other relevant entities have been addressed as necessary.

Seaworthiness. Given that the vessel to be purchased previously met the class standards required to operate, it is assumed that the standards are still met or can be met with reasonable repair at the time of purchase, including stability and strength requirements of the American Bureau of Shipping (ABS) and USCG regulations. Therefore, it was assumed that the requirements for seaworthiness and stability are within the requirements for cruise ships prior to conversion. This was then validated in the final engineering analysis.

Service Life Extension. The average service life of a well-built and maintained cruise ship is approximately 30 years. However, this vessel will be moored in port at all times except for rare circumstances requiring sortie or coastal relocation. In these cases, the vessel would operate at slow speeds. Due to this very narrow operational profile, the assumed projected service life of the chosen vessel, after conversion, will be an additional 30 years. A detailed hull inspection and life extension study is required to validate this assumption and qualify the maintenance costs to sustain such an extension.

1.5 Information Resources

Project Sponsor

Nick Collins. Senator Nick Collins serves as a member of the Massachusetts Senate, representing the First Suffolk District. Senator Collins serves as the Senate Chair of the Joint Committee on State Administration and Regulatory Oversight and the Senate Vice Chair of the Joint Committee on Community Development and Small Businesses. Additionally, he serves as a member of the Senate Committee on Bills in the Third Reading, and on the Joint Committees on Bonding, Capital Expenditures and State Assets; Mental Health, Substance Use and Recovery; and Public Service. Elected into the Massachusetts House of Representatives in 2010, he served four terms in the House representing the 4th Suffolk District. Senator Collins is sponsoring this study as part of his commitment to explore novel approaches to support his district and combat the mental health and substance use crisis it is currently facing.

Project Team

Panagiotis Rafail Athanasopoulos. LT Engineer Officer Panagiotis Rafail Athanasopoulos originates from Kiato, Greece, where he graduated with Honors from the Hellenic Naval Academy in 2014 with a specialization in Marine Engineering. Following his graduation, he embarked on a multifaceted career within the Hellenic Navy, serving across various vessels including Frigates, Gunboats, and LSTs, assuming pivotal roles as an Auxiliary Machinery Officer, Vice Chief Engineer, and Damage Control Officer. While actively serving, in 2017, he commenced his studies in Naval Architecture and Marine Engineering at the National Technical University of Athens, successfully completing his degree in 2022. Presently, he is sponsored by the Hellenic Navy for participation in the 2N Program (Naval Architecture and Marine Engineering) at MIT MECHE, concurrently pursuing a dual Master's degree in System Design Management at MIT Sloan School of Management. Beyond his professional pursuits, Rafail embodies a passion for exploration alongside his wife. They delight in traversing new destinations, immersing themselves in diverse cultures, savoring new cuisines, tuning into music, and delving into captivating books.

Emily Curran. LCDR Emily Curran is a 2010 graduate of Auburn University. Her operational assignments include Communications Officer, USS McCambell (DDG 85); Reactor Auxiliaries Division Officer and Deputy Reactor Training Assistant, PCU Gerald R. Ford (CVN 78); and Reactor Controls Assistant and Station Officer, PCU John F. Kennedy (CVN 79). Her seagoing tour included multiple freedom-of-navigation tours, Operation Tomadachi, and a six-month docking selected restricted availability. During her CVN tours, she supported the nuclear test program to include executing the reactor safeguards examination and completing initial power range testing for a first-in-class propulsion plant. Ashore LCDR Curran completed her Engineering Duty Officer Qualification at Supervisor of Shipbuilding Newport News, VA serving as Assistant Project Officer on the CVN 78 Project Team supporting ship trials, delivery, at-sea testing, and the post-shakedown availability. She is Level III PQM certified and has earned her Acquisition Professional Membership. LCDR Curran is currently pursuing degrees in Mechanical Engineering and Naval Architecture & Marine Engineering at MIT. In her spare time, she is busy exploring Boston and traveling with her husband and their three children.

Adam Pressel. LT Adam Pressel is a native of Philadelphia, Pennsylvania and graduated from the United States Naval Academy in 2018 with a Bachelor of Science in Computer Engineering. His first assignment was as the Weapons Officer on USS GABRIELLE GIFFORDS (LCS10), where he deployed to the Eastern Pacific Ocean. During his 2020 deployment, he led his ship's boarding team to interdict nine vessels, capturing $300M of suspected contraband and detaining 21 persons. Following deployment LT Pressel became the Assistant Operations Officer on USS JACKSON (LCS6). After transferring to the Engineering Duty Officer community, LT Pressel qualified as a Joint Diving Officer at the Naval Diving and Salvage Training Center. LT Pressel is currently pursuing dual degrees in Naval Engineering and Electrical Engineering and Computer Science at MIT; in his spare time, he is an avid cyclist, and dedicated mountaineer.

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- **Nancy Connolly, Psy.D.** Assistant Commissioner of Forensic Mental Health Services for The Commonwealth of Massachusetts
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- **Tracey Weeden, MSW LICSW** Executive Director, Brockton Behavioral Health Center
- **Benjamin Sward, Brendan Harris, Santeri Ihalainen** Foreship LLC
- **Deirdre Calvert, MSW LICSW** Director, Bureau of Substance Addiction Services
- **Thomas McKenney, Ph.D.** Associate Professor of Engineering Practice, University of Michigan
- **Riley Nichols** Legislative Aide, Office of Senator Collins
- **Chase Geschwilm** SEA05-D1 Project Naval Architect for T-AH(X), Naval Sea Systems Command
- **Robert Lager** President, Lager Maritime Corp.
- **2023 CASH 2.704 Team Members** LCDR Heather Willis, LCDR Jason Webb and LT Avi Chatterjee

1.6 Process Overview

The major tasks of this project were to:

1. Identify the requirements for a mental health and substance use recovery and rehabilitation hospital ship conversion.
2. Select a suitable cruise ship to serve as an example variant based on the requirements.
3. Develop a design to convert the selected cruise ship into a mental health and substance use recovery and rehabilitation facility.
4. Estimate the conversion project's cost and completion timeline.

The project team first developed overall vessel requirements from sponsor requirements, the DMH, DPH, and BSAS facility requirements, and requirements to support an afloat medical facility.

The initial conversion steps included the selection of an existing cruise ship available for purchase, evaluation of baseline hydrostatics, arrangements, and cost. The ship selection was the most budget-conscious model that was amenable to conversion with respect to the features and assumptions previously established in our initial unified design concept and as dictated by the sponsor's criteria. Both cost and completion time were heavily considered in this project as a result of being a state-sponsored project and due to the urgency of time for such a facility.

The project team then used various 3D Computer-Aided Design (CAD) software such as Rhinoceros (Rhino) and Fusion360 to develop the initial ship model and and then model the preliminary cruise ship redesign based on the developed arrangements requirements. The major aspects of this process included: (1) space and equipment rip-out, (2) living space modifications pursuant to medical facility requirements, (3) additional common treatment and administrative space installation, and (4) support system installation and/or upgrades. Additionally, topside modifications were made to support above requirements.

Once the final model was developed, a robust naval architecture analysis was performed using the Orca 3D Rhinoceros Plug-in (ORCA). Hydrostatics, weight, and stability were calculated and compared with the original design to determine the change. The project also evaluated the ship's maintainability, considering aspects of upkeep, sustainability, and long-term operability as a medical facility located pierside. Furthermore, the project ensured compliance with regulatory standards by engaging with subject matter experts, project sponsor, stakeholders, communities, and local authorities to address legal, health, and safety regulations.

Additionally, the team used primary source cost models from historical cruise ship refurbishments and hospital construction projects to estimate future capital requirements for this conversion. This estimate integrated the converted ship design with operational guidelines, staffing requirements, and protocols for providing mental health and rehabilitation services. A cost-benefit analysis encompassing initial investment, operational costs, and potential revenue streams was conducted. This evaluation compared conversion and operating costs to current state and city expenditures required to manage the opioid and mental health crisis in Boston.

Finally, the project team produced a comprehensive report and a final model, providing clear recommendations on the feasibility and sustainability of converting a cruise ship into a mental health and substance use recovery and rehabilitation facility.

2. Design Approach

2.1 Design Philosophy

The design philosophy of this project is motivated by the goal of designing a cost-effective facility that meets community medical needs. This drove the project team to use as much existing infrastructure as possible to create a facility that is feasible, affordable, and able to be developed in a timely manner. To achieve these goals, the project prioritized the following aspects of the conversion.

1. Meet medical facility compliance. The final designed facility must meet the same criteria as a land-based facility treating a comparable patient demographic. The facility is not helpful in alleviating the shortage of treatment space for mental health patients if the facility licensing requirements are not met.

2. Minimize the conversion duration. Since a cruise ship already has a configuration that supports lodging and habitability of many patients due to the nature of its hotel design, this can be capitalized on to minimize the conversion complexity and therefore the estimated construction time. The city and the commonwealth have an immediate need for such a facility, so making design decisions to accommodate a smooth and efficient conversion were prioritized. By using as much of the existing structure and systems as feasible, the project can drive down estimated schedule cost and risk.

3. Minimize conversion and maintenance costs. Much like minimizing construction time, the overall cost of the project is also an important factor. As a state-sponsored project, additional emphasis was placed on making hull selection and design decisions to meet medical facility requirements at the minimum cost possible. These decisions also included consideration of the operating costs following conversion. This is an effort to increase the feasibility of this project and meet the customer's requirements.

2.2 Design Parameters

The complete list of design parameters and associated threshold and objective values determined for the final mental health facility design is listed in Appendix C: Design Parameters and in Figure 2. These parameters were derived from the requirements for current medical and mental health facilities, substance addiction support facilities, hospital ships, cruise ships, and manning requirements [11] [12] [13]. Collectively, the design parameters support the customer requirement to create a mental health and substance recovery facility. The final design parameter list was refined with the assistance of subject matter experts from DMH, medical facility guidelines, NAVSEA, and other contacts from the Massachusetts medical system.

The engineering requirements for the converted facility are primarily aimed at ship stability and port access, as the converted vessel is intended to operate pierside most of the time. This operational profile made the medical facility requirements the highest priority. The Medical facility requirements are further delineated in Appendix D in accordance with facility guidelines for building a hospital [11]. This provides more

Capability	Characteristic	Threshold	Objective	Reference
Marine Performance	Draft	6.7m	6.5m	NOAA Chart: 13272
	Seaworthiness (Roll Period)	0.05-0.15	0.1	MIT 2N
	GM	11.875m	10.7m	
Hotel Services	Patient Laundry Services	Organic to Ship	Organic to Ship	FGI
	Housekeeping Storage	Organic to Ship	Organic to Ship	FGI
	Patient Storage	10 sqft/Patient	Organic to Ship	FGI
	Patient Dining Area	20sqft/Patient	20sqft/Patient	FGI
Administrative Services	Documentation/File Room	1 per facility		FGI
	Staff Support Spaces	1 per 25 Patients	1 per 20 Patients	FGI
	Staff Office Spaces	1 per 25 Patients	1 per 20 Patients	FGI
	On Call Rooms	1 per 35 Patients	1 per 30 Patients	FGI
Medical Facilities	Stretcher-capable elevator	1	4	FGI
	Triage/Intake Assessment	1 per facility	1 per facility	CMR 104
	Pharmacy	1 per facility	1 per facility	FGI
	Clinical Laboratory	1 per facility	1 per facility	FGI
	Nursing Stations	1 per unit	2 per unit	FGI
	Single Patient Rooms	100 sqft/Patient	100 sqft/Patient	FGI
	Multi Patient Rooms	80 sqft/Patient	80 sqft/Patient	FGI
	Group Treatment Rooms	1 per unit	225 sqft	FGI
	Exam Rooms	1 per unit	Not Specified	FGI
	Indoor Social Space	25 sqft/patient	120 sqft total min	FGI
	Outdoor Social Space	Not Specified	Not Specified	FGI
	Seclusion Rooms	1 per 24 patients	80 sqft minimum	FGI
	Restraint Rooms	1 per unit	80 sqft minimum	FGI
	Visitor Rooms	1 per unit	100 sqft minimum	FGI
	Secure Medication Coverage	In Accordance with DEA Guidance		DEA
Staffing Ratios	Recovery Specailists	1 per 16 Patients		CMR 104
	Care Coordinators	1 per 16 Patients		CMR 104
	Counselors	1 per 8 Patients		CMR 104
	Nursing Coverage	facility dependant		CMR 104

Figure 2: Facility design parameters.

specific consideration for patient and staff support spaces, as well as size and safety requirements for such spaces. Additional project design requirements are described below.

Port Access. The primary goal for this facility is to support the city of Boston. The vessel must be able to access the port of Boston, as well as multiple piers in the surrounding area, to be a feasible option. Additionally, the vessel must be able to access most major ports in the eastern United States so that relocation is possible in the event of necessary maintenance, emergency medical support, or permanent relocation. Pierside access maximizes accessibility to the facility and prevents the need for alternative personnel and supply transport methods between the ship and shore in the event that the ship cannot access a particular port or pier. Therefore, the draft of the vessel shall be less than the clearance for the port of Boston and the average depth of the port along the eastern United States.

Flexible Patient Care. The patient facilities onboard should be designed such that the facility can support varying levels of mental health and substance addiction patient care and varying gender and age demographics. This maximizes the usefulness of such a facility for the state. This flexibility could be achieved by the following:

- *Providing an excess of patient rooms.* The total number of rooms for each unit was determined by initially meeting the threshold number of rooms and then ensuring that all required medical facilities had the proper space allocated to them. Once this was complete, the remaining deck space was allocated to increase the number of patient rooms in each unit to meet or exceed the objective values. This allows for increased capacity if future needs change.

- *Physically securing each individual patient unit.* Having separate and physically secure units in accordance with the most restrictive DMH licensing regulations create the potential to support different patient demographics within the same overall facility. By designing to the most restrictive code, this alleviates significant future work to support additional mental health units.

Compatible with Pier Services. The facility should be able to integrate with the pier services to provide all the utilities and support services to meet both the habitability and medical requirements. It is important that the vessel has the ability to connect to common services to support docking at alternative pier locations in both Boston and other eastern US ports. The ability to integrate with local utilities ensures that sufficient resources are available and significantly reduces the required operational time of shipboard equipment. This increases reliability and extends the operational life of the equipment, as well as reduces the engineering personnel requirements for in-port operation.

2.3 Design Decision Considerations

Decisions guiding the design of this conversion project were determined by a combination of factors: the project's key priorities, the adherence to the established design philosophy, and valuable insights provided by subject matter experts. The design team focused heavily on the following aspects.

2.3.1 Defining Medical Compliance.

Identifying the requirements to meet the medical standards for this project was a key aspect of decision making. The sponsor requirement is to create a mental health and substance recovery treatment facility. Inpatient psychiatric facilities have different licensing requirements than strictly substance recovery facilities. To support both patient populations, the facility would have to be dual licensed. The units within the facility would also have to be physically separated and secured in accordance with their respective licensing requirements. The primary requirements referenced for this project were those of the FGI Guidelines for Design and Construction of Hospitals and the licensing requirements of DMH, DPH, and BSAS. These guidelines influenced all aspects of design decisions.

2.3.2 Utilization of Existing Arrangements.

Two driving factors in selecting a cruise ship as the platform for this type of conversion are the hull shape and the many compartments available to be used to support medical facility requirements. The project also wanted to use as much of the existing layout as possible to minimize the complexity and cost of the conversion according to the project priorities. The design of a cruise ship is much like a hotel, arranged to support many guests. This area was relatively simple to reconfigure into individual patient rooms and medical offices. Additionally, separate living and habitability facilities for guests versus crew on the cruise ship support a layout with separation between patient care and lodging spaces and staff and ship crew spaces. Ship support spaces such as machinery rooms, navigation spaces, and tanks were able to remain in the original configuration, which also helped to keep the conversion less complex and less costly. The key areas of the ship where decisions were framed around maximizing utilization of as-is are listed below.

- Navigation spaces
- Machinery spaces
- Cruise ship crew living spaces
- Guest rooms
- Storage spaces
- Galleys

2.3.3 Utilization of Installed Systems.

Capitalizing on as many existing ship systems as possible was also a driving factor in this conversion. A cruise ship also has many existing systems that support the long-term care and lodging of many patients. The selected ship for conversion was a fully functional cruise ship with all original systems included and operational [14]. This provides great value to the vessel and minimizes the systems that needed to be added to create a useful medical facility. This translates to significant cost savings in both planning and execution of the conversion. Design decisions were made to preserve the operational use of the systems listed below.

- Navigation equipment
- Steering systems
- Damage control equipment
- Lifeboats and safety equipment
- Propulsion
- Electrical distribution
- Water generation, storage, and distribution
- Heating, ventilation, and air conditioning systems
- Waste management systems
- Galley equipment
- Refrigerated storage units
- Commercial-grade laundry facilities

- Crew living and lounge accommodations

2.3.4 Port and Pier Location.

A key decision for project planning was to solidify the anticipated mooring location for the facility. The sponsor requirement was to be in or as close to the city of Boston as possible. This quickly narrowed the scope of evaluation for berth locations to only piers in Boston Harbor. The specific location was important to understand the available resources and pier access for the planned medical facility.

Figure 3: Flynn Cruiseport berth arrangement [6].

The project team was able to rely on previous research from the 2023 2N CASH team that evaluated various piers in the Boston Harbor. Flynn Cruiseport, in the Boston Seaport district, was determined to be a physically feasible option but infeasible due to scheduling and cost. The pier is typically at capacity during the peak season, September to November, and is booked months to years in advance. Furthermore, this is a major revenue source for the Massachusetts Port Authority (Massport)[6]. The cost of replacing the lost revenue from one of the cruise ship berths would add to the expected operating cost of this facility.

Additionally, the congestion from multiple ships does not make it a practical location for a medical facility. Figure 3 shows how close the ships are to each other. A medical facility of any kind requires unimpeded access for staff, patients, emergency medical vehicles, and supply shipments. The congestion of the cruise terminal during the peak season could create a logistical challenge.

An alternative location is the North Jetty Pier, highlighted in Figure 4, which is north of the Flynn Cruiseport. The North Jetty Pier was previously used in 2018 to dock a cruise ship for temporary emergency housing. This real-world event validates that the North Jetty Pier can support an extended mooring of a large cruise ship. Figure 5 shows the ship docked.

Figure 4: North Jetty Pier (highlighted in red)

Due to the North Jetty Pier meeting the sponsor requirement to be in or near Boston and being a proven option to moor a large cruise ship long term, this project conducted this study using the North Jetty Pier as the intended location for the converted facility. This pier and location were used for all project designs and estimations, specifically the access point, draft requirements, and available pier services.

Figure 5: Grand Celebration moored at North Jetty Pier, 2018.

The design parameters and considerations described in this chapter were applied by the project team in both concept exploration and design development, as described in subsequent chapters of this report.

3. Concept Exploration & Selection

3.1 Baseline Ship Variant Description

Figure 6: Celestyal Crystal [14]

This study could be applied to any commercial cruise ship or other large passenger ship, but the variant selected for this project was the Celestyal Crystal. This ship, shown in Table 1, is a 525-foot vessel that meets the customer's requirement to provide treatment facilities for 200 to 500 patients and be moored in the city of Boston. The detailed selection criteria that led the project team to use this specific hull are described in more detail in Section 3.3.1.

Gross Tonnage	25,611	GT
Length Overall	162	Meters
Beam	25.6	Meters
Draft	6.1	Meters
Cruise Speed	18	Knots
Guest Capacity	1,400	People
Main Engines	4 Watsila Pielstock 12PC2-SV40 diesels	
Total Power	19,400	Kilowatts
	25,996	Horse Power

Table 1: Celestyal Crystal ship specifications [14]

3.2 Concept Exploration Approach

In general, a cruise ship was selected as the ship variant for this project based on sponsor requirements, prior research into similar conversions, and the existing ship infrastructure. The ship selection influenced all other design decisions since part of the design philosophy was to utilize as much of the existing structure and systems as possible. This made the hull decision the first and most important decision. Understanding that all future decisions would be made specific to the hull, the project team took a point-based design approach to this project. This allowed the team to choose the starting point with hull selection, and then evaluate the modifications required to meet the requirements of a medical facility. Each design decision could be evaluated and adjusted as necessary until a satisfactory design was reached. The team was able to use applicable facility guides and subject matter experts on cruise ships and mental health treatment facilities to validate design options. The major steps in the design exploration and development were:

- Select a cruise ship variant.
- Identify the necessary modifications.
  - Explore design options.
  - Evaluate & analyze design options.
  - Select a resultant solution.

Section 3.3 describes each major design area and the corresponding design considerations and solutions.

3.3 Arrangement and System-level Evaluation and Selection

3.3.1 Ship Selection

The initial evaluation of potential ships for conversion was primarily guided by the sponsor requirements and project design parameters listed in Appendix C. Furthermore, reports from previous MIT 2N project teams and the NAVSEA Hospital Ship Replacement team provided guidelines to inform hull research [1] [6] [7]. Finally, primary source interviews with active clinicians and Massachusetts licensing experts from DMH and BSAS influenced the final hull decision. The main characteristics considered for the selection of the hull are described below.

Figure 7: Celestyal Crystal [15]

Potential Patient Capacity. The selected cruise ship needed to be large enough to accommodate patient care for 200 to 500 patients, clinical spaces for providers, and office space for administration. During the initial assessment, the project team compared the guest capacity per cruise ship for ships with a large number of guest cabins. Appendix E provides the complete list of ships explored as potential options for this conversion project organized from the largest number of guests to the smallest. Based on patient room size requirements and the requirement to each have a window, the initial estimate by the design team was that patient capacity would be approximately fifty to seventy-five percent of the advertised guest capacity. Based on this metric, Crystal met the requirement to support treatment of 200 to 500 patients.

Port Access. To meet the primary mission of supporting the city of Boston, Massachusetts, the ship needed to be able to access Boston Harbor and moor on a local pier. If a ship had too great a draft to enter the harbor or go alongside the desired pier, the channel and pier would require dredging. The selected vessel could have a maximum draft of 24 feet in accordance with the National Oceanic and Atmospheric Administration (NOAA) Boston Harbor Chart. Ships that exceeded this draft were immediately excluded as dredging was not considered a feasible solution due to the additional cost. In addition to Boston Harbor, major ports along the East Coast of the United States were also examined for draft and size restrictions. Although Boston is the desired location, the ship would potentially have to relocate along the coast in the event of an emergent sortie or repair work at an alternative location. Detailed port information is included in Appendix F and Appendix G [16]. The project team validated Crystal could enter any of these ports, including Boston and the desired North Jetty Pier.

Cost. As discussed in the design philosophy, cost overall is a major factor to consider for this project. In this spirit, the purchase cost of the selected vessel was strongly considered. The project team related desired patient capacity to the advertised cruise ship guest capacity. This was then compared to the gross tonnage of the hull which may translate to the gross purchase cost. This relationship may be used to support future hull selection. Using the ship data available in Appendix D, Figures 8 and 9 show the relationships between passenger capacity, gross tonnage, and purchase price.

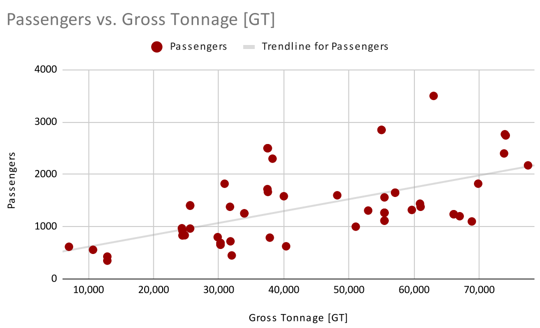

Figure 8: Passengers vs. Gross Tonnage

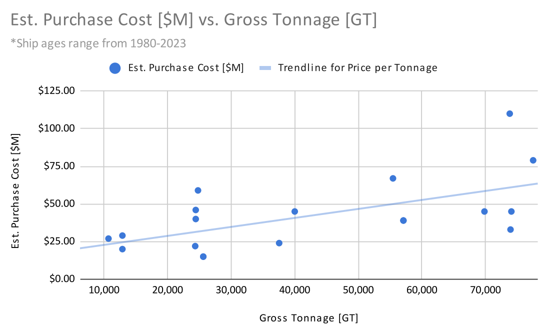

Figure 9: Estimated Purchase Cost vs. Gross Tonnage

Available Information. A consideration unique to the academic nature of this project was to find a vessel from which the project team could gather enough information to build a new design. The information required by the project team included basic ship size parameters, passenger capacity, and detailed deck arrangements. Although there are many cruise ships on the secondary market, not all of the ships had readily available information. This would not be a consideration for a purchased ship, as the proprietary detailed ship information would be included in the purchase price. For this project, Lager Maritime Corp. provided the project team with ship deck arrangements and feature descriptions necessary to conduct the conversion [14].

Available for Purchase. To meet conversion speed and cost objectives, the team focused the hull search on ships that were available for immediate purchase as of January 2024. Although other ships could meet the same physical criteria, the project focused on hulls that could be immediately be procured to further support the feasibility and affordability of the project. Each of the ships listed in Appendix D was available for purchase as of January 2024.

Hull Age. A major assumption for this project, as discussed in Section 1.4, is a service life extension for the converted vessel. Although the minimal operational profile supports this assumption, a thorough hull and infrastructure inspection will still be required to validate the remaining life expectancy of the hull. The project team sought the most recently constructed and renovated cruise ship hull within the required capacity range.

Taking these main factors into account, Crystal was selected as the vessel for conversion. This ship was the best balance of all factors and excelled in patient capacity, size, and cost.

3.3.2 Identifying Necessary Modifications

After selecting a hull, the project team had to determine what areas of the vessel required modifications to meet the requirements of the medical facility. This was achieved by evaluating the required design parameters described in Appendix C and comparing them with the existing ship design. The major areas considered for determining the necessary modifications are described in this section.

Determining Patient Capacity. The first major consideration was the potential patient capacity of the ship. The original assumption made was that patient capacity was fifty to seventy-five percent of advertised cruise ship guest capacity based on patient room square footage and window requirements. This assumption had to be validated and a more specific value determined that could be used to base the remaining design decisions on. Patient capacity drives both staffing and facility requirements.

Table 2 shows the initial estimate of patient capacity for Crystal. This was estimated using only existing cabins that meet patient room requirements [11]. This number was less than the initial gross estimate, but still exceeded the sponsor requirement of 200 to 500 patients. From this estimate, other design decisions were made to meet the requirements to provide care to 500 patients in accordance with the facility

Quantity	Size (sqft)	Allowed Occupancy	Patient Capacity
21	129	1	21
38	107	1	38
33	118	1	33
126	150	2	252
40	166	2	80
43	166	2	86
			510

Table 2: Initial passenger cabins available for patient rooms

guidelines listed in Appendix D. This also validated the decision to use existing guest cabins as patient care rooms which minimized the need for structural modifications, thus helping to minimize conversion man-hours and cost.

Determining Required Staffing. Once the patient capacity was determined, the required staff quantity could be determined. Like facility requirements, the staffing requirements are also dictated by the various licensing agencies for mental health and substance use recovery facilities. The most restrictive requirements are those of DMH, so these staffing requirements were used in subsequent design decisions to account for the maximum amount of staff required. This was in addition to the number of staff required to operate and maintain the ship, as it would remain an operational vessel.

Category	Percentage of Crew	Required for Conversion	Total Staff
Navigation	5	Yes	20
Engineering	20	Yes	81
Hospitality	50	No	0
Housekeeping	5	Yes	20
Culinary	5	Yes	20
Support	10	No	0
Retail	5	No	0
			141

Table 3: Estimated cruise ship staff breakdown [17]

The advertised staff size of the Crystal cruise ship while in service is 406 people. The cruise ship staff is divided into various categories. These are shown in Table 3 along with the industry percentages of each staff category. This shows the expected amount of staff required to maintain the vessel outside of the treatment facility requirements. The two areas of overlap are housekeeping and culinary. The project team made the assumption that these staff amounts would be sufficient to support the same type of services for the converted facility.

The number of clinical staff needed for a mental health and substance use recovery facility of this size was derived from the estimated patient capacity and the licensing requirements for DMH, DPH, and BSAS along with interviews of local facility staff. Table 4 breaks down the estimated clinical staff required to support the converted facility. The clinical staff combined with the ship staff are important considerations

Category	Minimum Required	Total Staff
Administrative Support	1 per unit	6
Direct Patient Care	6 nursing hours per patient	383
Registered Nurse	1 per unit	6
Attending Physician	1 per unit	6
Pharmacy	1 per facility	2
Clerical	1 per facility	2
Interpreter	1 per facility	2
		407

Table 4: Estimated clinical staff for dayshift [12]

for the overall capacity of the facility for habitability, access, and parking. The project team made the assumption that existing berthing and messing facilities of cruise ship staff would be adequate to provide the necessary facilities should the ship need to get underway. It is assumed that the clinical facility would be evacuated prior to leaving the pier. Therefore, the vessel conversion design accounted only for the clinical staff number in order to support all required administrative and clinical spaces.

Deck Plan Modifications. Once the estimated patient capacity and staffing requirement were developed, the project team analyzed how each deck of the ship needed to be modified. The key factors considered in deck modifications were structural supports, engineering spaces, existing passenger cabins, elevators, guest entertainment spaces, and the expected patient demographic.

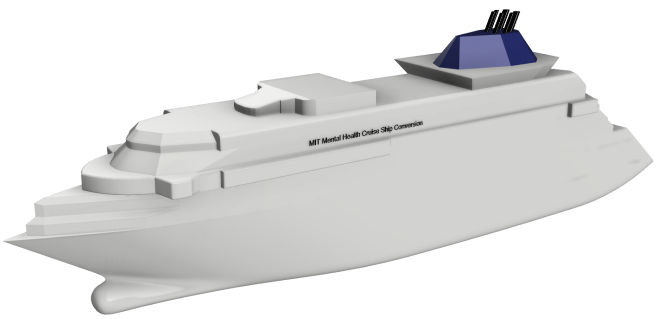

Figure 10: Initial representative model of Crystal

Crystal has six decks outfitted to support passenger lodging, dining, and entertainment. These decks are the areas of the ship converted to meet the requirements of the treatment facility while considering these key areas.

Ship support structure. For a typical cruise ship structure, there are structurally significant longitudinal support beams that support the upper superstructure. These are commonly located on the main deck to support the superstructure above it. These bulkheads also serve as watertight and fire-resistant barriers. To not jeopardize the structural integrity or safety of the ship, the project team approached the design in a manner that did not alter the longitudinal bulkheads on the main deck. The estimated location of these structural supports are labeled in Figure 11.

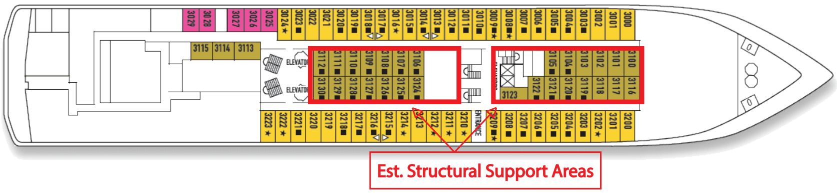

Figure 11: Approximate Longitudinal Support Structure Locations (Shown on Deck 3)

Engineering spaces. The main machinery rooms are located below the second deck. These decks were not considered part of the conversion, to leave in place the existing equipment and capabilities. In addition to the machinery rooms, there are intake and exhaust engine stacks that run from the machinery spaces up through the ship's superstructure. Consistent with the project design philosophy, the design was approached with consideration of not impacting the routing of the engine stacks. Rerouting them would further complicate the conversion and increase the cost. Figure 12 illustrates the estimated exhaust stack location.

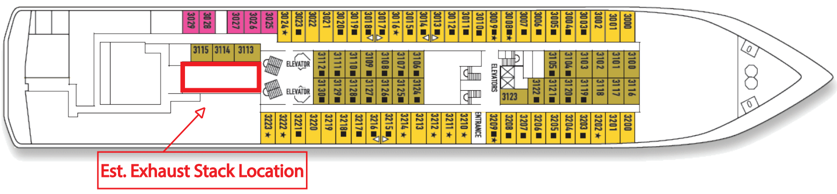

Figure 12: Approximate Representation of the Crystal's Exhaust Stacks (Shown on Deck 3)

Existing passenger cabins. The design utilized as many existing cabins as possible. The decks with the largest number of passenger cabins were used to create the largest number of patient rooms to maximize the use of the existing structure to the maximum extent possible.

Elevators. Elevators are a hospital requirement to support personnel transport between floors [11]. The elevators should be able to move between all decks on which patients may have lodging or treatment and be secured such that access between units can be controlled by staff.

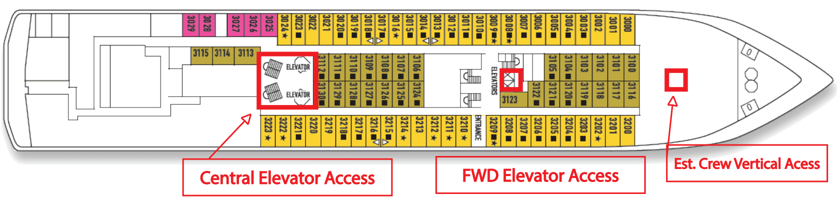

Figure 13: Actual and Estimated Location of Elevator Shafts (Shown on Deck 3)

Crystal is equipped with four passenger elevators located in the center of the ship as highlighted in Figure 13. These were assumed to be sufficient to meet the daily transport requirements of the treatment facility. For any larger transport requirements, such as cargo or larger hospital beds or equipment, existing cruise ship cargo elevators can be utilized. The design was developed to leave all existing elevators in place and remain serviceable.

Guest Entertainment Spaces. The Crystal has many spaces dedicated to guest entertainment, including pools, a casino, bars, and shops. These spaces were mostly located on decks 5, 8, 9, and 10. Figure 3.3.2 illustrates the entertainment spaces on Deck 8. The pools were the largest space and weight consideration that needed to be part of the conversion design. Each of these was removed. The design approach was to use as much of the exisiting structure of the remaining guest entertainment spaces as possible and repurpose them into the necessary communal dining and recreational spaces to support patient needs.

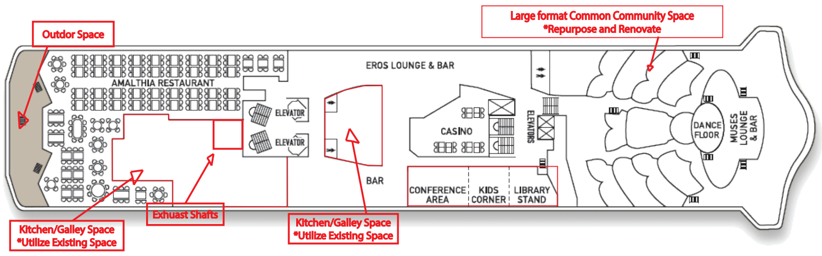

Figure 14: Guest Entertainment Spaces for Renovation (Shown on Deck 8)

Expected Patient Demographic. The anticipated patient population played a critical role in the deck modification designs. Different types and levels of patient care have different facility and safety requirements. Based upon the licensing regulations, the cruise ship space available for modification, and interviews with local subject matter experts, the conversion design was developed with the assumption the patient population of this facility would be 75% in-patient psychiatric care and 25% substance use treatment and recovery. This influenced the level of modification and facility arrangement designed into each deck.

Additional Modifications. Additional modification considerations required to complete this conversion were to support required outdoor recreation spaces, utility services, and access to the facility. These are all key attributes required to support a treatment facility pier side in accordance with the various licensing requirements. Each of the attributes below were accounted for in the overall conversion design.

Outdoor Patient Recreation Spaces. DMH licensing guidelines require and the FGI Guidelines for Mental Health Facilities recommend outdoor recreational space for patients. The conversion design aimed to use as much existing outdoor recreational space as possible so that only modifications to ensure patient safety with minimal structural work were required.

Figure 15: Outdoor spaces available for renovation shown from starboard side

On lower decks that had little or no outdoor space, consideration was given to adding additional space with as little structural work as possible. Figures 15, 16, and 17 highlight the outdoor space available on the Crystal from various perspectives.

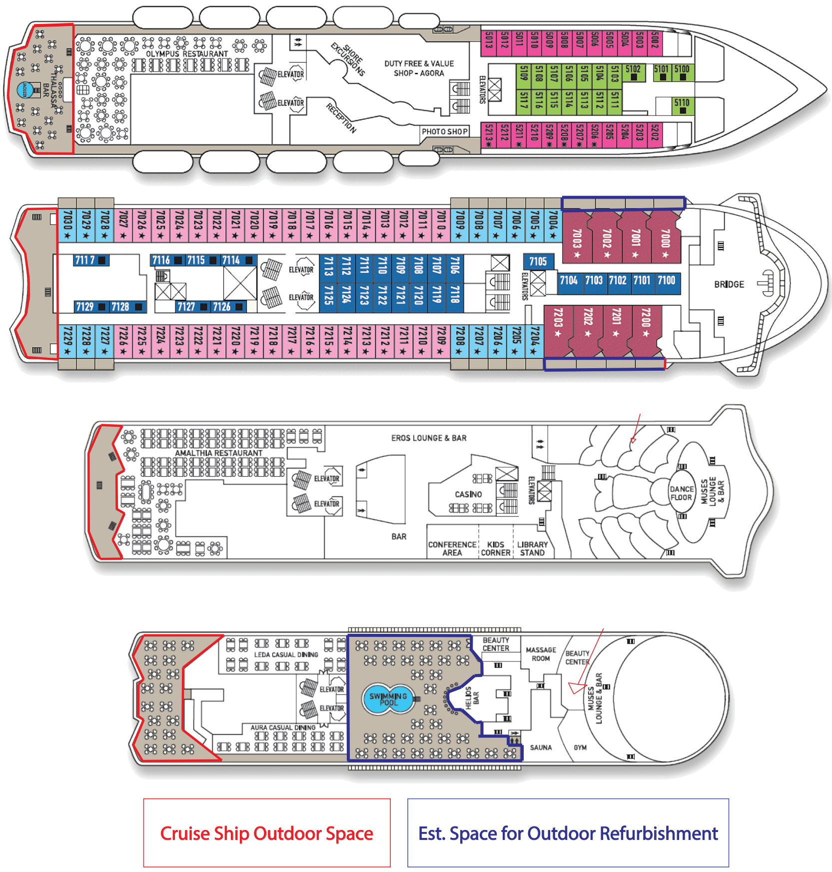

Figure 16: Outdoor spaces available for renovation (Shown on Decks 5-8)

Figure 17: Outdoor spaces available for renovation (Shown on Decks 5-9)

Utility Services. The Crystal has existing utility services onboard sufficient to support approximately 1800 people while out to sea. While this is sufficient to support the approximate 1050 people this facility will treat and employ, it is not desirable for the vessel to remain on ship services at all times. The constant operation of ship power generation, water generation and waste disposal systems would be costly, not environmentally friendly, and would shorten the useful life of the equipment in those systems. The operational profile of the ship utility services is such that all ship services remain operational and provide necessary services in the event the ship gets underway. While in port and moored, the project team assumed that all utilities will be primarily from shore facilities. Appendix F provides more detail on the services available to ships in Boston Harbor. The onboard equipment would serve as a backup in the event of the loss of any primary shore-based utility. These services include electricity, water, and waste disposal, including medical waste.

Facility Access. Facility access considerations were important in the development of the conversion design. The entire facility must be secure to prevent patient elopement, unauthorized access, and have no elevated ares which could enable self harm [12]. The design accounted for these considerations as well as being compliant with the requirements of the Americans with Disabilities Act (ADA) to the maximum extent feasible. Crystal was equipped with six wheelchair accessible cabins and included most public spaces to allow wheelchair access [18].

Medical Evacuation. The existing ship design could provide for medical evacuations by a walk-off brow or a small boat in the event the ship was not pier side. The conversion design took into account the need for medical evacuations from a treatment facility and considered the various options during design development.

3.4 Concept Variants Description, Evaluation, and Selection

For this conversion design, there were not significant variations between concepts once the facility requirements were clearly understood. The primary variations between concepts were the treatment unit separation design and the access method of the facility.

Design Constants. During concept development for conversion, and specifically, separation of treatment units and access to the facility, certain elements were maintained constant.

- Facility access is located on the second deck of the ship.
- All ship pools and hot tubs were removed.
- Guest elevators are central to the ship between all decks.
- Patient treatment units were treated as individual entities.
- No changes were made to:
  - Machinery spaces and engine smoke stacks.
  - Galley and laundry facilities.
  - Longitudinal structural bulkhead placement and location.
  - Ship support systems, such as HVAC, potable water, and service electric generation.

Facility Treatment Unit Layout Variations. In accordance with licensing regulations for security and patient care, individual patient treatment units require physical separation and controlled access. Due to the layout of the guest facilities on the cruise ship, there were two different manners in which treatment units could be created and physically separated.

Longitudinal unit separation. As discussed in Section 3.3.2, an early decision was made to use only exterior guest rooms to meet both the size and the window requirements for patient treatment rooms using existing ship structures. By not using internal rooms, this presented an opportunity to split the ship down the middle on each deck to provide unit separation. The separation is required to be secure but not provide structural support, so the bulkheads required to be added could be created around the existing structures remaining in place (i.e. smoke stacks and elevators). This layout would be particularly beneficial on decks like 3 and 5 where there are common guest spaces in addition to guest rooms. The common areas could be divided longitudinally between separate units. This would provide the necessary dining and recreation spaces on the same deck. It also presents the option to evenly divide the available patient treatment room space evenly by dividing each deck longitudinally; this would create relatively constant treatment unit capacities. Longitudinal separation presents a challenge in creating some of the habitability services and recreational spaces on the decks that were originally arranged predominantly as guest rooms and potentially increase the level of renovation required. Decks 4 and 7 are examples of this layout, where the deck mostly has guest rooms.

Vertical unit separation. The other way to separate new patient units was vertically by deck or decks. This would take advantage of the space separation already existing due to the ship construction. Each deck, or pair of decks, would be treated as a separate treatment unit that is physically separate from the others. The benefit of this approach is that less structural work would be necessary to create separate units. A method of security and restricted access could be added to doors and elevators to control access in and out. A challenge to this layout is that all facilities needed for a treatment unit may not be on the same deck, which will require transport via stairs or elevator. This could increase the renovation work required to make the stairs and elevators in compliance with facility safety and security requirements, as well as staff requirements to escort patients who need to transit between decks. A second challenge considers that Crystal's existing outdoor space is concentrated on upper decks - with decks 2-4 seeing zero.

After further evaluating the facility requirements to be included in the conversion and comparing the longitudinal separation scheme with the vertical, the project team chose to utilize a vertical scheme. The team decided this approach was most closely aligned with the project design philosophy, most notably to minimize the complexity of the conversion to save both man-hours and cost. The vertical separation scheme allowed greater utilization of existing structural components and minimized what must be added. The costs of significant structural work to separate each deck longitudinally outweighed the potential difficulty in managing stairway and elevator access. After deciding on this unit separation scheme, all design decisions for the modified deck arrangements were made consistent with this separation plan.

Facility Access Variations. The other area of conversion that had multiple options was how to control access to the facility. This is most important for medical evacuation considerations. Access and egress could be controlled via a walk-on brow, small boat transit, a drive-on ramp, or via helicopter. The small boat option, as is viable for USN hospital ships, was immediately eliminated due to the operational profile of this facility. The intent of operation is to be pier-side in Boston, so small boat access was not necessary or efficient for personnel transfers.

Walk-on brow. The existing access points to the ship were two walk-on brows, located on the port and starboard sides, respectively, about amidships. The expected mooring configuration of the ship at the North Jetty Pier is port or starboard side to the pier. This configuration makes use of one existing brow possible. The greatest benefit of this access is the minimal work required to meet access requirements. The negative of this option is access is only lmited to foot traffic.

Drive-on ramp. Another option for facility access is a drive-on ramp to allow vehicle access, particularly for emergency vehicle access. This type of ramp could be added to the stern of the ship or along the side of the ship. For this project, along the side of the ship is the most feasible location due to the anticipated mooring configuration. A ramp could be added to facilitate drive on into the second deck by refitting the open areas shown in Figure 18. This would require significant structural

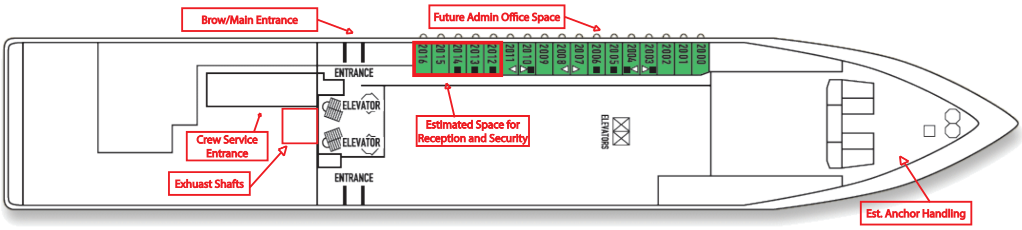

Figure 18: Main Entry Locations (Shown on Deck 2)

work and a ship stability analysis.

Helicopter landing pad. Helicopter access was considered for the case of medical evacuation. This would be in addition to one of the other methods of facility access and personnel transfers. To allow for a helicopter to land on the facility, the top deck layout would require extensive arrangement changes as well as a great deal of structural support added beneath this deck. This makes the addition of a helipad both complicated and costly. For USN hospital ships, this is a key design feature to allow for expeditious patient transfers when out to sea. Consideration of at-sea transfers is not required for this project, as the intent is to operate pier-side in Boston; however, helicopter access could prove useful for any medical emergency requiring airlifting to a hospital. The expectation of needing frequent air transport of patients is very low. Furthermore, the North Jetty Pier is located in relatively close proximity to Boston, so vehicle transport for emergency medical needs is reasonable. Due to the low risk presented by not having a helipad and the exceptional structural work and cost it would require, the project team eliminated the option of adding helicopter access to the vessel.

After thoroughly considering each of the facility access options, the project team decided to use the walk-on brow with an addition to make it fully enclosed from the pier to the ship. This design would provide adequate safe access for personnel while not adding a great deal of structural work to the conversion.

3.5 Preferred Concept

Listed below are the preferred design solutions for each of the main components of the ship conversion. Although not a complete list of all attributes of the facility, Table 5 depicts the major decision points reached before extensive deck arrangement design work could begin on the project.

Facility Attribute	Design Solution	Existing or Updated Structure
Unit separation scheme	Vertical	Updated
Facility access	Walk-on brow	Updated
Patient beds available	485	Existing
In-patient psych patient %	75	Updated
Substance treatment patient %	25	Updated

Table 5: Preferred facility design key attributes

4. Concept Definition & Feasibility/Performance Analyses

Once the design options were narrowed down to the preferred concept as described in Table 5, the project team was able to design each new deck arrangement and ship configuration. The detailed design process is described in this chapter.

4.1 Design Definition

The conversion design for this project was influenced by previous studies, subject matter experts, and medical facility licensing requirements. The project team consolidated the facility requirements from these resources into a set of attributes that could be designed into the new arrangements. The team could then create a design which incorporates all required attributes and ultimately assess the feasibility of this conversion.

As discussed in Section 3.3.1, the vessel selected for this conversion was the Celestyal Crystal. However, there was no publicly available three-dimensional (3D) ship model for this ship. The team was able to acquire limited ship information and deck arrangement data [14]. From this information, the team built an initial 3D representative model to begin the conversion design. The model was developed in Rhino using available ship data and educated assumptions where information was lacking. The design team created a hull shape based on standard curvatures for cruise ships and matched the Crystal's length, beam, draft, and displacement. This model, seen in Figure 19, then served as the starting point for design modifications - note the positions of the center of buoyancy (CB) and longitudinal center of flotation (CF).

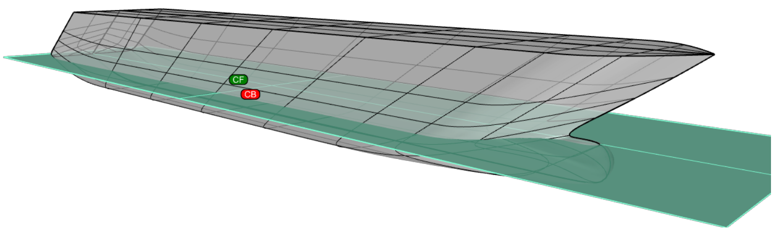

Figure 19: Perspective view, including design waterline

Using this representative model, the project team was able to insert the Crystal deck plans to visually show the original ship arrangement. The deck plans were scaled to the same size using the elevators as a reference point, ensuring that the elevator shaft areas were congruent across decks. This method was validated, as each deck closely matched the Crystal beam following the deck scaling. These initial deck plans were then modified during the development of the conversion design.

As each deck design was modified, the team tracked changes by weight and location to evaluate potential variations in the hydrostatic stability of the Crystal. The team began with the required patient spaces, then staff, and finally community spaces. Each of these elements was included while maximizing the use of the existing ship structure. This design plan was consistent with the project design philosophy to minimize conversion complexity and cost.

4.1.1 Ship Geometry

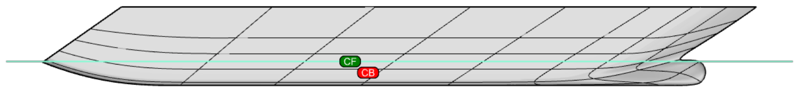

Figure 20: Profile view (center of flotation & buoyancy annotated)

Also consistent with the design philosophy, the design team maintained the original hull structure. No changes were made to the external geometry of the ship other than minor modifications to remove entertainment spaces on outer decks which were no longer required and to add additional safety features to the perimeter. Since the exact Crystal hull form is proprietary information and not available, the project team used the representative model described in Section 4.1 and shown in Figures 20 and 21. The model was validated against pertinent coefficients noted in Table 4.1.1.

Coefficients	***Destroyer***	***Cargo Liner***	***Harbor Tug***	***Bulk Carrier***	***Passenger Liner***	***Model***
C_B	0.52	0.64	0.58	0.87	0.59	0.83
C_{WP}	0.74	0.76	0.80	0.91	0.72	0.93
L/B	9.82	6.92	4.18	9.67	8.38	7.05
L/T	32.75	16.82	9.33	29.00	26.25	29.83
B/T	3.33	2.43	2.23	3.00	3.14	4.262

Table 6: Typical form coefficients [19].

This model was used to estimate the characteristics of the vessel and served as the baseline for all facility modifications and was also used to complete a baseline engineering analysis of the vessel. This analysis included evaluating the ship's displacement, metacentric height, and righting-arm at various angles - both before and after conversion. These data and analyses are expanded on in Section 4.2.

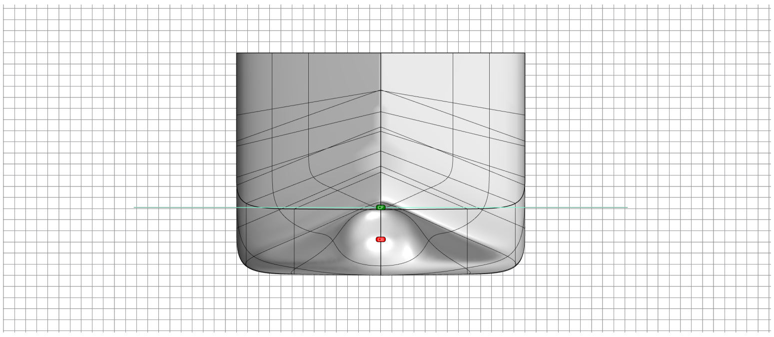

Figure 21: Body plan view

4.1.2 Arrangement Modifications

To meet the requirements of the new facility, Decks 2 through 9 were modified. Described below are each of the deck arrangements for the converted facility. The modified decks are illustrated alongside the original to highlight the changes. The deck designs were created using the approach described in Chapter 2 and Chapter 3. The team estimated deck heights of 2.7 m, a value consistent with the standard cruise ship industry design. The renovation design of all spaces was made with close consideration to the project design philosophy. All aspects of the conversion attempted to balance adherence to clinical requirements with maximum use of existing vessel infrastructure such that minimal structural modifications were required. The project team understands that an optimal facility would be built from the ground up; however, meeting the sponsor's intent to optimize cost and schedule, design decisions were made to balance the tradeoffs in design and cost throughout the project. These results are described in detail below.

Lower decks. The decks below Deck 2 consist of engineering spaces and berthing and habitability spaces of the cruise ship crew. Given the main entrance access on Deck 2, and a design draft of 6.1 m, the project team estimated that there were three levels of machinery spaces below Deck 2. Some of these specific spaces are also listed in the non-specified area of Deck 2, shown in Figure 23. These spaces were not modified in the final design. The project team made the assumption that the existing engineering and crew spaces were more than sufficient to meet the needs of the updated facility. Engineering spaces shall remain fully intact. Ship crew living and dining facilities shall be used to support medical staff on call as required and provide additional space margin for the project. The remaining spaces would remain in place as is until the need arises for more berthing space or storage. Furthermore, these spaces would be adequate to support the ship crew should the vessel need to get underway for any period of time.

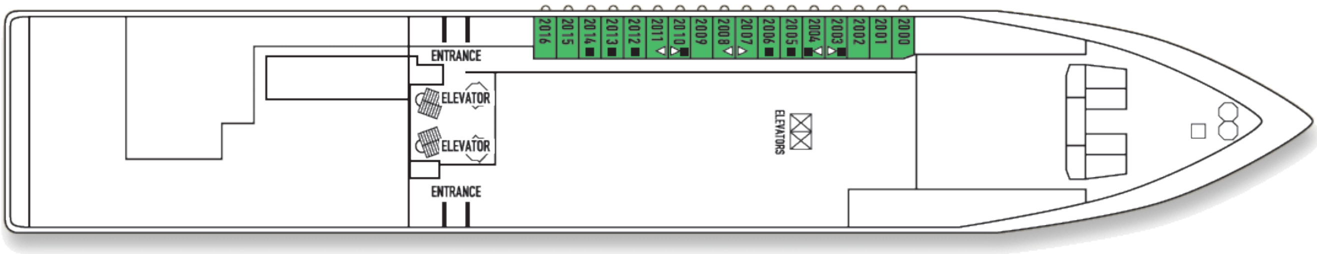

Figure 22: Original Deck 02

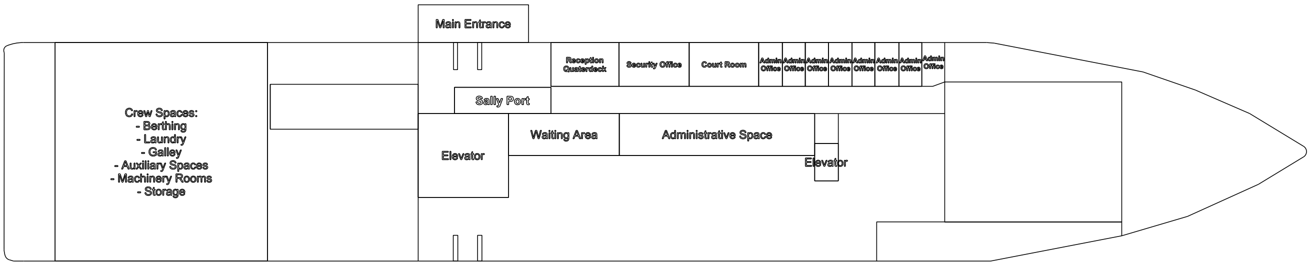

Figure 23: Deck 02

Deck 2. Deck 2, shown in Figure 22 is the ship's main deck and is the primary entry point of the vessel. This deck included a large portion of open space available to design a facility entrance that was secure and in accordance with the facility requirements listed in Appendix D. In this layout, the port side brow serves as the primary facility entrance via a sally port, or a series of two secure doors. The starboard side entrance will remain available but will not be used. There were a limited number of passenger cabins available on this deck that were modified to create administrative and storage spaces. The notable spaces on this deck are the facility reception and waiting area, a court room space, a security office, and administrative space that may be used for record storage. Both the forward and amidship elevators are accessible from this deck for personnel transfers. These spaces are shown in Figure 23.

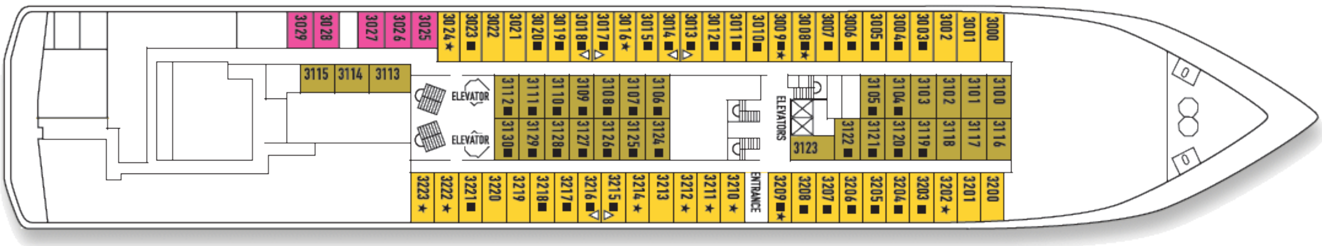

Figure 24: Original Deck 03

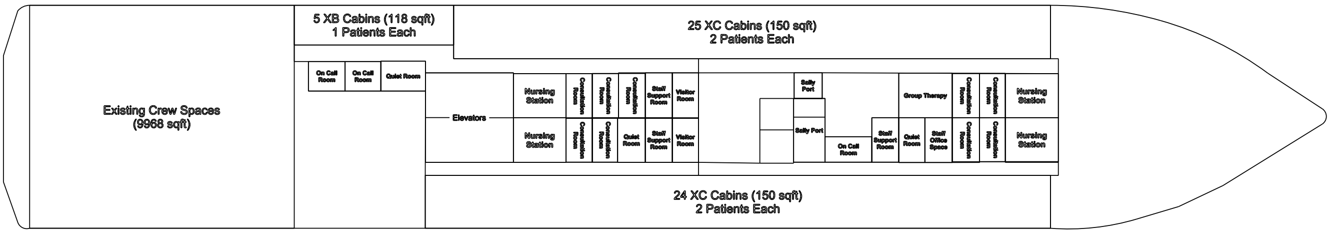

Figure 25: Deck 03

Deck 3. The original Deck 3 layout, shown in Figure 24, consisted primarily of guest cabins. These cabins were resized to create patient rooms to support inpatient psychiatric treatment. This deck is constructed to support up to four inpatient psychiatric units that can support a total of 103 patients, in both single- and double-occupancy rooms.

In addition to patient rooms, the central space of the deck is arranged such that common spaces may support each of the patient units on this deck by controlling access centrally. Access to and from the elevators is also separated between each unit. These common spaces include nursing stations, consultation rooms, quiet rooms, visitor rooms, staff support and on-call rooms, and a group therapy room. The existing crew spaces in the aft end of Deck 3 were not altered as the existing configuration is not public knowledge. Therefore, the project team left those spaces out of the modified design. Future work could investigate whether these spaces may be of use to provide additional facility spaces. Figure 25 shows the modified deck arrangement.

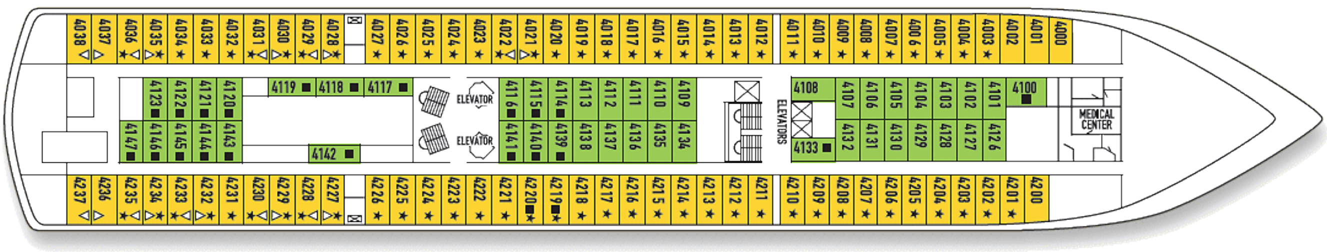

Figure 26: Original Deck 04

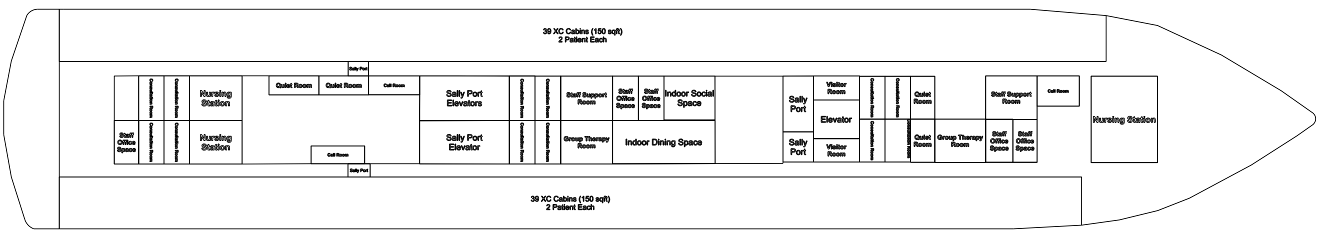

Figure 27: Deck 04

Deck 4. Deck 4 consisted exclusively of guest rooms prior to conversion. This translated well into a large number of patient rooms to support inpatient psychiatric treatment. The converted deck is arranged with 78 double-occupancy patient rooms on the port and starboard sides that can physically be separated into four separate units if required. Similarly to Deck 3, the center line spaces were converted to common support and staff spaces. These spaces include nursing stations, consultation rooms, quiet rooms, visitor rooms, staff support and on-call rooms, a recreation space, and a dining space. The ship's original galley spaces were retained as they were more than adequate to support the messing requirements of the modified facility and minimized the conversion by not remodeling. In the converted design, dining staff would transfer the food to any converted dining spaces not adjacent to the galley. This was an intentional design decision to not replicate facilities that were previously organic to the ship. Figures 26 and 27 show the original and modified Deck 4 arrangement.

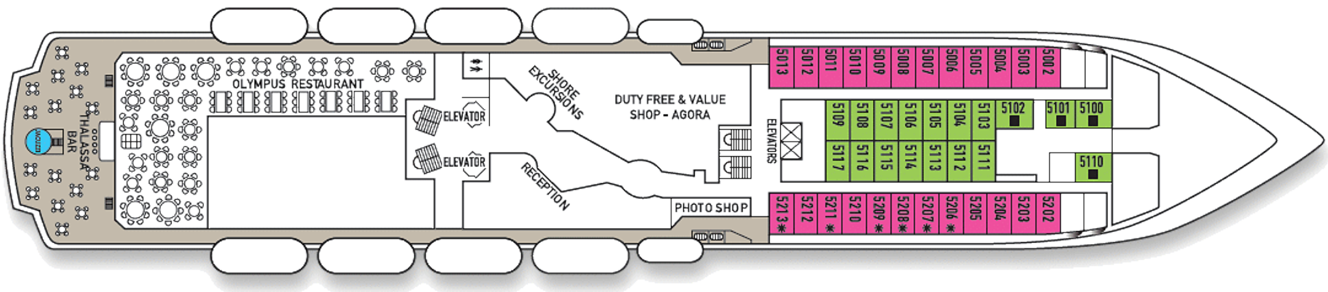

Figure 28: Original Deck 05

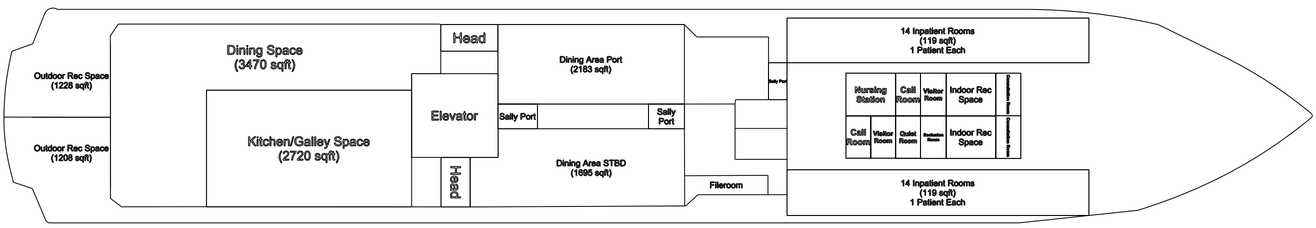

Figure 29: Deck 05

Deck 5. Figure 28 shows the original arrangement of Deck 5. This deck had a large dining space as well as a large shopping and reception area with some guest rooms up forward. This provided a large area available for remodeling into dining and community spaces to support the facility. The forward portion of the ship was redesigned with 24 single-occupancy rooms to support inpatient psychiatric treatment services.

The original dining spaces on the ship were redesigned to support multiple smaller dining rooms that could be used by different patient units. The team also left the existing galley spaces as-is with the assumption that the facilities would be more than sufficient to support the estimated patient and staff population, since it is much smaller than the orignal cruise ship guest and crew capacity. Deck 5 also has a large outdoor deck at the aft end. This is modified in the updated design to create two separate outdoor recreation spaces for patient use. The team also allocated space for access control between spaces via sally ports as required in accordance with facility security requirements. Figure 29 shows the redesigned configuration.

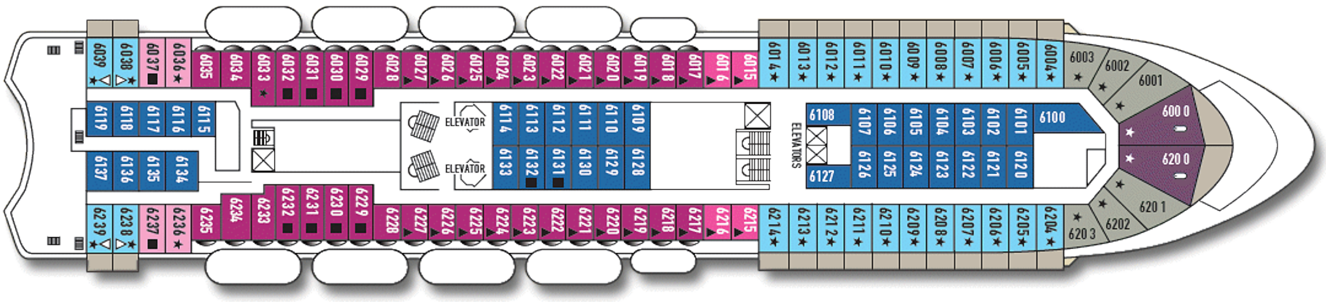

Figure 30: Original Deck 06

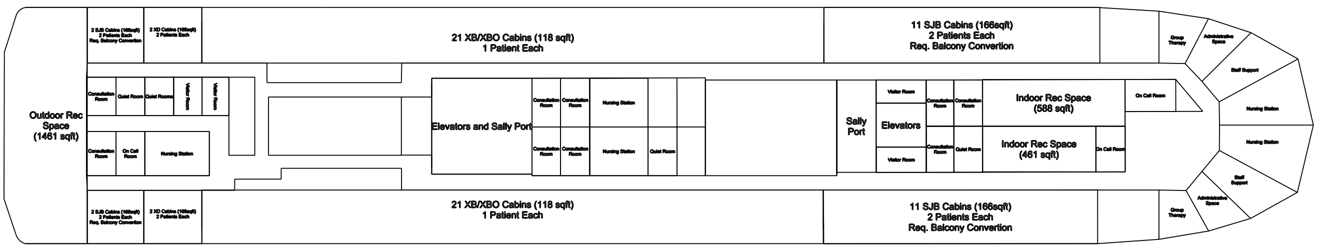

Figure 31: Deck 06

Deck 6. Deck 6, a deck of primarily guest rooms, is shown in the original configuration in Figure 30. The guest cabins were redesigned to support both single- and double-occupancy inpatient rooms. This deck was designed with the intent of supporting up to four inpatient psychiatric treatment patient units. Centerline spaces were repurposed as patient and staff support spaces for these units. These spaces, shown in Figure 31, include nursing stations, consultation rooms, visitor rooms, staff support and on-call rooms, administrative spaces, quiet rooms, and group therapy rooms. Additionally, Deck 6 includes nearly 1700 square feet of outdoor space in the transom available for outdoor recreation space.

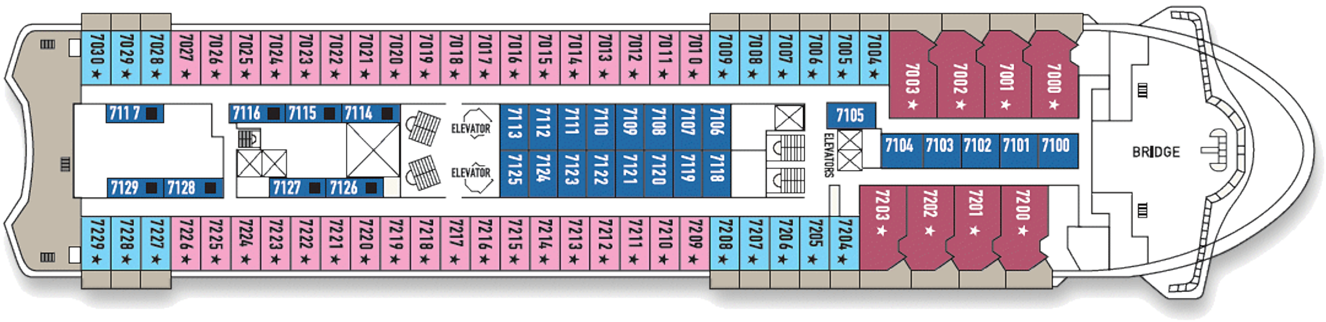

Figure 32: Original Deck 07

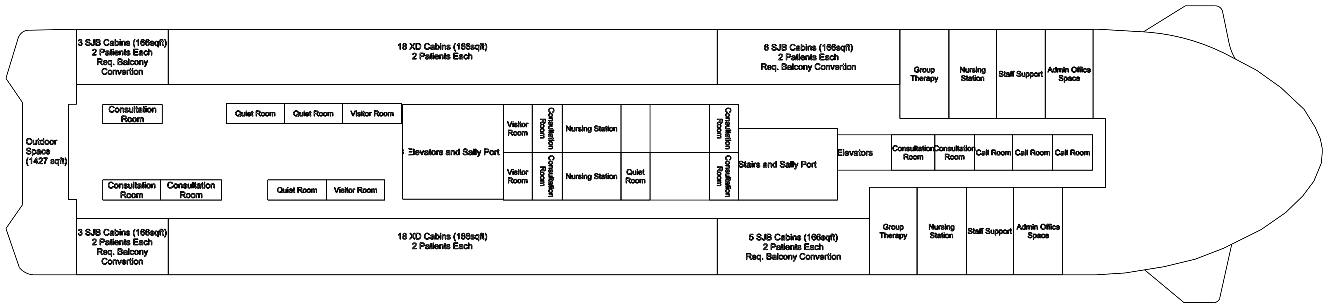

Figure 33: Deck 07

Deck 7. Decks 7, shown in Figures 32, consisted of primarily guest spaces. The redesign created patient rooms and support spaces on Deck 7 to support up to two separate addiction treatment units. These spaces include nursing stations, consultation rooms, visitor rooms, staff support and call rooms, administrative spaces, and group therapy rooms as shown in Figure 33. This deck included more group spaces to better meet the requirements of substance use treatment and recovery services.

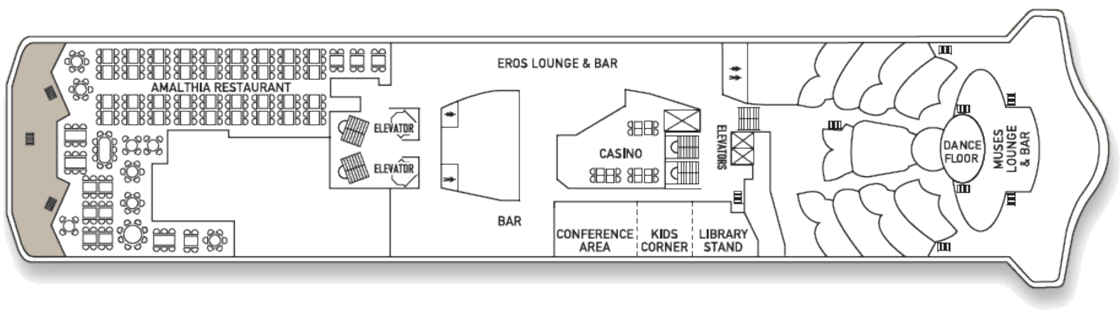

Figure 34: Original Deck 08

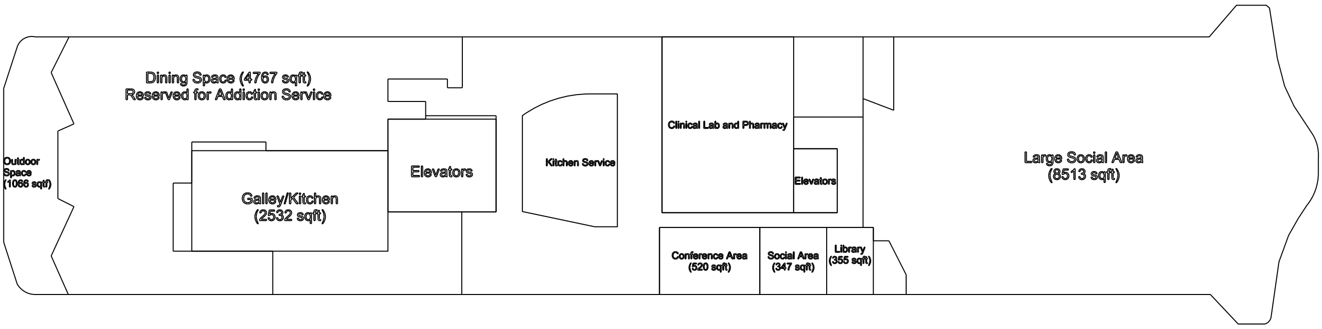

Figure 35: Deck 08

Deck 8. Deck 8, shown in Figure 34, had no guest rooms. Therefore, this deck was exclusively arranged to create common spaces in support of the addiction treatment units on Deck 7. The updated configuration, shown in Figure 35, includes dining spaces, a large indoor recreation space, a laboratory and pharmacy facility, and another large dining space for use by substance use treatment and recovery patients.

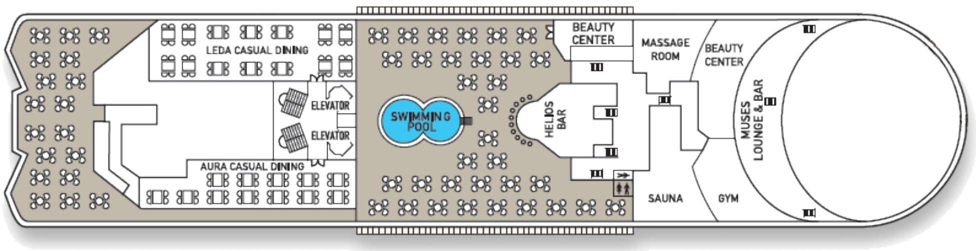

Figure 36: Original Deck 09

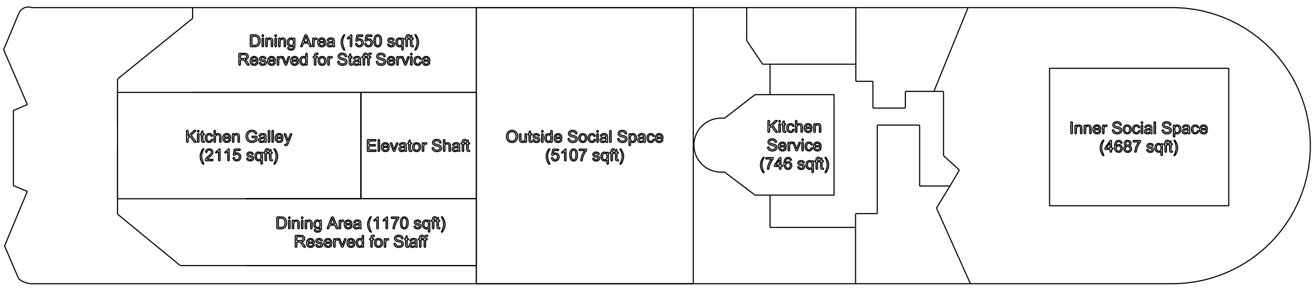

Figure 37: 2D Arrangement Plan for Deck 09

Deck 9. Deck 9 is the uppermost deck with available guest spaces, shown in Figure 36. The design team reconfigured this deck to create space for both indoor and outdoor recreation spaces, as well as additional dining areas. These spaces are currently intended for use by staff to minimize patient transfers through decks with differing levels of patient care. These spaces, shown in Figure 37, could be repurposed to support patient needs if desired in future studies.

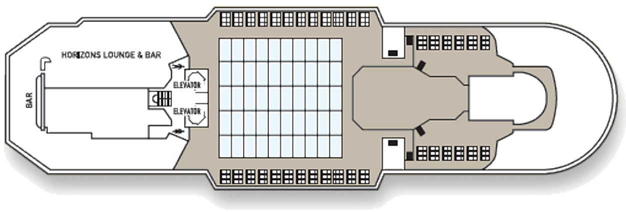

Figure 38: Deck 10

Deck 10. From the publicly available images, Deck 10 is primarily part of the superstructure. It also consists of the removable cover for Deck 9 amidships. This limited the useful deck space available, so this deck was left as is and not included as part of the renovated design.

4.1.3 Structural Arrangement & Design

The information available to assess the structural impact to the Crystal due to the proposed renovation was very limited. From research on general cruise ship construction, the project team made the assumption that the primary structural components consisted of the longitudinal supports discussed in section 3.3.2 as well as transverse watertight bulkheads. The project team designed the updated deck arrangements with the intent of not altering these major support structures. The design was developed based on available ship information and deck arrangement schematics; however, there is the possibility that design changes could impact other areas of the ship. A more thorough investigation of the impact of the design on the entire vessel would be required for the project to be pursued further. The major changes included in the conversion design that could affect the structural integrity of the ship are described below.

- *Removing guest amenities.* The largest weight and structure modifications to the vessel were removing the pools from Decks 5 and 9. The weight implications are discussed further in Section 4.1.8. The pools and larger guest amenities removed are spread throughout the ship and most are centerline, but the cumulative weight could be significant.
- *Removing cabin bulkheads.* While not expected to be major structural supports, there are many cabin bulkheads removed to support patient room sizes, and this could have a cumulative effect to the ship structure.

These items were evaluated individually and are not expected to impact the overall ship structural integrity due to the minimally invasive work required and being an insignificant weight compared to the entirety of the ship. However, the exact locations and weights of the removed ship components and bulkheads should be further investigated to understand the full impact to ship strength structural integrity.

4.1.4 Patient Room Modifications

Not shown visually in the modified two-dimensional (2D) deck arrangements are the detailed patient rooms. The team expects existing exterior passenger rooms on Crystal to feature passenger beds, a secure window, and an en suite bathroom. Ship wide, these rooms have a collections of single and double beds, as well as bunk beds. Figures 39 and 40 show examples of actual Crystal guest room bed and storage configurations.

Figure 39: Example Crystal guest room

To support mental health treatment, these rooms require extensive modifications aimed at preventing ligature or any other means of self-harm, ensuring the safety and well-being of patients. Modifications include removing rough-sea support bars and handles installed in the bedroom and bathroom as well as flush mounting lights, pipes, and closet fixtures. Additionally, all bunk beds, ladders, and rough sea retaining bars will be removed.

Figure 40: Example Crystal guest room storage

Figure 41 shows an example Crystal bathroom in a guest room. This clearly shows the abundance of handles, hooks, bars, and fixtures requiring removal to meet paitent room safety requirements. Moreover, note the shower curtain and flexible shower hose. These features, typically necessary to support small spaces and life at sea, present a unique challenge to designing for ligature prevention and would need to be removed from all patient spaces. The removal of all non-compliant passenger room amenitites and installation of compliant furniture and fixtures accounts for a large portion of the estimated renovation work. This is described in more detail as part of the cost estimates in Section 4.4.

Figure 41: Example Crystal guest room bathroom

While some aspects of cruise ship design do not translate well to medical treatment facility requirements, others are quite symbiotic. For example, all maritime spaces are designed with a 'secure-for-sea' mentality - this includes ensuring all furniture, decor, and room accessories are, to greatest extent practicable, rigidly attached to a deck or bulkhead. This aligns well with mental health facility requirements to ensure furniture and equipment cannot be moved or used in a manner which could cause harm to self or others.

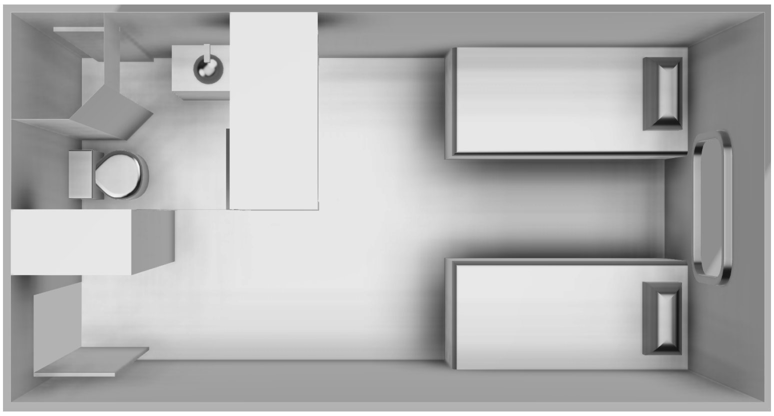

Figure 42: Example converted patient room - top view

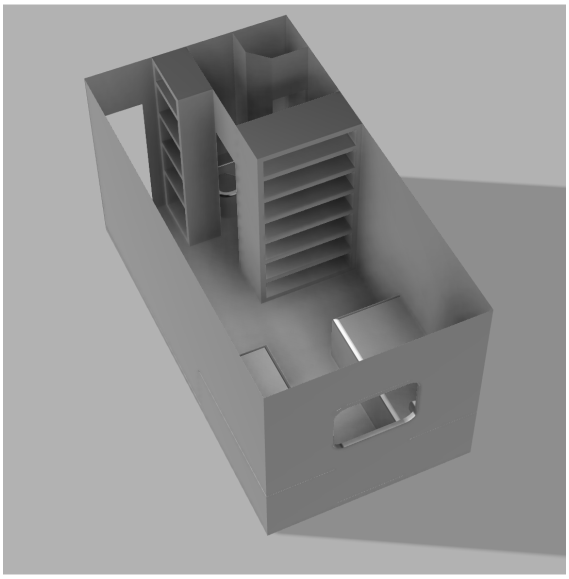

Figure 43: Updated patient room - perspective view

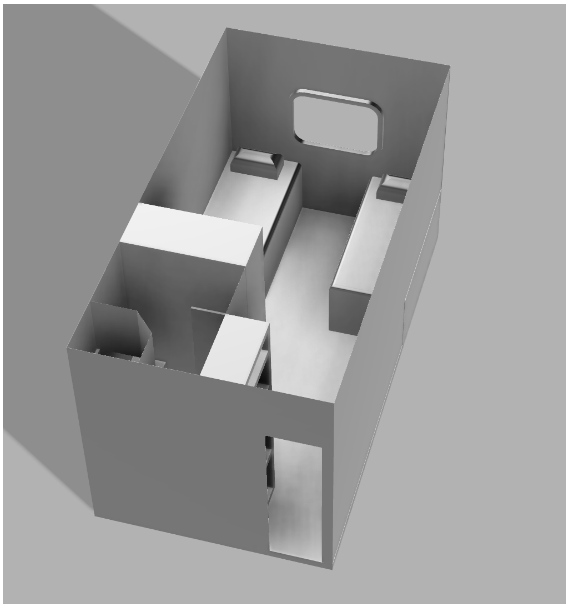

Figure 44: Updated patient room - front view

Figures 42, 43, and 44 show the estimated layout of a converted patient room. The specific arrangement and furniture plans for each of these spaces would be part of the detailed design should this project be further investigated. The project team accounted for this work as part of the cost estimates in Section 4.4.

4.1.5 General Modifications

Many attributes of the ship that must be renovated to meet the needs of a medical facility could not be modeled in a 2D deck arrangement. While they are not included in the arrangements, they were considered in the renovation weight and cost estimates described in Section 4.1.9 and Section 4.4. These items are described below.

Facility perimeter. A major consideration for the facility is the overall perimeter. Facilities licensed by DMH shall be secured such that patients may not elope, contraband may not be smuggled, and access may be controlled in and out of the facility [12]. The nature of the ship also adds another element of consideration for the general safety of personnel. The edge of the outdoor decks requires the addition of a perimeter wall, secured in a manner that they are unable to be climbed over or penetrated consistent with the patient room window shock requirements [11]. The wall would need to be added to all weather decks and outdoor recreation spaces that patients could reasonably access. The considerations for safety with respect to self-harm is most important on Deck 5 which is designed to support in-patient psychiatric patients.

Additionally, ship access should be restricted to only the main facility entrance at the brow on the Deck 2. Security considerations should be given to the edge of the pier and the hawseholes such that no one may attempt to cross to or from the facility via this manner.

Facility entrance. As described in Section 3.4, the method selected for facility access was to use the existing entry point for the brow on the port side of the ship. This would require a port-side-to mooring configuration at the pier.

Figure 45: Example cruise ship enclosed brow [20]

Figure 46: Example cruise ship enclosed brow [21]

To meet accessibility and safety requirements, the facility should consider acquiring a brow to use for the permanent entry and exit method that is both accessible to wheelchairs and gurneys and also enclosed to improve the safety of transit. Figures 45 and 46 provide examples of brow arrangements that may be considered.

Outdoor space security. As was discussed regarding the perimeter of the facility, the outdoor recreation space must be safe and secure. The outer edges of the deck would need to be secured as previously described. Furthermore, the spaces would need to be evaluated for potential hazards with respect to self-harm. The nature of a ship often includes many support beams and hooks. These should be removed to the maximum extent possible. The decks should also be made one level where possible to meet ADA requirements.

Elevator & ladder well security. A ship does not translate exactly to the layout possible for a tradition brick-and-mortar facility. This created some challenges for the design team to provide all patient facilities on the same deck. As described in Section 4.1.2, some of the patient facilities are located on decks different from the patient rooms. To help the design meet requirements of a mental health and substance use treatment facility, the access control between decks is very important. Each elevator and ladder well door shall be equipped with an electric lock that may be opened via badge. This will maintain control between all decks with the staff.

Patient space safety. A major consideration for patient safety in in-patient mental health units is to remove any element that may be used to case self-can to the maximum extent possible [11]. This requires creating smooth bulkheads and corners with no angle-irons, ledges, or hooks. Ships are not typically built in this manner, so this will require a good deal of cosmetic work. These modifications were also accounted for in the renovation cost estimates as described in Section 4.4. Additionally, patient rooms and adjoining bathrooms are expected to be fully gutted and reconstructed to install all safe furniture and fixtures for patient use as previously discussed in Section 4.1.4.

Patient treatment unit entrance. Each patient treatment unit shall be secured by a door with keypad entrance to be controlled by staff. This also includes going from common spaces, such as need elevators, to any of the patient spaces. This allows for further control of access to and from patient spaces.

These modifications, while not all major structural components, are important to draw attention to as they meet many of the operational requirements necessary for a mental health and substance use treatment facility. While accounted for in weight and cost estimations, a detailed scope of work would need to be further investigated to understand the true volume of work required.

4.1.6 Patient Support Capacity.

Based upon the final deck arrangement designs, the converted facility can support 489 patients as shown in Table 7. This shows the total number of patient beds on each deck and what patient demographic they were designed to serve as the facility requirements differ.

Deck	Addiction Service	Inpatient Service
2	0	0
3	0	103
4	0	154
5	0	24
6	0	102
7	106	0
8	0	0
9	0	0
Total:	106	383
Total Patients:	489	

Table 7: Total patient capacity - evaluated by deck

Each deck is constructed such that it may be divided both forward/aft and starboard/port to create separate secure patient treatment units. They may also be left as one larger combined unit. Each of these quadrants divides the patient rooms along with some support facilities.

However, due to the initial ship layout, not all decks have access to outdoor space or large recreational spaces. Figure 47 lists each notional patient unit and the community spaces that support those patients. The patient units are labled by their location on each deck, F (forward) or A (aft) and S (starboard) or P (port). Also highlighted are the spaces organic to the patient deck or located elsewhere in the facility. Some community support spaces are on alternate decks to allow for more space as well as outdoor space. As previously discussed, access would be controlled by the staff at each door, elevator, and ladder well to ensure access is limited to the appropriate personnel. Moreover, badged access sally ports can be installed at critical space junctures.

Services Organic to Patient Deck							Services Assigned to Unit on Separate Deck					
Deck	Unit	# Pt	Dining Req [sqft]	Dining [sqft]	Indoor Rec [sqft]	Outdoor Rec [sqft]	Dining Location	Dining [sqft]	Outdoor Location	Outdoor [sqft]	Indoor Location	Indoor [sqft]
3	**3FP**	28	560	0	0	0	Deck 5 FP 1	550	Deck 5 Port	1228		
3	**3FS**	26	520	0	0	0	Deck 5 FS 1	565	Deck 5 Stbd	1228		
3	**3AP**	27	540	0	0	0	Deck 5 A 1	500	Deck 5 Port			
3	**3AS**	22	440	0	0	0	Deck 5 A 2	500	Deck 5 Stbd			
4	**4FP**	56	1120	0	243	0	Deck 5 FP 2/3	1100	Deck 5 Port			
4	**4FS**	54	1080	481	0	0	Deck 5 FS 2	565	Deck 5 Stbd			
4	**4AP**	22	440	0	0	0	Deck 5 A 3	500	Deck 5 Port			
4	**4AS**	22	440	0	0	0	Deck 5 A 4	500	Deck 5 Stbd			
5	**5**	24	480	0	560	0	Deck 5 A 5	500	Deck 5 Fwd			
6	**6FP**	22	440	0	588	0	Deck 5 FP 4	550	Deck 5 Port			
6	**6FS**	22	440	0	466	0	Deck 5 FS 3	565	Deck 5 Stbd			
6	**6AP**	29	580	0	0	730	Deck 5 A 6	500				
6	**6AS**	29	580	0	0	730	Deck 5 A 7	500				
7	**7P**	54	1080	0	0	715	Deck 8	4300	Deck 8	500	deck 8	4000
7	**7S**	52	1040	0	0	715	Deck 8	4300	Deck 8	500	deck 8	4000

Figure 47: Patient Unit Breakdown by Deck with Facilities Space Noted

Figure 47 highlights one of the major trade offs made in aligning with the design philosophy to minimize conversion complexity and cost: space cohesiveness. To work within the existing structure of the ship, the converted facility layout creates more of a logistical challenge to meet facility and security requirements. It would be up to facility staff to control access to shared spaces by creating schedules and routines that best support all patients.

4.1.7 Power and Propulsion Plant

The facility will primarily rely on shore power while moored for an extended period; however, the Celestyal Crystal is fitted with two Wärtsilä 6R32 diesel generator sets and one Wärtsilä 4R32 diesel generator set, rated at 3500 kW and 1500 kW [14]. Additionally, Crystal is equipped with a MAN D 2542 MTE diesel generator set for emergency situations (300 kW). These power generators should be kept in operational condition to support the facility in the event of sortie or relocation. In addition, they shall serve backup power source for the facility in the event of a loss of shore power.

The converted vessel will also retain its existing main engines. The Crystal is equipped with four identical Wärtsilä-Pielstick type 12PC2-5V-400 diesel engines for propulsion, providing a combined installed power of 19,200 kW or 25,996 HP. These engines enable the vessel to achieve a maximum speed of 21 knots (with a cruising speed of 18 knots), which exceeds the necessary requirements to support the converted vessel's limited operational profile.

4.1.8 Auxiliary Systems

The existing auxiliary systems will also remain unchanged to minimize conversion work. The ship's original auxiliary systems, including HVAC (Heating, Ventilation, and Air Conditioning), plumbing, and electrical systems, will be maintained; however, refurbishment to these systems may be required based upon further inspection of the current systems conditions. This was considered very minor in the study of the Crystal since the ship is being sold fully functional and was operating with a full crew and guests as recently as August of 2023. The actual work scope would be validated through a thorough hull inspection during the acquisition process. Additional systems that will be required to support the converted facility's operation as a mental health and substance use treatment and recovery facility are a security and surveillance system and an improved waste disposal system that supports medical waste removal requirements.

4.1.9 Weight Estimation

To determine the overall weight changes due to conversion, the project team tracked the estimated material removal and addition by deck throughout the design process. The most significant features removed were the swimming pools. The greatest structural work resulting in weight changes was patient room configurations requiring the combination of two or more cruise guest rooms. Table 8 shows the estimate weight change by deck in metric tons (MT). The total change is weight is estimated to be a reduction of nearly 71 MT.

Deck	Weight Change [MT]
2	-00.195
3	+00.145
4	+00.45
5	+00.44
6	-00.46
7	-01.34
8	+00.11
9	-70.00
10	00.00
Total:	-70.85

Table 8: Estimated weight change by deck

More detail can be found in Appendix J which itemizes the scope of renovation required for each space to complete the conversion.

4.1.10 Design Summary

The completed conversion design resulted in a modified vessel with the same hull form but significantly altered interior arrangements. Since the modifications required for this conversion were mostly associated with arrangements, the major ship performance parameters were unchanged. The most significant change due to the conversion was the weight of the ship. The updated ship design and weight were further evaluated in Section 4.2 to better assess the feasibility of this conversion project.

4.2 Feasibility & Performance Analyses

Once the conversion design was complete, the project team analyzed the modified vessel to assess ship performance and the conversion feasibility.

4.2.1 Weight Distribution and Load

As described in 4.1.9, the estimated change in weight following conversion is a reduction of nearly 71 MT. This is specifically due to structural and material changes to the ship itself as a result of the interior renovation, as well as removal of extraneous luxury items found on a cruise liner.

Another change to the ship weight is the amount of personnel expected onboard. The Crystal had a larger crew size and guest capacity than is anticipated for the updated medical facility. Table 9 shows the difference in personnel loading between the original and modified vessel.

Personnel Category	Cruise Ship	Medical Facility
Ship Crew	406	141
Medical Staff	0	407
Guests	1400	0
Patients	0	489
Total	**1806**	**1037**

Table 9: Estimated personnel loading before and after conversion.

This difference in personnel results in an estimated additional reduction of approximately 70 MT in loading. This is not significant given the overall ship displacement of 25,000 MT. Due to the ship's symmetrical arrangement, the weight change due to conversion and personnel reduction is not expected to significantly impact the vessel's list or trim.

4.2.2 Reserve Buoyancy

The Crystal has significant reserve buoyancy because of the substantial enclosed volume above the waterline. Prior to conversion, the freeboard was 31.17 ft. Following conversion it is estimated to be 31.22 ft, only a minor change due to the estimated weight removal.

The estimated tons per inch (TPI) immersion for the vessel prior to the conversion, considering a waterplane area of 43551.68 sqft, is calculated to be 103.69 MT/in. Post-conversion, with a waterplane area of 43554.1 sqft, the TPI immersion is projected to be 103.7 MT/in. This implies that the ship has approximately 38781.72 MT reserve buoyancy before the conversion and is estimated to have 38853.84 MT reserve buoyancy after modification. As predicted due to the minimal amount of structural work required, the post-conversion reserve buoyancy closely aligns with pre-conversion reserve buoyancy.

This analysis was only considered for an intact condition due to the operational profile. The vessel will not operate at sea for any extended period of time, so a damaged profile was not considered.

4.2.3 Strength

Due to the minor changes in estimated weight distribution and loading, as well as the minor structural modifications required, the project team was not concerned with any negative impact to ship strength following conversion. It was assumed that the ship design had adequate strength to support loading before conversion, so it would remain adequate after conversion. This would need to be validated by a more detailed ship and hull inspection during the ship acquisition process.

4.2.4 Stability Analysis

To determine the impact of the conversion to ship stability, the project team determined the change in the Vertical Center of Gravity (VCG). Given the lack of technical information on Crystal publicly available, the team estimated VCG with a bounded Roll Period Coefficient (GMt/B ratio) using the representative 3D model. Standard industry acceptable ranges are between 0.05 and 0.15 with an average of 0.10. Using the ORCA plugin for the hull and equation GMt = KB + BM - KG based on the existing B, the initial VCG was estimated to be 10.7 m or 35.105 ft. Using this estimate, the project team calculated the initial righting arm curve shown in Figure 48. The full report can be found in Appendix H.

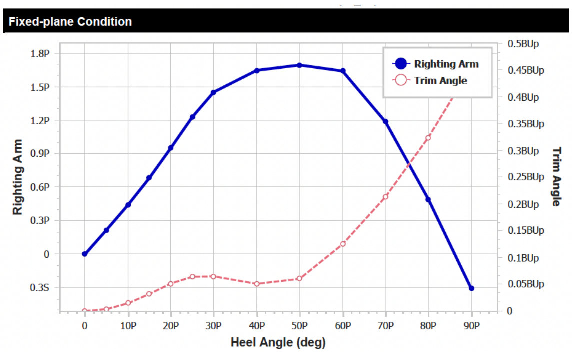

Figure 48: Initial righting arm curve

Taking the final displacement obtained from the final weight estimation and factoring in the VCG of each deck, the overall VCG was calculated to be 10.698 m or 35.098 ft. The project team then used this value to calculate the final righting arm curve shown in Figure 49. The full report can be found in Appendix I.

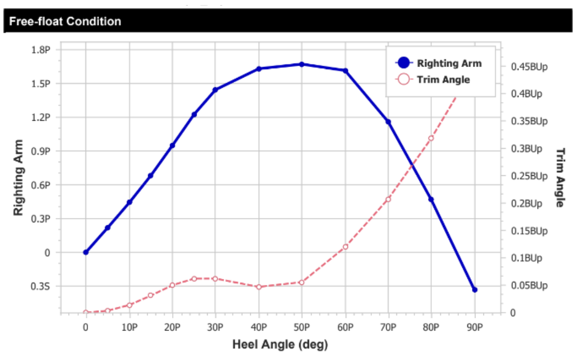

Figure 49: Final righting arm curve

From the analysis, the project team determined there would not be a significant change to trim or heel due to the minor structural and weight changes. A detailed study of the vessel would need to be completed to validate this assumption.

4.2.5 Power and Resistance

The Crystal's advertised maximum speed is 21 knots with a rated cruising speed of 16 knots. No changes in power or resistance estimations are expected as those systems are expected to remain in their original state following ship conversion. However, for a complete picture, the ship's resistance was computed for various speeds by applying Froude's number. Additionally, the Crystal model's design speed was calculated as 29 kts (for a Lwl of 167m); however, this is well beyond the typical operational profile of a cruise ship. A comprehensive table illustrating these calculations was produced utilizing the ORCA3D plugin and is shown in Figure 50. The data suggests the Crystal will reach cruising speed at a total propulsive power of 12,500 kW which is well within the rated capacity of the main engines. With regard to maneuverability, the Crystal is equipped with two Kamewa controllable pitch propellers (CPP), two Kamewa maneuvering thrusters, and a rudder system. The project team recommends further analysis to confirm Crystal's full maneuvering characteristics including her turning radius and stopping distance. Within the context of the project team's findings reinforce the conclusion that the modified ship will sufficiently exceed any power and propulsion requirements should the vessel need to get underway.

Speed (kt)	Fn	Cf (x 1000)	Cr (x 1000)	Rbare(N)	PEtotal (kW)	Rtotal (N)
8.000	0.102	1.640	1.199	162219.5	667.6	162219.5
10.000	0.127	1.594	1.187	248948.1	1280.7	248948.1
12.000	0.152	1.558	1.246	361081.4	2229.1	361081.4
14.000	0.178	1.528	1.430	514881.3	3708.3	514881.3
16.000	0.203	1.503	1.759	732894.0	6032.5	732894.0
18.000	0.229	1.482	2.225	1039528.8	9626.0	1039528.8
20.000	0.254	1.463	2.846	1470308.6	15127.8	1470308.6

Speed (kt)	Fv	Rbare (N)	PEtotal (kW)	PPtotal (kW)	Prediction Check
8.000	0.248	162219.5	667.6	1335.2	OK
10.000	0.310	248948.1	1280.7	2561.4	OK
12.000	0.372	361081.4	2229.1	4458.2	OK
14.000	0.434	514881.3	3708.3	7416.6	OK
16.000	0.496	732894.0	6032.5	12065.1	OK
18.000	0.558	1039528.8	9626.0	19252.1	OK
20.000	0.620	1470308.6	15127.8	30255.7	OK

Figure 50: Power and Resistance Table

Additionally, the power versus speed graph for the model is shown in Figure 51. The complete resistance report can be found in Appendix I.

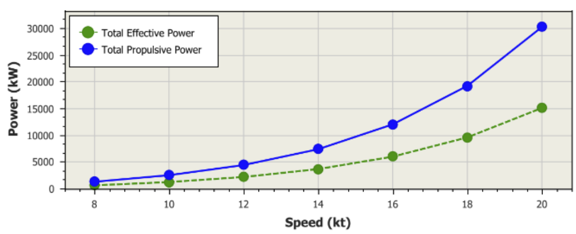

Figure 51: Power vs Speed

4.3 Cost

Estimating the total cost of any conversion project is a challenging task, particularly a conversion as novel as this proposed project. It is difficult to fully bound the complete scope of work involved. This is due to the volume of unknown growth work that may exist. Examples of work not fully known prior to a thorough hull inspection are the material condition of the hull, the status of the HVAC system, electrical distribution, and especially tanks. It is nearly impossible to definitely itemize and price the various aspects of a total ship overhaul and renovation with a high level of fidelity. Estimating the conversion cost for this project was even more challenging due to the lack of publicly available technical data, reference documents, and engineering logs for the Crystal.

Furthermore, the maritime overhaul and repair industry is highly competitive with organizations and companies keeping specific project bids, associated costs and margins held close. Publicly available data is often incomplete, generalized, and lacks critical nuances such as total scope of work, the age of the vessel, and initial condition of the ship. The maritime industry is also subject to significant fluctuations secondary to global geopolitical and economic factors. It is also difficult to trend costs as these overhauls are completed all over the world leading to large variance in skilled wages and associated costs.

Accounting for the total conversion cost is further challenged by the lack of commercial historical precedent in outfitting a hospital ship. Regarding military hospital ships, the United States Naval Ships (USNS) Mercy and Comfort were converted from repurposed tankers, built to military standards, and included enormously complex infrastructure additions (such as a flight deck). These projects involved complete keel up renovation including all propulsion, power, and auxiliary systems. In contrast, the proposed Crystal conversion project is pursuant to Massachusetts State Code, vice the Bureau of Navy Medicine, as well as civilian regulations from the US Coast Guard and American Bureau of Shipping.

Understanding that a traditional military ship or hospital ship overhaul would not be adequately representative of the scope of work anticipated for this conversion, the project team drew estimates from financial data for both cruise ship refurbishments and medical facility construction. The historical data was then used to generate meaningful cost estimates for the proposed conversion. The project team used engineering best practices, limited data, and primary source interviews to itemized, analyze, and estimate total costs of this project. Additionally, the project team interviewed senior managers at the leading naval engineering consulting firm, Foreship, and incorporated their feedback and expertise into the financial analysis.

Cost Itimization	Revovation Type	Total Square Feet [sqft]	Price Per Square Foot [$/sqft]	Initial Capital [$USD]	Percent of Initial Captial	Total [$USD]
Hull Purchase	None	0	0	**15000000**	0.00%	**$15,000,000.00**
Hull Inspection	Marine	0	0	0	2.50%	**$375,000.00**
Hull Structural Overhaul	Marine	0	0	0	5.00%	**$750,000.00**
Hull Misc. Overhead	Marine	0	0	0	5.00%	**$750,000.00**
Project Management	N/A	0	0	0	4.00%	**$600,000.00**
Design and Engineering	N/A	0	0	0	2.50%	**$375,000.00**
Supply and Logistics	N/A	0	0	0	1.50%	**$225,000.00**
Drydocking	N/A	0	0	0	4.00%	**$600,000.00**
Overhaul, Facility Structural	Marine	8051	325	0	0.00%	**$2,616,575.00**
Refurbish, Patient Room	Inpatient	31864	350	0	0.00%	**$11,152,400.00**
Refurbish, Patient Room	Addiction	8798	50	0	0.00%	**$439,900.00**
Refresh, Hospitality	Hospitality	46097	35	0	0.00%	**$1,613,395.00**
Refresh, Administrative	Administrative	6203	40	0	0.00%	**$248,120.00**
Refurnish, Hospital Systems	Hospital	15322	300	0	0.00%	**$4,596,600.00**
Overhaul, Facility Ligature	Hospital	0	0	0	1.00%	**$150,000.00**
Facility Security Installation	Hospital	0	0	0	1.00%	**$150,000.00**
					Initial Total:	$39,341,990.00
					Margin:	50.00%
					Total:	**$59,012,985.00**

Figure 52: Complete Acquisition and Conversion Cost Analysis

Overall, for a purchase price of $15M, this conversion will cost an estimated $44M for a combined total of less than $60M. Moreover, this project will take, approximately five to six weeks, starting at the time the vessel arrives in a shipyard. The full cost breakdown and analysis is shown in Figure 52.

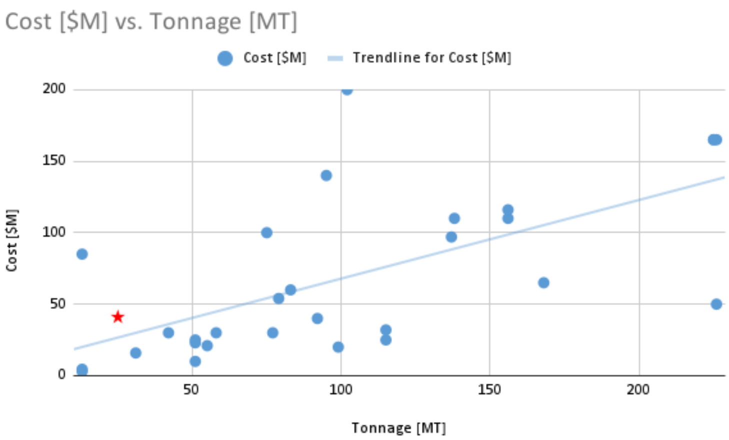

Figure 53: Projected cost analysis - evaluated against historic values

In figure 53 this project is denoted as the red star against data from historic cruise ship renovations organized by cost per tonnage. Clearly, as described above, these data can be misrepresented: the age, scope of work, and more are not included in the public data. Despite that, as a validating metric, the conversion cost for this project is consistent with the expected value for a 25 MT vessel. However, a novel project, such as this proposed conversion, with little commercial precedent can be expected to cost more than an industry standard cruise liner renovation.

4.3.1 Acquisition Cost

As discussed in Section 3.3.1, the Crystal is currently available for purchase with an asking price of $15 million dollars. While significant, this does not reflect the total scope of the acquisition cost. To purchase, the vessel would require a contingent full inspection - estimated at 2.5% of the the purchase price. This inspection would evaluate and test all systems and subsystems onboard the ship. The project team budgeted 5% of purchase price for growth work found during inspection; for example, overhauling the ships HVAC, or waste water infrastructure. An additional 5% was budgeted for miscellaneous overhead including preventative corrosion maintenance, IT systems management, and other unspecified growth work. These estimates were validated by numerous industry professional. Moreover, the ship is currently moored in Greece, necessitating logistics, crew and fuel to sail to a United States or Foreign shipyard. While significant, these costs vary considerably over the specific transit. For example, sailing from Greece to the Vigor Shipyard Portland, OR involves a transit through the Panama Canal. While contracting a facility in Italy would involve a much shorter transit. Given this variability, the team incorporated transit costs into project overhead and margin.

4.3.2 Engineering Cost

While predominate costs of this conversion are defined by the initial capital of the ship and the actual work, a significant fraction must be budgeted towards professional engineering services. 2.5% of the vessel's cost was budgeted for licensed profession engineers and naval architects, with an additional 4% for project management. Following the initial inspection overseas by divers, the ship would most likely need to enter into a short dry dock period (on the order of a few days). The project team estimated this would cost 4%, or about $600,000. Given uncertainty in the ship's maintenance log, the design team assumed that the ship has not had a comprehensive cleaning and inspection recently, necessitating these fundamental inspections. Finally, the team budgeted for supplies and logistics over the entire conversion at 1.5%. This includes material and crane barges, along with trucks of supplies and waste material. These parameterized values were validated against industry standards and primary source interviews.

4.3.3 Refurbishment and Conversion Cost

Half of the estimated total conversion cost (about $30M) is accounted for through the itemized work breakdown. The team primarily used nominal cost per square feet to evaluate individually codified work items. However, some system-wide features like installed facility security were calculated using the vessel's purchase price. A vessel's purchase price is roughly proportional to the ship's gross tonnage. Therefore, for conversion of total ship systems where refurbishment area is difficult to estimate, cost was estimated using a small percent of the initial capital cost. Modifications made to prevent patient ligature or self-harm were estimated at 1%; these can include taking away handrails, drain pipes, or door hinges, or incorporating sensors on top of doors. Additionally, the team allocated 1% for comprehensive security systems across the whole facility including, badge accessed doors, security cameras, and sally ports.

Regarding individual space renovation, the experts at Foreship codified vessel work in three categories: refreshment, refurbishment, and overhaul. Refreshment is minimally invasive, involving purely cosmetic changes to a facility such as new paint, veneer, or furniture. Refurbishment is defined by major work in a space, short of altering the ship's structural foundations. Overhaul is reserved for a complete change to the internal structure of a compartment, along with the rerouting of critical ship systems. The project team used this information to then characterize each proposed conversion space by type of work including: structural overhaul, hospitality and administrative refreshment, and refurbishment of hospital systems and patient rooms with distinctions made for addiction and inpatient treatment rooms. The full list of spaces is listed in Appendix J.

The team comprehensively evaluated all modifications made in Section 4.1 by evaluating the total square feet, as shown in Table 10. Administrative renovations were defined as cosmetic changes to spaces to better facilitate office productivity; these included conference rooms, office spaces, file rooms. Similarly, hospitality changes to Crystal include indoor and outdoor recreational space, visitor and staff support rooms, and dining spaces. These changes were evaluated at $35 and $40 per square foot using publicly available parameters for hotel renovation.

Renovation Type	Square Feet
Administrative	6203
Inpatient	31864
Addiction	8798
Hospital	15322
Hospitality	46097
None	34673
Structural	8051
Total Square Feet:	151008

Table 10: Complete Conversion Area by Renovation Type

Refurbishment to hospital systems were distinguished from changes made to both inpatient and addiction service rooms; this decision was made to best characterize the nuances between the three types of work. Evaluated at $350 per square foot, inpatient rooms presented the the largest change from existing cruise ship infrastructure. These patients require specific and deliberate furnishings to facilitate care as well as patient and provider safety, with particular attention made to prevent the possibility of self harm. All hospital systems were evaluated at $300 per square foot. These included nursing stations, therapy rooms, consultation rooms, and seclusion rooms. Both of these numbers were informed by data from RSMeans' construction estimating database as well as primary source interviews [22]. While changes to inpatient service spaces are pursuant to CMR 104, requirements for addiction service are less stringent (and are in accordance with CMR 105). The project model changes to these rooms ($50/sqft) follows pricing from the hotel industry. Finally, structural work ($325/sqft) was defined as any space in which bulkheads were removed or altered. These spaces were accounted for in both structural overhaul and also their respective renovation category.

4.3.4 Operations and Support Cost

The overall operations and support costs of the converted facility is multifaceted. The total cost encompasses the cost of ship maintenance and operations, pier lease rates, utility costs, and clinical staffing costs.

Ship maintenance costs. It is difficult to estimate the operations and support costs of the converted facility as a marine vessel. Both private organizations, as well as the Department of Transportation (DOT) publish data on the operational costs of vessels of all types. However, these analyses are conducted for vessels with significant underway operational profiles. In contrast, the converted vessel in this study is meant to both stay in port and utilize pier hotel services. In a 2009-2010 study, the Maritime Administration published an analysis of the operational cost profile of all classes of maritime vessels, shown in Figure 54 [23]. Notably, these values were calculated 15 years ago. Contemporary expenses should be expected to be significantly more based upon wage increases and inflation. While the converted Crystal would maintain some semblance of a marine vessel, its daily operation, expenses, staff, insurance, and overhead maintain little parallel with that of an ocean-going commercial vessel. Specifically, it can be noted that all five of the characterized operational costs would either not apply or be significantly reduced due to a reduced maritime crew, equipment in lay-up, and the vessel's in-port status. These costs would be more representative during the rare times the converted facility is underway. This includes both personnel and the maintenance materials.

	Bulk Carrier+				Average - All Vessel Types^			
	U.S.		Foreign		U.S.		Foreign	
Cost Categories	2009	2010	2009	2010	2009	2010	2009	2010
Daily Wages*	$11,962	$11,490	$1,993	$2,013	$13,616	$13,655	$2,565	$2,590
% of Total	58.3%	65.1%	34.8%	34.7%	62.5%	68.1%	34.6%	34.8%
Magnitude	6.00	5.71			5.31	5.27		
Daily Stores/Lubes	$1,681	$1,362	$620	$638	$1,303	$1,158	$1,041	$1,073
% of Total	8.2%	7.7%	10.8%	11.0%	6.0%	5.8%	14.1%	14.4%
Magnitude	2.71	2.14			1.25	1.08		
Daily M&R	$5,049	$3,019	$1,680	$1,736	$3,976	$2,994	$2,294	$2,390
% of Total	24.6%	17.1%	29.4%	29.9%	18.3%	14.9%	31.0%	32.1%
Magnitude	3.01	1.74			1.73	1.25		
Daily Insurance	$1,643	$1,527	$765	$745	$1,158	$1,057	$817	$692
% of Total	8.0%	8.6%	13.4%	12.8%	5.3%	5.3%	11.0%	9.3%
Magnitude	2.15	2.05			1.42	1.53		
Daily Overhead	$198	$257	$663	$676	$1,722	$1,189	$693	$709
% of Total	1.0%	1.5%	11.6%	11.6%	7.9%	5.9%	9.4%	9.5%
Magnitude	0.30	0.38			2.48	1.68		
Daily Operating Costs	**$20,532**	**$17,656**	**$5,721**	**$5,807**	**$21,774**	**$20,053**	**$7,410**	**$7,454**
% Change		**-14.0%**		**1.5%**		**-7.9%**		**0.6%**
Magnitude	**3.59**	**3.04**			**2.94**	**2.69**		

*Crew costs generally include basic wages, subsistence, overtime, travel costs, training, pensions, and union fees.

+Includes Handymax and Supramax sized vessels (25,000 - 65,000 DWT).

^While costs specific to U.S.-flag tankers were omitted to protect carrier confidentiality, tankers were included in average costs for all U.S.-flag vessels.

Figure 54: Commercial ship operational costs

Lease rate. The two major contributors to the pier side operational costs are the utility costs and the lease rate. The proposed mooring location for the modified cruise ship is the North Jetty Pier in Boston. As documented in Team CASH's report, the current (as of 2021) tenant of the pier is Eastern Salt, a private development company [6]. At that time Eastern Salt was also renting over 10 acres of surrounding land (Parcels 7 & 8 in Figure 55) and in the process of upgrading the site at a cost of several million dollars. The Eastern Salt's lease agreement stipulates an annual rent of

$202,000. It is expected the lease for the converted facility would be a similar rate.

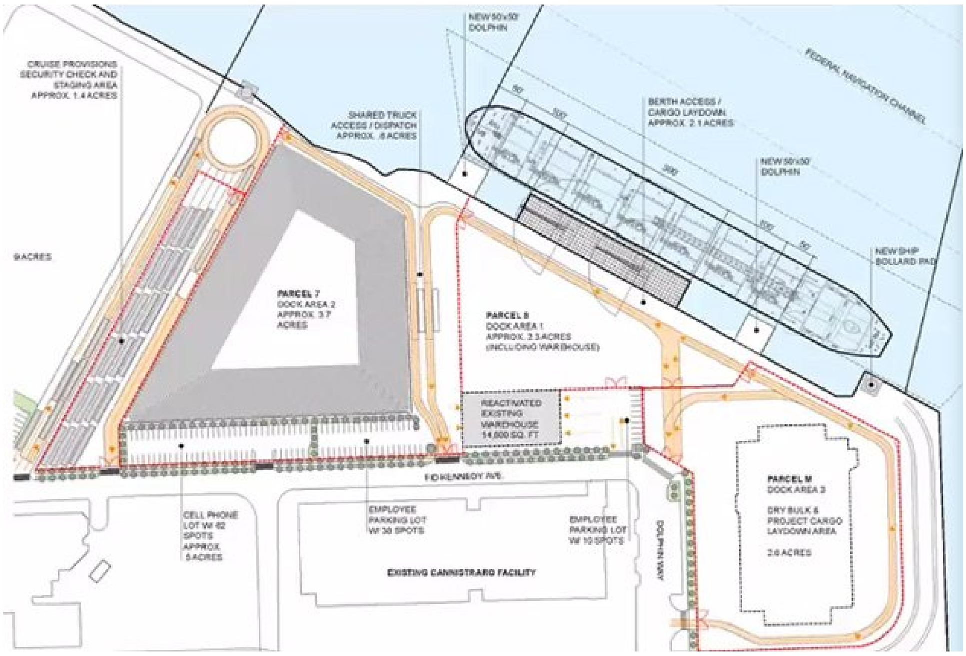

Figure 55: North Jetty Pier Lease Agreement

Utility costs. Utility costs would also depend on current rates for electricity, water and waste disposal. Again to reference Team CASH's report, the city should expect a discounted utility power rate of 20 ¢/kWh. While their analysis was for 350 people, this facility would accommodate 1000; accordingly, a first order estimate on annual utility costs would be about $6 million, or three times that of Team CASH.

Clinical staffing costs. The average operational cost per patient is exceptionally difficult to calculate. This value would encompass not only the daily costs associated with the vessel, but also the opportunity cost/benefit to the state from the availability of other emergency service agencies. Additionally, according to a 2019 study [24], Massachusetts faces a shortage of behavioral health care professionals, with only 9 full-time equivalents allocated to designated shortage areas and facilities experiencing a deficit in such professionals. To tackle this issue, an additional 15 full-time professionals are required in these areas, including two needed specifically for correctional facilities. This highlights the increased complexity of ensuring adequate staffing is available and then estimating the costs associated with employing this staff. Disregarding a staffing shortage, the team estimated these costs at an average annual clinical salary of $75k. With 407 staff members, the approximate annual clinical staffing costs are $30,525,000. Total operational cost estimates with any degree of fidelity would require more analysis, evaluating similar medical facility operating costs.

4.3.5 Total Life Cycle Cost

To generate an estimated total life cycle cost for the proposed mental health and substance use treatment facility, the project team considered the combination of each of the cost categories described in the previous sections. Table 11 shows the estimated totals for both fixed and operational costs for this project.

	Fixed Costs		Annual Operational Costs
Acquisition	$15,000,000	Ship Maintenance	$1,000,000
Conversion	$45,000,000	Lease	$200,000
		Utilities	$6,000,000
		Staffing	$30,525,000
Total	**$60,000,000**	**Total**	**$37,725,000**

Table 11: Overall estimated cost summary

While the values in Table 11 are gross estimates for each cost category, they do present a reliable initial estimate and describe the expected order of magnitude cost to complete and maintain a cruise ship converted to a mental health and substance use treatment and recovery facility. The fidelity of these estimates could be improved with continued research into this proposed conversion.

4.4 Technical Feasibility and Risk Assessment

4.4.1 Feasibility Assessment

The technical feasibility of this project is high. All modifications made to the existing ship are based upon proven technologies and processes. The modifications also involve minimal structural work, minimizing risk to the construction process. The engineering, adaptations, refurbishment, and conversion are all well within current manufacturing and industrial standards. Moreover, given intuition gained from cruise industry professionals, this project is attainable in a time period far shorter than the project team's initial estimates. The maritime industry is used to building projects of significantly greater scale, complexity, and technical risk.

4.4.2 Outstanding Risk

The project team identified three main areas of outstanding risk for the proposed conversion: accurately modeling project operational costs, extending hull life for an adequate number of years to support the modified facility, and successfully obtaining all required facility operating licenses from all stakeholders and governing agencies involved.

As described above, estimating the annual operating costs of the proposed facility is very complex. The project team provided a best first-pass estimate. However, a more detailed analysis would need to be completed to fully understand what the state would be required to fund to operate a facility of this nature.

Cruise ships removed from service typically range from 20 to 30 years in age. Although, the Crystal was renovated multiple times since entering service, the hull is still quite old. An extensive hull inspection would need to be completed on the Crystal (or any procured vessel) in order to validate the assumption for an extensive service life extension that supports the required lifespan of the converted facility.

Finally, navigating the intricacies of collaboration with agencies, teams, and organizations not accustomed to such partnerships poses a significant challenge in achieving project completion. Securing endorsement and cooperation from key entities such as DPH, DMH, the Massachusetts Legislator, and identifying suitable companies for the renovation add complexity to this endeavor. The challenge is further heightened by the foundational design principle emphasizing the optimization of existing infrastructure to minimize costs which makes the facility atypical in many ways compared to a more conventional land-based facility. Obtaining operating approval from each of the governing agencies to open a facility built in this manner is the largest outstanding risk to this project.

This conversion concept, while technically feasible, carries a large amount of outstanding risk to execute. By focusing future efforts on these areas of greatest risk, the state could make the project more feasible.

5. Conclusions & Recommendations

Based on the findings discussed previously, the project team has evaluated the conversion of a cruise ship to a mental health and substance use treatment facility as feasible. Final conclusions and recommendations for future work to continue this study are described in this chapter.

5.1 Summary of Final Concept Design

This project evaluated the feasibility of converting a commercial cruise ship into a mental health and substance use treatment and recovery facility to support the city of Boston, MA. The general design and capabilities of a cruise ship made the possible conversion of a cruise ship to a medical facility a study worth investigating. The infrastructure of a cruise ship is designed to house and feed a large number of people, so the design team anticipated this would significantly reduce the modification required to repurposed the vessel. While large guest amenities would need to be removed and altered, the team anticipated that this weight would not be significant enough to have major implications to ship strength or stability. This project was motivated by the 2023 CASH project investigating the feasibility of converting a cruise ship to affordable housing [6]. The Commonwealth of Massachusetts was interested in further pursuing this concept to see if a cruise ship conversion may provide a possible solution to support the mental health and substance recovery treatment hospital bed shortage in Boston [1]. The project sought to determine whether the acquisition and conversion of a cruise ship into a medical facility of this kind would be feasible, faster, and less expensive than a traditional brick-and-mortar facility.

The project involved developing design requirements based on the sponsor and facility licensing requirements. The main requirement was that this facility should be able to be constructed for less time and money than building a new hospital and support 200 to 500 patients. Although it was possible to locate a ship of this nature anywhere, the intent was to support Boston. This directed most of the research to the requirements of Boston Harbor. Based upon established requirements, the Celestyal Crystal was selected for conversion due to its smaller size, guest capacity, and purchase price. After the hull was selected, the project team developed a representative three-dimensional model to understand the ship parameters and space available. Two-dimensional deck plans were then developed and use to design a new ship arrangement to support the needs of a medical facility. The updated deck plans accounted for:

- Renovated patient rooms
- Patient support spaces
- Staff support spaces
- Removal of all major guest amenities
- Improved security and deck separation

Once new deck arrangements were developed, the project team analyzed the changes in weight throughout the conversion. This was then used to evaluate any changes to ship stability. The extent of renovation required was also tracked throughout the conversion. The data was then used to generate an estimated conversion cost based on historical costs of ship conversions and hospital construction. Finally, the project team evaluated what would be required for the converted vessel to operate pier side in Boston indefinitely. These operational cost estimates were also included in the total life cycle cost.

The final conversion design included an updated ship arrangement that supported facilities and services for 489 patients. The updated vessel hull structurally remains the same. As such, it is anticipated the ship would maintain stability, maneuvering, and estimated stability and sea keeping capabilities similar to those of the original Crystal. The updated facility is equipped with adequate facilities to meet the space and accommodation requirements in accordance with state licensing requirements. It also has sufficient margin space due to the spaces originally designed for cruise ship staff that were not considered in the conversion. The updated facility was able to utilize existing machinery equipment, propulsion system, and auxiliary systems, significantly reducing the cost and complexity of conversion. The design also retained the original galley and refrigeration storage equipment. Being able to take advantage of existing infrastructure and working around this, the project team was able to keep the cost of conversion as low as reasonable. Additionally, but selected a moderately sized cruise ship the purchase cost was also as low as feasible in order to support the required patient population size. The estimated total cost of purchase and conversion is approximately $60 million. The Boston fiscal year 2024 budget had $600 million dedicated to addiction and treatment programs. In addition, the city spends millions on police overtime and emergency medical response each year, as well as additional police force requirements. Hospitals and clinics are also known to have to improve private security, which is estimated to cost another few million dollars a year [1]. The estimated conversion cost is less than 10% of the estimated annual costs that the city of Boston currently spends each year managing the drug and homelessness crisis, which stems in part from a lack of these types of facilities. Therefore, the project team believes that the estimated conversion cost is reasonable enough to consider this project further.

In conclusion, a cruise ship could serve as a very effective baseline for a mental health and substance use treatment facility. Independent of the specific ship chosen for conversion, this project determined that many features of a cruise ship can be repurposed or directly used in a converted medical facility. This fact makes it possible to reduce the required project timeline. Therefore, converting a cruise ship to a medical treatment facility could have the added benefit of being a significantly faster construction project than a land-based facility. Additional areas of study and further recommendations are presented in the following section, but in summary, a cruise ship provides a feasible option for conversion to a mental health and substance use treatment facility.

5.2 Areas for Further Study

The project team concluded that the conversion of a cruise ship into a mental health and substance use treatment facility is feasible and recommends further study into the following areas to bring this concept to fruition.

Pier location and facilities. This study assumed that the mooring location for this facility would be the North Jetty Pier. Lease and utility considerations were evaluated on the basis of this assumption. The North Jetty Pier was approved for major improvements in 2021 by a private company [25]. A new lease agreement and land arrangement would need to be further discussed between the Commonwealth and the new developers. The Commonwealth needs to assess whether the pier still provided a suitable location that provides sufficient services for a medical facility and is conducive to surrounding development. In the event that the North Jetty Pier is no longer a viable assumption, other piers in Boston Harbor may be evaluated. The ship evaluated in this study can access the entire harbor. The major difference in location is expected to be the established infrastructure and annual operating costs. In addition, consideration should be given to upgrade the pier services at whichever pier is the final decision to better support long-term operations. This is an additional cost not currently considered in the estimates of this study.

Specifically, looking at one alternative, the Boston Dry Dock 2 is another potential location for the facility; however, sufficient technical information regarding the referenced dry dock was challenging to find. A cursory investigation suggests that it is quite derelict. Initial research indicated Dry Dock 2 was sold by North American Ship Repair to a commercial developer in 2020 [26] [27]. The current status of the dry dock and surrounding real estate would require further study to determine the feasibility of this location. In general, any of these dry docks or serviceable pier locations could be feasible locations to support this facility given adequate clearance for a ship (beam, draft, length) and sufficient utility services (power, sewage, etc.). In addition, available parking and proximity to public transportation should be considered for each potential mooring location. Many of these challenges could be overcome with sufficient funding or time. The largest variable in cost would be the addition of required utility infrastructure to support a semi-permanently moored ship. This would require additional analysis to better estimate the cost.

Baseline ship selection. The project team chose Celestyal Crystal as the ship to evaluate in this study because it met the requirements of this project but also in large part because it was available for sale as of January 2024 and sufficient information about the ship was available to complete the study. Evaluating more cruise ships could also help lower the purchase cost based on a more thorough market search. Additionally, this project exclusively considered the conversion of a cruise ship based on previous research and sponsor interest. In order to further minimize costs and have fewer excess systems and spaces to convert and maintain, a berthing barge may also be fruitful to investigate.

Detailed Space and Engine Room Analysis. Throughout this conversion study, the project team had to make many assumptions about space arrangements, structural architecture, and existing onboard systems, due to the relative lack of detailed information available publicly. For example, the two-dimensional deck plans used as the basis for arrangement modifications provided a starting point for an initial feasibility and redesign assessment but lacked the granularity to propose truly detailed changes. Moreover, the unavailability of any sort of engine room drawing layout severely limited the team's ability to recommend meaningful changes within this space. It is assumed that these systems can remain in their current state, but more detail would further improve the reliability of this study. In addition, complete ship schematics with more information on existing crew berthing and messing spaces would provide the information necessary to consider these spaces for further conversion. This could provide additional treatment and support spaces, further improving the space margin.

Hull inspection and corrosion control. A significant assumption for this study is an extensive service life extension for the ship following conversion. The minimal operational profile of the converted vessel supports this; however, this assumption would be further validated following a thorough hull inspection to assess the condition of the selected ship. This would also further improve cost estimates by minimizing the risk of growth work associated with the hull. To further extend the life of the hull, adequate corrosion control measures would need to be in place since the ship will remain in the water. This is a maintenance cost not considered in this project. Furthermore, understanding the method of control and hull longevity will be important in estimating the periodicity of dry-docking required for the converted vessel.

Patient population. This study was conducted under the assumption that the converted facility would support 75% inpatient psychiatric care and 25% inpatient substance use treatment and recovery services. This was based on initial interviews with local officials and medical representatives. Facility licensing requirements supported the assumption that inpatient psychiatric patient spaces had the highest physical requirements to ensure patient safety, translating into the largest refurbishment requirement for patient spaces. This conversion could be applied to different patient populations to support either a different ratio of inpatient treatment or outpatient treatment. The level of refurbishment required for treatment spaces would need to be evaluated and the cost estimates updated to reflect the new facility design. The project team's estimate is that any patient treatment level lower than inpatient psychiatric care would require a lower conversion cost than what is presented in this report. However, this would require further analysis to increase the fidelity of the cost estimate.

State & federal licensing compliance and waivers. This study was conducted taking into account the facility guidelines for hospital construction and the specific licensing requirements of the Commonwealth of Massachusetts. However, the team that completed this study has no experience building medical facilities or mental health and substance treatment services. The project endeavored to meet the requirements as much as possible within the constraints of an existing ship structure and the limited understanding of the regulations by the team. It is recommended that a collaborative team of the licensing agencies involved more closely evaluate the project to determine further modifications that may be required to acquire license. This project also only considered the requirements for adult patients. If any other patient demographic was to be treated, additional requirements would need to be considered. Additionally, an experienced medical team should validate the exact patient population requiring treatment from this facility to ensure appropriate licensing is obtained.

For regulations not met, the state would need to seek waivers from the governing agency. Two such requirements not met by the project team were double-occupancy room square footage and substance use treatment medication storage. Double-occupancy rooms are 150 square feet in the current design, 10 square feet short of the facility requirement [11]. This was a conscious design decision to optimize using the existing structure as much as possible. By using the existing rooms instead of removing all guest rooms and then rebuilding, the conversion is significantly less complicated and less costly. The second is meeting the physical security requirements of storing controlled medications used for treating substance use recovery patients. The state would need to seek a waiver from the Drug Enforcement Agency or seek an arrangement with an outside organization to deliver required medication doses daily. Any other deviations discovered would need to be adjudicated.

Emergency evacuation plan. The converted vessel is intended to treat patients pier side. In the event of an emergency, such as a hurricane, or significant maintenance requiring relocation, such as dry-docking, the state would need to have a plan to transfer patients to other facilities. It is not intended that patients be present if the ship should have to leave the pier.

5.3 Recommendations

Based on this study, the project team recommends considering the conversion of a cruise ship as a creative and feasible option to provide the city of Boston a supplemental mental health and substance use recovery facility. The main considerations for the team's recommendation to continue research on this conversion are described below.

- Purchasing a cruise ship is an option that is immediately available to further pursue the project. This acquisition could be much faster than acquiring land and building a new facility from the ground up.
- The limited structural work required to convert a cruise ship to a mental health and substance use treatment facility makes a cruise ship well suited for this conversion. This also significantly reduces the required time and money required to complete the project.

Upon completion of this study, the project recommends that the state continue to pursue this project with the assistance of a collaborative team of experts in shipbuilding and medical facilities.

A. Project Study Guide

Study Guide

Cruise Ship Conversion

An investigation into the utility and
feasability of converting a cruise ship into
a mental health and rehabilitation facility

Project Team: Rafail Athanasopoulos
Emily Curran
Adam Pressel

Course: 2.704

December 20, 2023

1. Introduction

This document defines the process, research, sponsor requirements, and assumptions that will be used to perform a feasibility assessment on the conversion of a commercial cruise ship to a state-supported mental health and rehabilitation facility. Patient capacity, mobility, and services, as well as ship arrangements, required for a medical facility will be evaluated throughout the process. In addition, this project will estimate conversion, maintenance and operations costs, while identifying technical risk areas juxtaposed with feasibility.

2. Study Objectives

2.1 Course Description

MIT Course 2.704 - Projects in Naval Ship Conversion Design - builds on previous coursework in naval construction and engineering (including subjects: 2.701, 2.702, and 2.703) in the MIT 2N Program to identify new mission requirements, and recommend significant modification to an existing ship. Major syllabus requirements and objectives include: (a) application of naval architecture and ship design knowledge/skills to complete a conversion/modified-repeat ship concept design project; (b) ability to plan and execute work as part of a design team; and (c) demonstration of effective communications, in both written reports and oral presentations. These objectives must be considered in specifying requirements and planning the project. Lastly, this paper will conduct a detailed trade-off study in the area of at least one unproven but promising technology for shipboard application as it applies to a cruise ship conversion.

2.2 Project Description

The objective of this conversion project is to determine the feasibility of converting a decommissioned cruise ship to a floating medical facility that supports mental health services and drug rehabilitation treatment for the Commonwealth of Massachusetts. The goal of this facility is to specifically support the city of Boston, so the evaluation will consider Boston the primary docking location; however, alternative mooring locations and ship's mobility will be considered. Since this is a state-funded project, the conversion cost must be reasonable as compared to the construction of brick and mortar structures. The time required to complete such a project is also a major consideration, as there is an immediate need for such a facility in Boston with hospital bed shortages for this service currently in the hundreds. In addition to the cost and completion time of the conversion, other objectives used to determine the feasibility of the project include the infrastructure available to support the converted ship and the overall sustainability and serviceability of the final product.

2.3 Key Insights

From these study objectives, the project team identified potential areas of insight that require additional analysis due to their impact on the success of the conversion design. These items are outlined below.

Arrangements. Determine what major spaces and equipment can / need to be removed and what needs to be retained to support this conversion and maximize the amount of treatment and living space on board. What changes are required for the topside arrangement to support egress and medical evacuation (medivac) capability? Further, what significant medical equipment and spaces will be required on board? How can the passage ways, corridors, rooms, and ships ladders be adapted to accommodate for disabled personnel or the movement of hospital beds and stretchers?

Habitability. Determine the major design decisions and considerations necessary to convert existing hotel-style rooms into Massachusetts-regulation-compliant treatment rooms and living spaces for long-term patients. This will require a particular emphasis on safety and the requirements of the Department of Health and the Department of Mental Health.

Concept of Operations. Determine how this type of facility can support short-term treatment and also for those ranging from weeks to months. Determine whether this requires housing facilities for staff in addition to patients. Evaluate what engineering requirements are generated from housing full-time occupants with medical services. Consider the hotel services required of medical patients compared to cruise ship guests.

Support Systems. Determine what in-port infrastructure needs to either be put in place or upgraded (with respect to shore power, potable water, garbage disposal, etc.) to support long-term docking of this type of vessel? How will these additional costs be accounted for? What additional pier services are required for a medical facility?

Survivability. What ship features needed to be retained and/or upgraded to support long-term docking and short-notice sortie in case of extreme weather conditions?

Cost. Determine the affordability of purchasing a cruise ship from the parent company. Determine the affordability of the overall conversion process. Determine the cost to operate and maintain following conversion. Compare to the nominal costs of running a conventional land-based facility.

These key insights were incorporated into the project approach and areas for additional research to ensure the project objectives are best met.

3. Project Overview

This feasibility study will investigate the feasibility of converting a decommissioned ship or water-based vessel into a floating mental hospital for mental health substance abuse and recovery. The study will investigate the creation of a floating medical facility that can support state-mandated mental health commitments, as well as additional rehabilitation treatments for 200 to 500 patients. [7] The ship will be capable of long-term support pier side in Boston, MA and also seagoing to support sorties or relocation on the East Coast of the United States.

3.1 Motivation

Boston, like many major metropolitan areas, is struggling with an opioid and public safety crisis. Specifically, in 2023, there have been 352 overdose deaths reported in Boston. [7] A major contributor to this crisis is the lack of housing and medical needs to support the state's most vulnerable population. The current demand for accessible mental health services far exceeds the available resources, and the city is facing rising overdose deaths waiting for a solution. An article in the Boston Globe on 9 April 2023 cited a survey by the Massachusetts Health and Hospital Association and the Massachusetts Association of Behavioral Health Systems stating that the average wait time for patients requiring long-term inpatient care was 197 days. In addition, in the last year, the overcrowding of sheltering units has caused more than 1,200 people to be stuck in hospital beds with no place to be discharged. [5] These data underscore the rapid need for innovative approaches to address the alarming imbalance between the growing demand for mental health support and the limited supply of resources. An existing alternative proposed solution involves the restoration of the Long Island Rehabilitation Center. The construction is projected to begin in the Spring of 2024 and last for 16 to 24 months. [7] While this facility would ameliorate the mental health crisis, additional resources are still required.

Since the onset of the 2020 coronavirus pandemic, much of the cruise industry has been forced to close. Consequently, there is a large supply of cruise ships on the market for sale. In 2022 alone, 18 cruise ships were scrapped. [6] As Boston is located on the coast, the prospect of capitalizing on an available cruise ship to help provide space for the lack of medical facilities has been proposed as a potential course of action. This report proposes a study to determine the feasibility of converting a cruise ship as a model to provide treatment and living spaces for people undergoing treatment and/or recovering from substance use, as well as facing mental health challenges. This project will serve as a proof-of-concept for a possible solution to the mental health crisis.

3.2 Concept of Operations

The intended operational profile of the vessel is characterized by prolonged in port time with limited voyages. The exception to this is to support a sortie for personnel safety due to extreme weather conditions. This may also extend to responding to another crisis in need of surge medical care along the eastern coast of the United States. When in transit, the ship is expected to operate at a slow speed 100% of the time. This operational tasking presents unique challenges for a maritime asset as compared to traditional seagoing vessels; for example, while most maritime equipment is designed for continuous use, this vessel shall have emergency service generators and other hull, mechanical & electrical (HME) equipment in periods of prolonged mechanical lay-up. These are at an increase risk of rust, seizure, and failure with inadequate maintenance.

3.3 Sponsor & Derived Requirements

The sponsor requires that the vessel: be able to support medical services required for mental health, substance use treatment, and recovery services for 200 to 500 patients; the ship must be able to remain pier side in or near Boston; the ship must be relocatable; and it must cost less in time and money to complete than a land-based facility. Analysis of these baseline requirements yielded derived requirements, or the requirements that need to be met to ensure the customer requirements are achieved. The itemized list of given requirements with their derived requirements is below.

1. The ship must provide medical services for 200 to 500 patients receiving mental health and/or substance recovery services and rehabilitation.
    - 1.1 The facilities must be compliant with the Massachusetts Departments of Mental Health and Public Health licensing and operational standards.
    - 1.2 The vessel must support adequate staffing facilities for offices and berthing.
    - 1.3 The finished product must be comparable to facilities built on land for the same target population.
2. The ship must be able to operate pier side in Boston indefinitely.
    - 2.1 The ship must be within draft/size restrictions associated with Boston and its surrounding waters.
    - 2.2 The finished product must be compatible with pier services available or be self-sufficient the case of missing services.
    - 2.3 This ship must be retrofitted with hotel services requisite of a dedicated medical facility vice a recreational cruise ship.
3. The design shall retain onboard auxiliary electrical power and distribution in case of loss of normal shore power and in order to provide power during transit.
    - 3.1 Any additions or modifications made to the purchased ship design will need to fit within the installed electrical capacity.
    - 3.2 The ship must maintain organic service generators and dedicated fuel system.
4. The converted cruise ship must be ”relocatable” to address weather conditions requiring sortie and support any required movement along the eastern United States.
    - 4.1 The ship must maintain adequate stability to withstand at-sea transit.
    - 4.2 The ship must retain systems involved with light/sound requirements for at-sea transit.
    - 4.3 The ship must be self-propelled or be readily towable.
    - 4.4 The ship must be built with fixtures, and services that are easily ’secured for sea’ by hospital staff prior to ship’s movement.
5. The ship must accommodate limited mobility and disabled personnel.

5.1 Arrangements shall be designed for air transport of critical patients.

5.2 The ship will include access for delivery of daily cargo.

4. Assumptions

In order to complete this study, specific assumptions will be made in order to fill in areas where data is not available and to support reasonable conclusions for areas that this project will not have time to evaluate.

4.1 Initial Assumptions

Given that the vessel to be purchased previously met the class standards required to operate, it is assumed that the standards are still met or can be met with reasonable repair at the time of purchase. Therefore, it will be assumed that the requirements for seaworthiness and stability are within the requirements for cruise ships prior to conversion.

Similarly, it is assumed that all in-port support system infrastructures exist (shore power, potable water, sewage, garbage disposal) at the chosen port to support a vessel of this size. However, given that these systems will be required to operate at all times, increased costs and possible upgrades or alternative solutions to both the in-port and onboard infrastructure will need to be considered. Moreover, it is assumed that additional in-port medical services exist, such as medical waste disposal, medication delivery, and oxygen storage tanks.

The average service life of a well-built and maintained cruise ship is approximately 30 years. This will be the assumed projected service life of any vessel purchased for conversion. However, consideration will be given to extending the service life of the converted vessel given its significantly narrow operational profile.

4.2 Project Margins

The operational profile of the vessel is that it will be docked in-port at all times, except for circumstances that require sortie to ensure personnel and vessel safety or a disaster on the East Coast of the United States requiring surge medical support. Due to this operational profile, margins and allowances shall be reduced, if necessary, to accommodate better facility and treatment conditions and capacity. Additionally, with respect to future additions to accommodate more comprehensive medical treatment, or to convert this vessel to a fully fledged hospital, particular attention will be made towards ensuring adequate weight margin. The team recognized that specialized medical equipment like MRI machines, trauma surgical suites and ECMO infrastructure requires significant space, weight and power; given the potential to use this vessel to support future care, the team will consider how to incorporate these upgrades in a conversion. Similarly, a cruise ship would provide an optimal platform for mobile humanitarian and disaster relief (HADR). The team will ensure adequate margin to afford future modification or upgrade for this similar mission set.

5. Approach

Initial conversion steps include the evaluation and selection of an existing cruise ship, determination of a baseline displacement, arrangement and cost. A preliminary search of suitable options listed on an online marketplace indicated a variety of available sizes and cost options. Our team will choose a budget-conscious model that is most amenable to conversion with respect to the features and assumptions previously established in our initial unified design concept and as dictated by the sponsor's criteria. The level and extent of conversion will depend on many factors including maximum occupancy, facilities, displacement, and auxiliary system accommodations to allow sustained patient care and living onboard. Because this is a state-funded project, the overall cost of the project should be kept to a minimum and conform to sponsor guidance, and cost will be a more significantly limited factor than a warship conversion project. Additionally, the projected time to complete the project will also be a significant factor due to the urgency of this project.

Factors such as the number of patients and number of required treatment rooms will help the team down-select from the many cruise ship model options. Additionally, the evaluation process will consider factors such as size, condition, and adaptability for conversion. This down-selection process will continue across our most significant assumptions, as we effectively eliminate cruise ship models that will be unable to support these assumptions or design goals. At the end of this process, we anticipate being able to choose a single cruise ship model from which all subsequent modeling work and evaluation will be conducted.

Next, the project requires gathering facility requirements to meet mental health and medical treatment facility guidelines in Massachusetts. This criterion will guide the identification of the specific requirements for the facility and ship arrangements, as well as the required ship services.

The required arrangement data will be used to plan the comprehensive ship design conversion, utilizing 3D modeling techniques to illustrate the transformation of the ship's layout into a medical treatment environment. In addition, a strip-down analysis will be performed to assess the structural integrity of the ship, mechanical systems, and the feasibility of retrofitting for mental health services. The planned study extends to evaluate the ship's maintainability, considering aspects of upkeep, sustainability, and long-term operability as a mental health facility located pierside.

In addition to the updated ship design, the project will develop a robust operations and cost model that integrates the converted ship design with operational guidelines, staffing requirements, and protocols for providing mental health and rehabilitation services. The design will support state-mandated treatment programs and services to meet the diverse needs of patients. Financial viability and sustainability will be analyzed through a comprehensive cost-benefit analysis, encompassing initial investment, operational costs, and potential revenue streams. Current state expenditures to manage the opioid and mental health crisis in Boston will be used for comparison and to develop discussions of the potential cost benefits or losses for the Commonwealth of Massachusetts. [7] Furthermore, the project will ensure compliance with regulatory standards by engaging with stakeholders, communities, and local authorities to address legal, health, and safety regulations.

Finally, the project team will produce a comprehensive report and a final model, providing clear recommendations on the feasibility and sustainability of converting a cruise ship into a mental health and rehabilitation facility.

5.1 Tools to Support Project

The team anticipates using various 3D Computer-Aided Design (CAD) software such as Rhinoceros (Rhino) and Fusion360 to import the chosen model and model the preliminary cruise ship redesign. The major aspects of this process will include: (1) space and equipment rip-out, (2) living space modifications to transition from a ”hotel” to a ”living and treatment” model, (3) additional treatment space installation, and (4) support system installation and/or upgrades. Additionally, topside modifications will be made to support above requirements. Once the model reflects the converted design, a robust naval architecture analysis will be performed using the Orca 3D (Orca) Rhino plugin. Hydrostatics, weight, and stability will be calculated and compared with the original design to determine the change.

Additionally, the team will use primary source cost models from historical cruise ship and hospital ship availability's to estimate future capital requirements for this conversion.

5.2 Evaluation Criteria

The evaluation of this cruise ship conversion will be conducted based on a comprehensive set of criteria. A successful project will meet or exceed the sponsor's requirements, with the primary focus on assessing the cost-effectiveness and adherence to the rapid building schedule. This involves scrutinizing the affordability of purchasing and converting the cruise ship compared to conventional land-based facility construction, taking into account the project's financial feasibility within the state budget. Additionally, the evaluation will ensure the project aligns with the urgent timelines set by the sponsor to address the critical need for mental health facilities in Boston. Additionally, regulatory compliance with state and federal hospital and maritime codes will be a key consideration, along with affirming the seaworthiness, docking capabilities and relocation ability of the converted facility. Moreover, the team will propose and evaluate a robust maintenance plan to facilitate long-term operability of the facility with respect to budget and staffing limitations. The team will consider the constraints incumbent in staffing a maritime health facility - including additional training requirements of providers, and staff like firefighting and emergency egress. Infrastructure, staffing limitations, habitability, accessibility, serviceability, and the concept of operations will also be thoroughly examined to guarantee the success of the project. Regular assessments and feedback loops will be integrated to adapt to emerging challenges and refine the project approach as necessary.

5.3 Schedule & Deliverables

Date	Milestone	Deliverable	Team Lead
12/05/23	Initial Planning	Project Proposal	AP
12/16/23	Ship Information Collection Begin	List of Unknowns	RA
12/19/23	SME Interview Begins	Initial List of Contact Info	AP
12/20/23	Detailed Planning	Study Guide	EC
12/23/23	Design Space Exploration Begins	Individual Assignments	RA
12/31/23	Hull Decision	3D Model	AP
12/31/23	Design Exploration	Design Space Narrowed	RA
01/05/24	SME Interviews Complete	Past Practices/Lessons Learned	EC
01/06/24	Design Decision	Final Design	EC
01/06/24	Ship Information Collection Complete	Ship Maintenance/Operation	AP
01/08/24	Course Begins	Start Conversion	–
01/13/24	Rip Out Complete	Design Stripped Down	RA
01/10/24	Design Review	Chapters 1 & 2	EC
01/15/24	Design Review	Chapter 3	AP
01/19/24	Design Review	–	–
01/20/24	Install Complete	Modifications Completed	RA
01/24/24	Mid-Point	Sponsor Brief	EC
01/27/24	Initial Analysis Complete	Problems to Address	AP
01/31/24	Design Review	Chapters 4 & 5 & Presentation	EC
02/03/24	Final Analysis Complete	Improved Design	RA
02/05/24	Project Complete	Product and Analysis	EC
02/07/24	Peer Review	Final Presentation	AP
03/22/24	Report Complete	Final Report & Deliverables	RA
TBD	Final Brief	Sponsor Brief	EC

6. Study Resources

In order to effectively conduct this feasibility study, a multi-disciplined team will work together to benefit from differing expertise and experience to include organizations from both the Commonwealth of Massachusetts and the United States Navy. The project team, the sponsor, and additional organizations supporting this project are listed below.

6.1 Project Team

Panagiotis Rafail Athanasopoulos. LT Engineer Officer Panagiotis Rafail Athanasopoulos originates from Kiato, Greece, where he graduated with Honors from the Hellenic Naval Academy in 2014 with a specialization in Marine Engineering. Following his graduation, he embarked on a multifaceted career within the Hellenic Navy, serving across various vessels including Frigates, Gunboats, and LSTs, assuming pivotal roles as an Auxiliary Machinery Officer, Vice Chief Engineer, and Damage Control Officer. While actively serving, in 2017, he commenced his studies in Naval Architecture and Marine Engineering at the National Technical University of Athens, successfully completing his degree in 2022. Presently, he is sponsored by the Hellenic Navy for participation in the 2N Program (Naval Architecture and Marine Engineering) at MIT MECHE, concurrently pursuing a dual Master's degree in System Design Management at MIT Sloan School of Management. Beyond his professional pursuits, Rafail embodies a passion for exploration alongside his wife. They delight in traversing new destinations, immersing themselves in diverse cultures, savoring new cuisines, tuning into music, and delving into captivating books.

Emily Curran. LCDR Emily Curran is a 2010 graduate of Auburn University. Her operational assignments include Communications Officer, USS McCambell (DDG 85); Reactor Auxiliaries Division Officer and Deputy Reactor Training Assistant, PCU Gerald R. Ford (CVN 78); and Reactor Controls Assistant and Station Officer, PCU John F. Kennedy (CVN79). Her seagoing tour included multiple freedom-of-navigation tours, Operation Tomadachi, and a six-month docking selected restricted availability. During her CVN tours, she supported the nuclear test program to include executing the reactor safeguards examination and completing initial power range testing for a first-in-class propulsion plant. Ashore LCDR Curran completed her Engineering Duty Officer Qualification at Supervisor of Shipbuilding Newport News, VA serving as Assistant Project Officer on the CVN 78 Project Team supporting ship trials, delivery, at-sea testing, and the post-shakedown availability. She is Level II PQM certified and has earned her Acquisition Professional Membership. Currently, LCDR Curran is currently pursuing degrees in Mechanical Engineering and Naval Architecture & Marine Engineering at MIT. In her spare time, she spends her time exploring Boston and traveling with her husband and their three children.

Adam Pressel. LT Adam Pressel is a native of Philadelphia, Pennsylvania and graduated from the United States Naval Academy in 2018 with a Bachelor of Science in Computer Engineering. His first assignment was as the Weapons Officer on USS GABRIELLE GIFFORDS (LCS10), where he deployed to the Eastern Pacific Ocean. During his 2020 deployment, he led his ship's boarding team to interdict nine vessels, capturing $300M of suspected contraband and detaining 21 persons. Following deployment LT Pressel became the Assistant Operations Officer on USS JACKSON (LCS6). After transferring to the Engineering Duty Officer community, LT Pressel qualified as a Joint Diving Officer at the Naval Diving and Salvage Training Center. LT Pressel is currently pursuing dual degrees in Naval Engineering and Electrical Engineering and Computer Science at MIT; in his spare time, he is an avid cyclist, and dedicated mountaineer.

6.2 Project Sponsor

Senator Nick Collins serves as a member of the Massachusetts Senate, representing the First Suffolk District. Senator Collins serves as the Senate Chair of the Joint Committee on State Administration and Regulatory Oversight and the Senate Vice Chair of the Joint Committee on Community Development and Small Businesses. Additionally, he serves a member of the Senate Committee on Bills in the Third Reading, and a member on the Joint Committees on Bonding, Capital Expenditures and State Assets; Mental Health, Substance Use and Recovery; and Public Service. Elected into the Massachusetts House of Representatives in 2010, he served four terms in the House representing the 4th Suffolk District. Senator Collins is sponsoring this study as part of his commitment to explore novel approaches to support his district and combat the mental health and medical facility shortage it is currently facing.

6.3 Supporting Personnel & Organizations

In addition to the project sponsor and the team members, additional organizations are supporting this study. Listed below are the individuals assisting the project team.

Nancy Connolly, Psy.D. Assistant Commissioner of Forensic Mental Health Services for The Commonwealth of Massachusetts

Chase Geschwilm SEA05-D1 Project Naval Architect for T-AH(X), Naval Sea Systems Command

Greg Annisette SEA05-D1 Project Naval Architect for Hospital Ships, Naval Sea Systems Command

2023 CASH 2.704 Team Members LCDR Heather Willis, LCDR Jason Webb and LT Avi Chatterjee

Massachusetts Department of Mental Health

Massachusetts Department of Public Health

6.4 Additional Resources

An initial investigation into the possibility of converting a cruise ship to a mental health and drug rehabilitation facility has revealed previous studies in similar areas of work, but no full-scale projects have been completed. Previous studies relevant to this work have examined the feasibility of converting a cruise ship to a hospital ship and an affordable housing complex. Elements of each of these studies will be considered during this project.

The concept of providing Boston medical care via a converted ship is not an entirely novel idea. In the 1890s, Boston was home to the innovative Floating Children's Hospital, a ship dedicated to treating ill children, particularly from low-income families, and offering them the benefits of fresh sea air and isolation from city pollutants. [1] Although the ship facilities were reestablished on land after a ship fire in 1927, the hospital has remained an important facility serving Boston children more than 100 years later. This pioneering approach in the use of maritime resources for healthcare can inspire modern adaptations.

A Washington-based architecture firm proposed a cruise ship conversion to address the affordable housing crisis in Miami in 2022. [8] In their model, a portion of the ship would be retrofitted with a parking garage and an interior courtyard. Initial estimates placed the cost per unit at $1,250 per month. The 2023 CASH team built on this work to further explore the conversion of a cruise ship to an affordable housing complex. Their conversion design resulted in 246 housing units that could accommodate people. As a starting point, this shows great possibilities for the number of patients that could be treated in a similar conversion. This would have a significant impact on cities facing hospital and treatment room shortages. In Boston, specifically, the waiting list for inpatient rehabilitation care is more than 100 people long. The 2023 CASH team projected that the rent of its 246 housing units to range from $475 per month to $3000 per month based on the size and amenities of the unit. [3] These two cost options do not readily translate into the cost of providing a medical facility; however, their cost metrics will be used to investigate the theoretical operating costs of a ship-based facility.

In 2019, Oakland City Council President Rebecca Kaplan proposed the idea of converting a cruise ship to affordable housing to help solve its growing homeless population. [2] The study of a cruise ship to a mental health and rehabilitation facility will take this proposal one step further, as the ultimate goal to be solved in Boston is a combined problem of drug use and homelessness. The Port of Oakland ultimately proved to be an untenable docking option due to federal regulations. One of the main technical issues raised was addressing the permanent shore power and sewage connections necessary to maintain livable conditions onboard, as well as the required garbage service cadence, which would allow healthy, safe, and dignified living for the ship's residents. These same concerns apply to a mental health facility, as a primary concern of opposition to this study is the notion that this would not provide adequately humane and dignified care for a portion of the population in need. These issues, while originally raised for affordable housing, are equally relevant for a rehabilitation facility and present an outstanding area of concern our project will need to investigate further.

A 2021 team also investigated the conversion from a cruise ship to a hospital ship. Their study aimed to seek options for potential replacements of the United States Navy hospital ships, as both current ships are expected to be decommissioned in the mid-2030s. Their study estimated a conversion cost of 3 to 5 billion dollars and accounted for unique elements of a hospital such as the services required and the hospital bed and wheel chair accommodations for ship transit. [4] Using elements of this study combined with affordable housing studies will provide a reasonable starting point to analyze the feasibility of creating a mental health and rehabilitation facility on a cruise ship.

Furthermore, although the idea of a dedicated and afloat public mental health treatment facility is not a common idea, the concept of providing medical care in a crisis is not new. The United States Navy has used ships to provide emergency care when needed in times of natural disasters and resulting humanitarian crises, such as in New Orleans after Hurricane Katrina and in Haiti after a devastating earthquake. These examples show the potential benefits of an afloat medical treatment facility of any kind. They provide a unique medical surge capacity that can be relocated as needed. Each of the above instances requires further research to support the validity of a conversion of a cruise ship to a mental health and rehabilitation facility. Additional research and collaboration with experts in marine engineering, healthcare, and urban planning are necessary to bring this visionary concept to fruition. This will provide a starting point for additional in-depth research to support this project.

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B. List of Acronyms

ABS American Bureau of Shipping

ADA The Americans with Disabilities Act

BSAS Bureau of Substance Addiction Services

CAD Computer-Aided Design

CASH Cruise Ship Conversion into Affordable Housing

DMH Massachusetts Department of Mental Health

DOT Department of Transportation

DPH Massachusetts Department of Public Health

FGI The Facility Guidelines Institute

MIT Massachusetts Institute of Technology

Massport Massachusetts Port Authority

NAVSEA Naval Sea Systems Command

NOAA National Oceanic and Atmospheric Administration

ORCA Orca 3D Rhinoceros Plug-in

Rhino Rhinoceros 3D

USN United States Navy

USNS United States Naval Ship

USCG United States Coast Guard

VCG Vertical Center of Gravity

2N Naval Construction and Engineering

C. Design Parameters

Capability	Characteristic	Threshold	Objective	Reference
Marine Performance	Draft	6.7m	6.5m	NOAA Chart: 13272
	Seaworthiness (Roll Period)	0.05-0.15	0.1	MIT 2N
	GM	11.875m	10.7m	
Hotel Services	Patient Laundry Services	Organic to Ship	Organic to Ship	FGI
	Housekeeping Storage	Organic to Ship	Organic to Ship	FGI
	Patient Storage	10 sqft/Patient	Organic to Ship	FGI
	Patient Dining Area	20sqft/Patient	20sqft/Patient	FGI
Administrative Services	Documentation/File Room	1 per facility		FGI
	Staff Support Spaces	1 per 25 Patients	1 per 20 Patients	FGI
	Staff Office Spaces	1 per 25 Patients	1 per 20 Patients	FGI
	On Call Rooms	1 per 35 Patients	1 per 30 Patients	FGI
Medical Facilities	Stretcher-capable elevator	1	4	FGI
	Triage/Intake Assessment	1 per facility	1 per facility	CMR 104
	Pharmacy	1 per facility	1 per facility	FGI
	Clinical Laboratory	1 per facility	1 per facility	FGI
	Nursing Stations	1 per unit	2 per unit	FGI
	Single Patient Rooms	100 sqft/Patient	100 sqft/Patient	FGI
	Multi Patient Rooms	80 sqft/Patient	80 sqft/Patient	FGI
	Group Treatment Rooms	1 per unit	225 sqft	FGI
	Exam Rooms	1 per unit	Not Specified	FGI
	Indoor Social Space	25 sqft/patient	120 sqft total min	FGI
	Outdoor Social Space	Not Specified	Not Specified	FGI
	Seclusion Rooms	1 per 24 patients	80 sqft minimum	FGI
	Restraint Rooms	1 per unit	80 sqft minimum	FGI
	Visitor Rooms	1 per unit	100 sqft minimum	FGI
	Secure Medication Coverage	In Accordance with DEA Guidance		DEA
Staffing Ratios	Recovery Specailists	1 per 16 Patients		CMR 104
	Care Coordinators	1 per 16 Patients		CMR 104
	Counselors	1 per 8 Patients		CMR 104
	Nursing Coverage	facility dependant		CMR 104

D. Guidelines for Design and Construction of Hospitals

2022 FGI Guidelines for Design and Construction of Hospitals					
		FGI Section	Specifics	Model Requirement	Future Consideration
General Hospital Requirements					
Parking	1 per staff normally present during one weekday shift plus one space for every 5 beds	2.1-1.3.2	Parking= # staff/shift + 1/5# patient beds+outpatient needs		X
	additional required if outpatient services				X
Specific Requirements for Behavioral and Mental Health Hospitals					
General Considerations	Consideration for harm prevention in all aspects of design/architecture	2.5.1.5.1.2			X
	Means for visual observation (electronic surveillance)	2.5.1.5.1.3			X
	All shared spaces must meet more restrictive requirements (mental health)	2.5-1.4		X	
Security	Level of security appropriate to type of patients and service	2.5-1.2-4.6			X
External Security	Contain patients within care unit or treatment areas outside unit; staff may escort between	2.5-1.5.2.2		X	
	Prevent patients leaving		Secure perimeter with controlled access/exit and safe	X	
	Prevent contraband smuggling in/out			X	
	Control visitor access			X	
	All openings (doors, windows, gates) controlled via a lock when required by safety assessment				X
	Use of security cameras permitted				X
Internal Security	Entrances secure	2.5-2.2.1.1		X	
Accessibilty	Access control for all entrances	2.5-2.2.1.2	Secure perimeter with controlled access/exit and safe	X	
	Primary access through a sally port (two locked doors in series)		Main entrance/exit with two doors in series	X	
Doors	min 32 in width	2.1-7.2.2.3	Minimum 32in door width	X	
Windows	tempered glass; security locks; resist 2000ft-lb loads applied from inside	2.5-7.2.2.5			X
	total visisble area should be at least 8% of the total floor area of common spaces combined		Window area = 8% floor area	X	X
General Facilities					
Ceilings	all systems contained within the ceiling for safety	2.1-7.2.3.3			X
Electrical	NFPA 99, 101, 110 - have essectial electrical systems IAW those standards	2.1-8.3			X
	Receptacles in patient rooms must be tamper resistant and protected by ground-fault circuit breaker				X
Unit call system	must have one	2.5-8.5.1.2			X
Elevators	must have one if services on different floors	2.5-8.7.2.2	At least one between floors where services are located	X	
Fire suppression system	must have one if services on different floors	2.5-8.6.1			X
Patient Facilities					
Toilet Rooms	Each patient room has a directly accessible toilet room *can be omitted in specific rooms where use of corridor access is part of written plan	2.5-2.2.2.6	One bathroom per patient room to include toilet and shower/bathtub/sink	X	
	1 per no more than 2 patient rooms, no more than 4 patients			X	
	Have toilet and a handwashing station			X	
	Doors with keypad lock from outside				X
	Swing outwards if swinging				X
Bathing	No shower curtains in shower	A2.5-2.2.2.6 (6)(b)			X
	Bathtub or shower for every six beds not otherwise served by bathing facilities at patient bedrooms	2.5-2.2.2.7	NA if condition above is met	X	
Bedrooms	Storage for 7 days' worth of clothes per patient	2.5-2.2.2.8			X
	100 sq ft for single patient room; 80 sq ft per patient for multiple patients	2.5-2.2.2.2	100 for single/160 for double room	X	
	Shall have a window	2.5-7.2.2.5		X	
Treatment Facilities					
Airborne infection isolation (AII) room	Need determined by infection control risk assessment (ICRA) - assume not required	2.1-2.4.2			X
Seclusion Room	Require 1/24 patient beds; designed for a single patient. Have access to toilet.	2.1-2.4.3	Must have 1 seclusion room per 24 patient beds; min 60 sq ft. Wall length 7-12 ft	X	
Restraint Room	if restraints, min 80 sq ft			X	
Quiet Room	Minimum 80 sqft; can be visitor room if not being used as consultation room	2.5-2.2.4.4	80 sq ft; safe and private room	X	
Consultation Room	1 per every 12 beds; 100 sqft; acoustic and visual privacy; may use visitor room	2.5-2.2.8.16	1/12 patient beds; 100 sqft	X	
Group Therapy room	225 sqft; need 2 doors	2.5-2.2.8.18	225 sq ft; 2 doors	X	
Exam Room	may serve more than one unit; can be on a different floor	2.1-3.2.1		X	
Laboratory Services		2.1-4.1	include at least one in facility	X	
Pharmacy Services		2.1-4.2	include at lease on in facility	X	
Staff Facilities					
Nurse Station	all units must have one of each; may arrange to support more than one unit	2.5-2.2.8.2		X	
Offices for staff				X	
Staff support Area				X	
Staff on call room				X	
Support Areas	all units must have one of each; may arrange to support more than one unit	2.5-2.2.8.1			
Visitor room	100 sqft	2.5-2.2.10.1	100 sqft (can be consultation room)	X	
Documentation Area	charting area with acoustic and patient file privacy			X	
Social Spaces	at least 2 separate spaces, one noisy and one quiet; combined area 25 sqft per patient, at least 120 sqft total		2 spaces; 120 sq ft total; 25 sqft/patient	X	

Dining Area	20 sqft per patient; may use social space wiht extra 15sqft per patient added		20 sqft/patient + 15 sqft/patient if also social space	X	
Patient Laundry	require washer and dryer	2.5-2.2.10.3		X	
Handwashing station		2.5-2.2.8.7		X	
Medication safety zone		2.5-2.2.8.8		X	
Nourishment area	combo or nourishment station, kitchentte, kitchen with handwashing, secured storage, refrigerator, facilities fo rmeal prep	2.5-2.2.8.9		X	
Clean workroom		2.5-2.2.8.11		X	
Equipment and supply storage	must not present a patient risk; admin storage, medical storage, cleaning and janitorial storage	2.6-2.2.8.13		X	
Conference Room		2.5-2.2.8.17		X	
Patient storage	store patients' effects that may be harmful; can combine with clean workroom	2.5-2.2.10.4		X	
Visitor storage room	secure space for visitor effects	2.5-2.2.10.5		X	
Food and Nutrition Services		2.1-4.3		X	
Sterile Processing		2.1-5.1		X	
Linen Services		2.1-5.2		X	
General Storage	20 sqft per inpatient bed	2.1-5.3.3.2	may be consolidated in another building on campus	X	
Waste Management		2.1-5.4		X	
Environmental Services		2.1-5.5	Housecleaning space/storage	X	
Engineering and Maintenance Services		2.1-5.6		X	
Reception area	desk or kiosk visible from entrance	2.5-6.2.2		X	
Waiting Area	within sight of reception desk or security via cameras	2.5-6.2.3		X	
Outdoor spaces	Not always required but if required for care plan must meet requirements	2.5-2.2.10.6			
Walls/Fences	fence/wall that cannot be climbed; minimum height of 14ft above outdoor area elevation; angled inward where height exceeds 10 feet but less than 14 feet			X	
Gates	Swing outward				X
Security cameras					X
Elevated courtyards	no skylights or unprotected walkways or ledges			X	
Duress alarm	have one				X
Forensic Behavioral and Mental Health Patient Care Unit					
Unit entrance	sally ports at unit entrances	2.5-2.6.1.2		X	
Specific use spaces	additional treatment areas, police and courtroom space, security considerations	2.5-2.6.2	Include a room that coule be for courtroom use	X	

E. Hull Selection Information

Name/ Type	Company	Gross Tonnage [MT]	LOA [m]	Beam [m]	Draft [m]	Age	Major Upgrade	Passengers	Cabins	Crew	Pass/ Crew ratio	# Decks	Est. Purchase Cost [$M]	Type
Cruise Roma	Grimaldi Lines	63000	254	31		2008		3500	499					Ro-pax ferry
Cruise Sardegna	Grimaldi Lines	55000	225	31		2009		2850	413					Ro-pax ferry
Cruise Olympia	Grimaldi Lines	55000	225	31		2009		2850	413					Ro-pax ferry
Sovereign-class cruise ship by Chantiers De L'atlantique	YACHTWORLD	73941	268.22	32.31	8.53	1992	2016	2767	1175	912	3.0	13	$33.00	Cruise Ship
RCCL Sovereign by ATLANTIQUE CHS FLAG: BAHAMAS	GRS FERRY + CRUISE	74077	268.32	32.2	7.88	1992		2744	1178			6	$45.00	Cruise ship
Cruise Bonaria	Grimaldi Lines	37482	214	26		2000		2500	231					Ro-pax ferry
HSF Cruise Bonaria	Grimaldi Lines	37551	214	26.4	7.1	2000		2500	231					Ro-pax ferry
VISION CLASS CRUISE SHIP I RCCL FLAG: BAHAMAS	GRS FERRY + CRUISE	73817	279	36 (MAX)	7.82	1996	2017	2400	975			12	$110.00	Cruise ship
El. Venizelos	ANEK Lines	38261	175.5	28.5	6.4	1992		2300	510					Ro-pax ferry
Sun-class Cruise Ship by Fincantieri	GRS FERRY + CRUISE	77499	261.3	32.25	8.1	2000	2017	2172	1008	889	2.4	15	$79.00	Cruise ship
MEYER JL GMBH & CO - GEU FLAG: BERMUDA	GRS FERRY + CRUISE	69842	260	32.2	7.9	1995		1822	911				$45.00	Ro-pax ferry
Cruise Ausonia	Grimaldi Lines	30902	200	25		2002		1821	198					Ro-pax ferry
MS Kydon Palace	Minoan Lines	37482	214	26.4	7.3	2000		1718	231					Ro-pax ferry
1,664 Passenger Cruise Ship by Wartsila Finland	GRS FERRY + CRUISE	37548	214.88	28.48	7	1982	2015	1664	724	540	3.1	10	$24.00	Cruise ship
S Class by Finciantieri	GRS FERRY + CRUISE	57092	219	31	7.3	1996	2016	1650	675			13	$39.00	Cruise ship
S Class Cruise Ship by Fincantieri	YACHTWORLD	57092	219	31	7.3	1996	2020	1650	675	578	2.9	13	$39.00	Cruise ship
Costa neoRiviera	Costa Crociere	48200	215	32	7.5	1999		1600	624	475	3.4	12		Cruise ship
Aker Cruise Ship	GRS FERRY + CRUISE	40000	202.85	35.5	6.3	2002	2017	1582	633	426	3.7	10	$45.00	Cruise ship
Ice Class D Passenger Cruise Ship by Fincantieri	GRS FERRY + CRUISE	55451	219	30.8	7.5	1993		1560	629			14	$67.00	Cruise ship
Volendam	Holland America Line	60906	238	32	7.8	1999		1440	720	561	2.6	10		Cruise ship
WARTSILA AB- TURKU FLAG: MALTA	GRS FERRY + CRUISE	25611	158.88	25.18	5.91	1980		1409	476			9	$15.00	Ro-pax ferry
Ice Class 1,400 PAX by STX	GRS FERRY + CRUISE	25611	162	25.2	6	1992		1400	480			10	$15.00	Cruise ship
Zeus Palace	Grimaldi Lines	31730	211	25		2001		1380	202					Ro-pax ferry
Ms Amsterdam	Holland America Line	61000	238	32	7.8	2000		1380	690	615	2.2	12		Cruise ship
Rotterdam	Holland America Line	59652	237	32	7.8	1997		1320	660	593	2.2	12		Cruise ship
Costa Classica	Costa Crociere	52950	220	31	7.6	1992		1308	654	650	2.0	10		Cruise ship
Maasdam	Holland America Line	55451	219	30	7.5	1993		1266	632	557	2.3	10		Cruise ship
Statendam	Holland America Line	55451	220	30	7.5	1993		1266	633	557	2.3	10		Cruise ship
Veendam	Holland America Line	55451	220	30	7.5	1996		1266	633	561	2.3	10		Cruise ship
Thomson Spirit	Thomson Cruises	33930	215	27	7.5	1983	2023	1255	627	520	2.4	10		Cruise ship
Marella Celebration	Thomson Cruises	33930	214.6	27.26	7.7	2005		1254	627	520	2.4	10		Cruise ship
Marina	Oceania Cruises	66084	239.25	32	7.32	2011	2023	1238	629	776	1.6	16		Cruise ship
Riviera	Oceania Cruises	66084	239.25	32	7.32	2012	2022	1238	629	776	1.6	16		Cruise ship
Vista	Oceania Cruises	67000	241	32		2023		1200	629	800	1.5	16		Cruise ship
Celestyal Journey	Celestyal Cruises	55451	220	30	7.5	1994		1115	633	557	2.0	10		Cruise ship
Ryndam	Holland America Line	55451	220	30	7.5	1994		1114	633	557	2.0	10		Cruise ship
Crystal Serenity	Crystal Cruises	68870	250	34	7.6	2003		1100	550	650	1.7	9		Cruise ship
Crystal Symphony	Crystal Cruises	51044	237.1	30.2	7.6	1995		1000	480	545	1.8	8		Cruise ship
1993 Custom Cruise Ship by Union Navale de Levante	YACHTWORLD	24344	195.82	22.52	5.41	1993	2019	970	485	371	2.6	8	$22.00	Cruise ship
Celestyal Crystal	Celestyal Cruises	25611	162	25.6	6.1			964	529					Cruise ship
BLOHM + VOSS GMBH 1 FLAG: LIBERIA	GRS FERRY + CRUISE	24427	180.45	25.5	7.25	2000		922	418				$40.00	Ro-pax ferry
BLOHM + VOSS GMBH 2 FLAG: LIBERIA	GRS FERRY + CRUISE	24782	180.45	25.5	7.4	2001		836	418				$59.00	Ro-pax ferry
Blohm & Voss Cruise Ship	GRS FERRY + CRUISE	24427	181	25.6		2000	2014	832	416	353	2.4	7	$46.00	Cruise ship
Igoumenitsa	Grimaldi Lines	29841	188	29		1999		800	191					Ro-pax ferry
Prinsendam	Holland America Line	37845	205	28	7.2	2002		790	395	443	1.8	9		Cruise ship
MS Asterion II	Superfast Ferries	31804	192	27	6.6	1991		720	150					Ro-pax ferry
Pacific Princess	Princess Cruises	30277	181	25.5	6	2002		688	344	373	1.8	9		Cruise ship
Ocean Princess	Princess Cruises	30277	181	25.5	6	2002		688	344	373	1.8	9		Cruise ship
Insignia	Oceania Cruises	30277	180.95	25.45	5.95	1999	2018	656	333	409	1.6	11		Cruise ship
Nautica	Oceania Cruises	30277	180.95	25.45	5.95	1999	2022	656	333	409	1.6	11		Cruise ship
Regatta	Oceania Cruises	30277	180.97	25.45	5.95	2019		656	333	410	1.6	11		Cruise ship
Seabourn Encore	Seabourn Cruise Line	40350	198.1	25.6	6.9	2017		625	302	450	1.4	10		Cruise ship
SHIMONOSEKI		7,003	136.6	21	12.3	1994	2010	616		30	20.5			Ro-pax ferry
		10700	183	28.7	7.4	1994		558	307			4	$27.00	Ro-pax ferry
Seabourn Odyssey	Seabourn Cruise Line	32000	198	25.6	6.5	2009		450	225	330	1.4	10		Cruise ship
OKEAN SSZ FLAG: MALTA	GRS FERRY + CRUISE	12892	133.55	20	5.827	1996		428	175			4	$20.00	Ro-pax ferry
Boutique Cruise Ship	GRS FERRY + CRUISE	12892	133	20.3	5.8	1989	2017	350	190	160		6	$29.00	Cruise ship

F. Boston Harbor Information

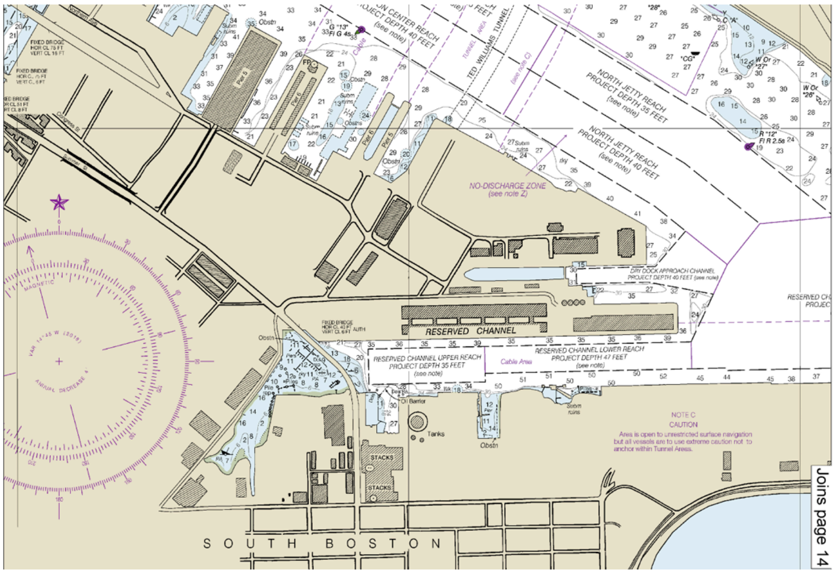
Boston Harbor Information

Boston Port lies in Boston Harbour and is the biggest port in Massachusetts. It is also an important facility on the east coast of the U.S. It has been historically at the forefront of the growth of Boston City and was earlier situated in what is today the city's downtown area, the Long Wharf. It is endowed with 8 berths for sea-going ships and 6 riverside berths. It handles steel, bulk, palletised and general cargo, paper, forest products, containers, etc. Around 600 ships and 700,100 tonnes of cargo are handled at the port annually. Before America was colonized, the region was a trading post for Native Americans. Soon, the Boston settlement was established by John Winthrop in the 1600s, and a shipbuilding industry began to take shape. In that period, commodities of trade were lumber, constructed vessels, salted fish and rum. The Port of Boston is also home to the Flynn Cruiseport, a cruise terminal operating since 1986, running from April to November with cruise ships destined for Bermuda, Panama, San Diego, Europe and Canada. The Conley Terminal handles containerised cargo at the Boston Port. It has been operating since the Second World War and was known as the Castle Island Terminal during that time.

The most effective space to moor a cruise ship for a long term period is the North Jetty Pier. The most important factor is that the ship is held as close to the city of Boston as possible. Cruise ships visiting Boston have two prominent alternative mooring locations, providing flexibility for maritime activities. The Black Falcon Cruise Terminal, located in the dynamic South Boston Waterfront area, stands as a primary docking facility equipped to handle cruise ship arrivals and departures. Additionally, the Flynn Cruiseport Boston, also situated in the same waterfront region, serves as another excellent alternative for cruise ship mooring. Both terminals, part of the Port of Boston, offer modern amenities and services to ensure a smooth experience for both passengers and cruise lines. As docking arrangements may be subject to change, it is advisable to confirm specific details with the port authority for the most up-to-date information.

Cruise terminals in Boston offer essential utility services to accommodate the needs of visiting vessels. These services include access to freshwater, electricity, and waste disposal facilities. Vessels can connect to the water supply for their freshwater needs, typically providing a specified cubic meter per hour capacity to ensure an adequate and reliable water source during their stay. Electricity services are available to provide power to ships while they are docked, with a designated capacity measured in kilowatts (kW). Additionally, waste disposal programs are in place to manage and responsibly dispose of the ship-generated waste, aligning with environmental regulations and sustainability practices. All of these services are available for use, including in our scenario where the mental health hospital vessel is moored at the North Jetty Pier in Boston.

Navigating the ship into the port of Boston involves adherence to specific regulations and considerations. The channel width in Boston's port varies, and it is crucial to ensure that the cruise ship's draft requirements align with the available depths in the navigation channels. Prior to mooring, ships must follow established procedures, including communication with the port authorities and adherence to any designated entry points. It's essential to be aware of and comply with the port's regulations regarding safe navigation and environmental practices. Detailed information on channel widths, draft requirements, and specific docking procedures should be obtained from the Port of Boston or terminal operators for a seamless and compliant arrival. However, provided below is an image sourced from NOAA's Booklet Chart for the Port of Boston, indicating that the Crystal can enter Boston Harbor and moor at the North Jetty pier.



Boston Port has the following specifications:

Entrance Restrictions:

- Mean Tide: 10 feet
- Tide: No
- Overhead Limit: Yes
- Swell: No

Water Depth:

- Channel: 36 - 40 feet (11 - 12.2 meters)
- Cargo Pier: 41 - 45 feet (12.5 - 13.7 meters)
- Mean Tide: 10 feet
- Anchorage: 41 - 45 feet (12.5 - 13.7 meters)
- Oil Terminal: 36 - 40 feet (11 - 12.2 meters)

Harbor Characteristics:

- Harbor size: Large
- Shelter: Excellent
- Max Vessel Size: Over 500 feet in length
- Harbor Type: Coastal Natural
- Turning Area: Yes

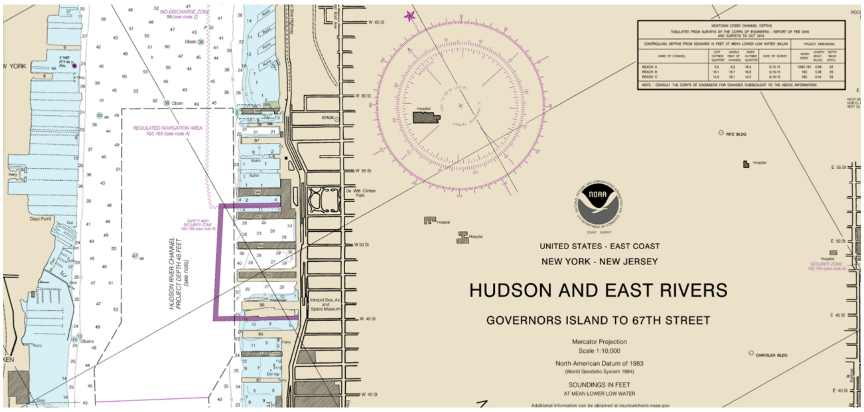
Reference: https://www.searates.com/port/boston_us

G. East Coast Harbor Information

Major US East Coast Port Harbor Information

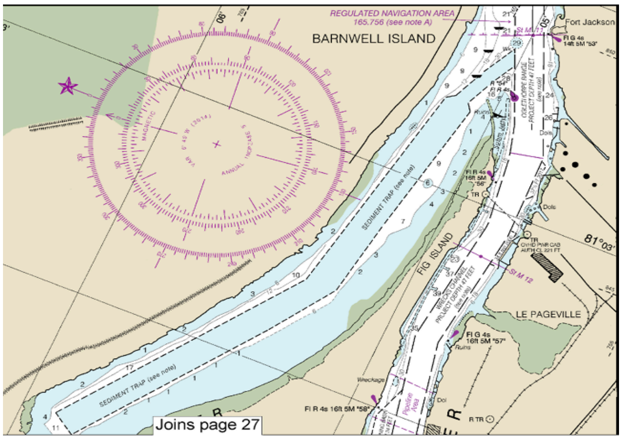
1) Port of New York & New Jersey, NY:

The Port of New York and New Jersey is nestled between Brooklyn, New Jersey and Manhattan. A principal port on the east coast of the U.S, it handles an array of cargo and all types of ships, ranging from container carriers, RORO, bulk carriers, tankers etc. Per estimates, this port accounts for more than one-third of all North Atlantic trade. In order to tackle rising competition from the other East Coast Ports and handle bigger ships from the recently expanded Panama Canal, the Port of New York and New Jersey deepened its harbor to about 50 feet. In New York City and New Jersey there are a lot of piers for a small Cruise Ship to be docked either near the NYC or further away (like the Long Island area).



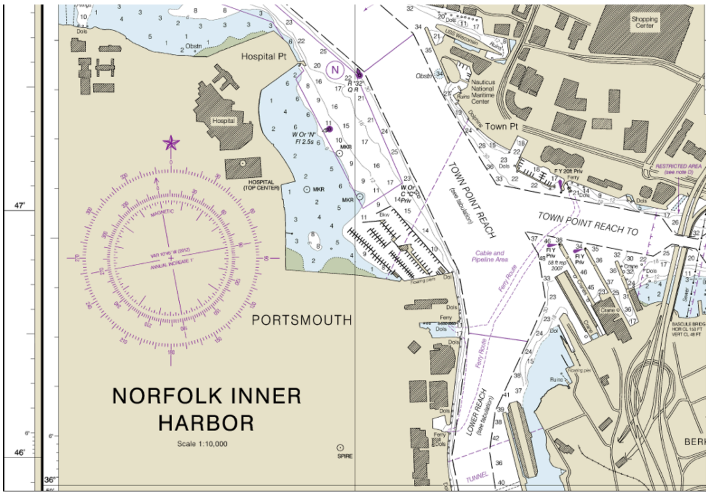
2) Port of Savannah, GA:

Savannah Port is home to the biggest single-terminal container area, one of its kind in North America. It includes two deepwater terminals called the Garden City Terminal and the Ocean Terminal. The natural landlocked harbor 15 nautical miles up the Savannah River from the Atlantic Ocean is operated by the Georgia Ports Authority. Apart from these 2 terminals, there are many private berth operators and a Free Trade Zone.In Savannah a possible pier for a small Cruise ship to be docked is the Fig Island pier as you can see below.



3) Port of Virginia, VA:

The Port of Virginia has 6 terminals covering 1864 acres. The port's harbor is the deepest such facility on the U.S East Coast, sheltering the largest naval base in the world. The port has 50-foot channels, inbound and outbound, making it the only port on the east coast of the U.S with authorisation from Congress to dredge to 55 feet, going ahead with Norfolk Harbor Dredging Project to attain a depth of 55 ft, enabling it to retain the deepest channel on the east coast. The studied Cruise ship is able to be docked in many spaces in the Norfolk harbor.

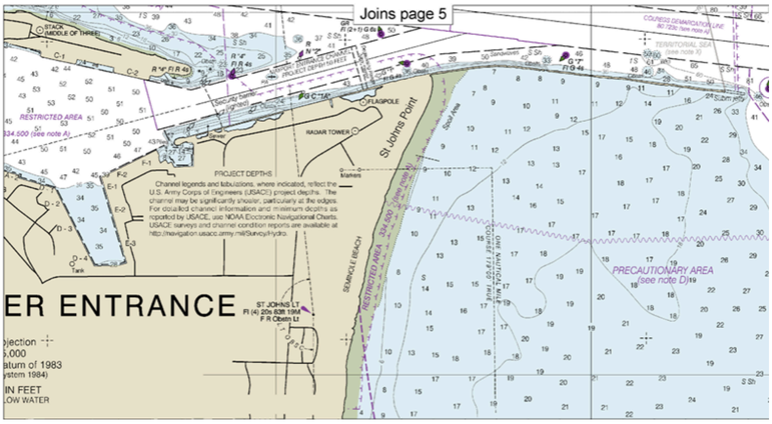


4) Port of Charleston, SC

Charleston Port lies in South Carolina in the southeastern US, spanning municipalities of Charleston, Mount Pleasant and North Charleston. In Charleston there are two major terminals. The Union Pier Terminal handles forest products, metals, breakbulk and cruise ship operations. The Columbus Street Terminal handles project cargo, RORO and breakbulk.
The Union Pier Terminal can easily handle a cruise ship the size of which we study.

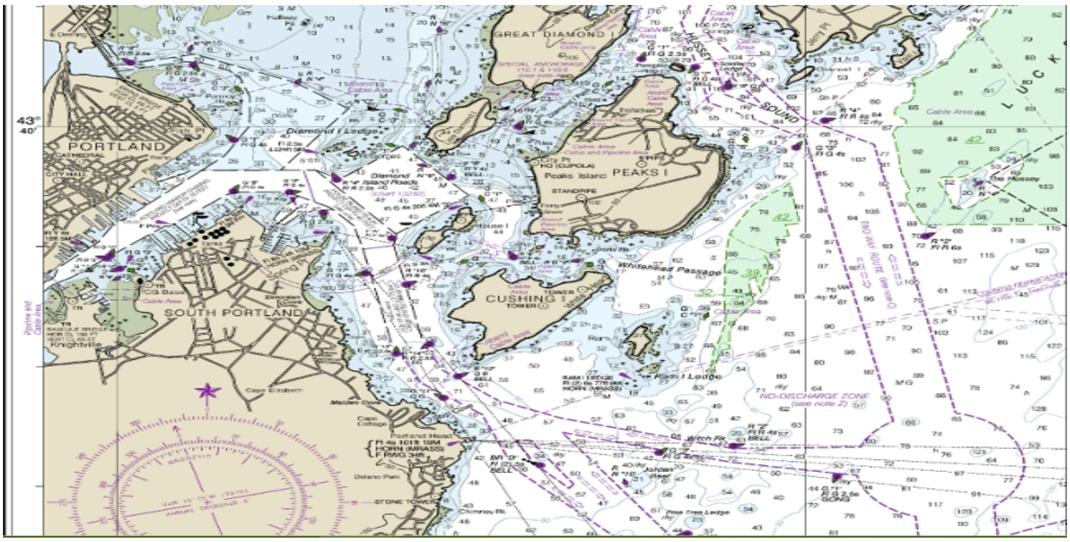
5) Port of Jacksonville, FL

Jacksonville Port is located in northeast Florida on the St.John's River, some 24 nautical miles from the Atlantic Ocean. It has 4 facilities along the river banks. The Blount Island Marine Terminal and the Ed Austin Terminal handle container cargo. The other two include the Talleyrand Docks and Terminals and the Commodore Point Terminal. The port also handles vehicles, bulk, RORO and general cargo.



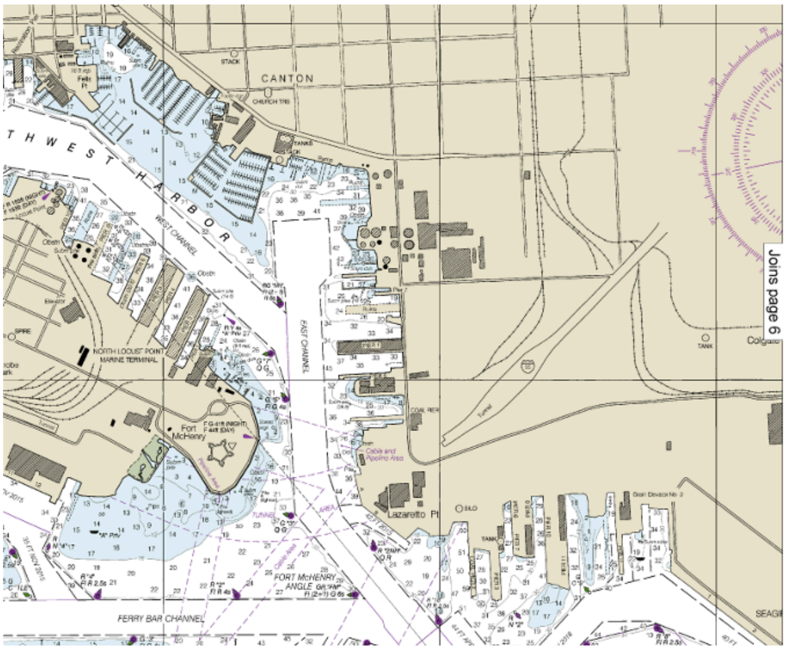
6) Port of Portland, ME

Located in Portland, Maine, this is the second biggest seaport in New England in terms of tonnage and also one of the biggest oil ports on the East Coast. This well-protected port remains open all year and has ample space for massive ships. Portland has 9 terminals and 2 passenger facilities, the Casco Bay Ferry Terminal and the Ocean Gateway International Marine Passenger Terminal. It is also a popular cruise destination, and 100 cruise ships docked in Portland in 2019, making it Maine's second-biggest cruise ship Port.



7) Port of Baltimore, MD

Baltimore Port lies close to the Chesapeake Bay in Maryland, the eastern part of the U.S, on the Patapsco River, making it one of the busiest ports and industrial centres in the region. The Port of Maryland has the deepest harbour in Chesapeake Bay. It is also closer to the Midwest than any other East Coast Port and also just an overnight drive of one-third of the country's population.



H. Initial Ship Data

Initial Righting Arm Curve

Default Project
Upright Equilibrium Stability Analysis with Righting Arm (with fixed load or flotation plane)
Default Company
1/27/2024 1:17:36 PM Orca3D Version 3.0.13 WIP (1/8/2024)
C:\Users\2N\Documents\2N Students\Pressel\2704\Orca\Celestyal_Crystal.3dm

Hydrostatics Summary

Load Condition Input Parameters

Condition	Weight/Sinkage	LCG/Trim	TCG/Heel	VCG (m)
Fixed-plane Condition	6.100 m	0.000 deg	0.000 deg	10.700

Resulting Model Attitude and Hydrostatic Properties

Condition	Sinkage (m)	Trim (deg)	Heel (deg)	Ax (m^2)
Fixed-plane Condition	6.100	0.000	0.000	0.000

Condition	Displacement (kgf)	LCB (m)	TCB (m)	VCB (m)	Wet Area (m^2)
Fixed-plane Condition	22812644.564	99.076	0.000	3.231	5725.957

Condition	Awp (m^2)	LCF (m)	TCF (m)	VCF (m)
Fixed-plane Condition	4046.084	103.658	0.000	6.100

Condition	BMt (m)	BMl (m)	GM_T (m)	GM_L (m)
Fixed-plane Condition	9.965	369.475	2.496	362.006

Condition	Cb	Cp	Cwp	Cx	Cws	Cvp
Fixed-plane Condition	0.839	0.000	0.931	0.000	2.970	0.901

Notes

1. Locations such as the center of buoyancy and center of flotation are measured from the origin in the Rhinoceros world coordinate system.
2. The orientation of the model for an Orca3D hydrostatics solution is defined in terms of "sinkage," "trim," and "heel." The sinkage value represents the depth of the body origin (i.e., the Rhino world origin) below the resultant flotation plane and is sometimes referred to as "origin depth." Heel and trim represent angular rotations about the Rhino longitudinal and transverse axes, respectively, and are taken in that order. For a more detailed description of these terms see the Orca3D documentation.
3. Hull form coefficients are non-dimensionalized by the waterline length.
4. Calculation of Cp and Cx use Orca3D sections to determine Ax. If no Orca3D sections are defined, these values will be reported as zero.
5. For conditions that are part of a stability criteria evaluation, where the associated heeling arm changes the mass properties (such as icing), the results include the effects of the mass properties change.
6. For conditions that include damaged compartments, the wetted surface area includes the wet area of the damaged spaces, and the waterplane area (and inertia) of damaged spaces are excluded.

Initial Righting Arm Report

Default Project
Upright Equilibrium Stability Analysis with Righting Arm (with fixed load or flotation plane)
Default Company
1/27/2024 1:17:36 PM Orca3D Version 3.0.13 WIP (1/8/2024)
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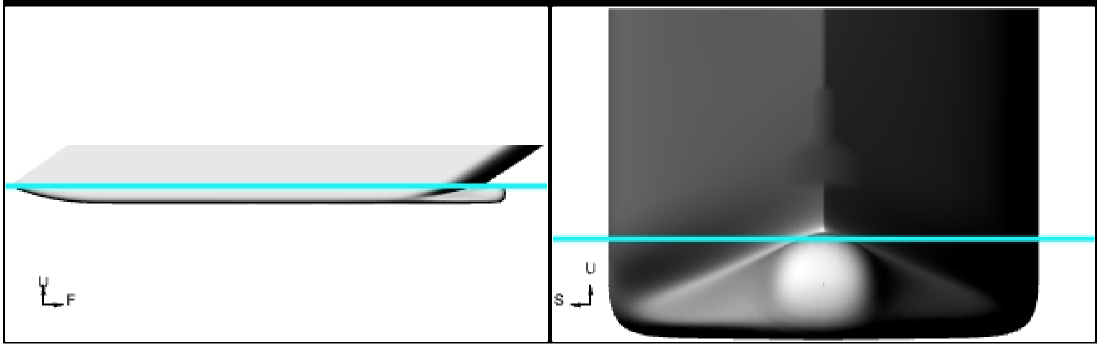
Fixed-plane Condition



Mass Properties			
Weight	22812644.564	kgf	(Computed from input sinkage)
LCG	99.076	m	(Computed from input trim)
TCG	0.000	m	(Computed from input heel)
VCG	10.700	m	(Specified as input)

Resultant Model Orientation					
Sinkage	6.100	m	T_{FP}	6.100	m
Trim	0.000	deg	T_{AP}	6.100	m
Heel	0.000	deg	T_M	6.100	m

Overall Dimensions				
Length Overall, Loa	182.137	m	Loa / Boa	7.005
Beam Overall, Boa	26.000	m	Boa / D	1.300
Depth Overall, D	20.000	m	D / Loa	0.110

Waterline Dimensions				
Waterline Length, Lwl	167.102	m	Lwl / Bwl	6.427
Waterline Beam Bwl	26.000	m	Bwl / T	4.262
Navigational Draft, T	6.100	m	D / T	3.279

Initial Righting Arm Report

Default Project
Upright Equilibrium Stability Analysis with Righting Arm (with fixed load or flotation plane)
Default Company
1/27/2024 1:17:36 PM Orca3D Version 3.0.13 WIP (1/8/2024)
C:\Users\2N\Documents\2N Students\Pressel\2704\Orca\Celestyal_Crystal.3dm

Fixed-plane Condition

Volumetric Parameters

Displacement Weight	22812644.564	kgf	Displ-Length Ratio	136.258
Volume	22236.714	m^3		
LCB	99.076	m	FB / Lwl	0.505
TCB	0.000	m	TCB / Bwl	0.000
VCB	3.231	m		
Wetted Surface Area	5725.957	m^2		
Moment To Trim	4846530.627	N-m/cm		

Waterplane Parameters

Waterplane Area, Awp	4046.084	m^2		
LCF	103.658	m	FF / Lwl	0.532
TCF	0.000	m	TCF / Lwl	0.000
Weight To Immerse	41508.781	kgf/cm		
I (transverse)	221588.669	m^4		
I (longitudinal)	8215916.832	m^4		

Sectional Parameters

Ax	0.000	m^2	Ax Location / Lwl	0.000
Ax Location	0.000	m		

Hull Form Coefficients

Cb	0.839	Cx	0.000
Cp	0.000	Cwp	0.931
Cvp	0.901	Cws	2.970

Static Stability Parameters

Mt	7.096	m	Ml	366.606	m
BMt	9.965	m	BMl	369.475	m
$GM_{Tuncorrected}$	2.496	m	$GM_{Luncorrected}$	362.006	m
Trans FS Correction	0.000	m	Longl FS Correction	0.000	m
$GM_{Tcorrected}$	2.496	m	$GM_{Lcorrected}$	362.006	m

Initial Righting Arm Report

Default Project
Upright Equilibrium Stability Analysis with Righting Arm (with fixed load or flotation plane)
Default Company
1/27/2024 1:17:36 PM   Orca3D Version 3.0.13 WIP (1/8/2024)
C:\Users\2N\Documents\2N Students\Pressel\2704\Orca\Celestyal_Crystal.3dm

Fixed-plane Condition

Surface Meshing Parameters			
Density	1.000	Min edge length	0.000 m
Maximum angle	0.000	Max edge length	0.000 m
Maximum aspect ratio	0.000	Max dist edge to srf	0.000 m
Minimum initial grid quads	0	Jagged seams	False
Refine mesh	True	Simple planes	True

General Info				
Fluid Density	1025.900	kg/m^3	Up Direction	Positive_Z
Fluid Type	Seawater		Forward Direction	Negative_X
Mirror Geometry	False			

Notes

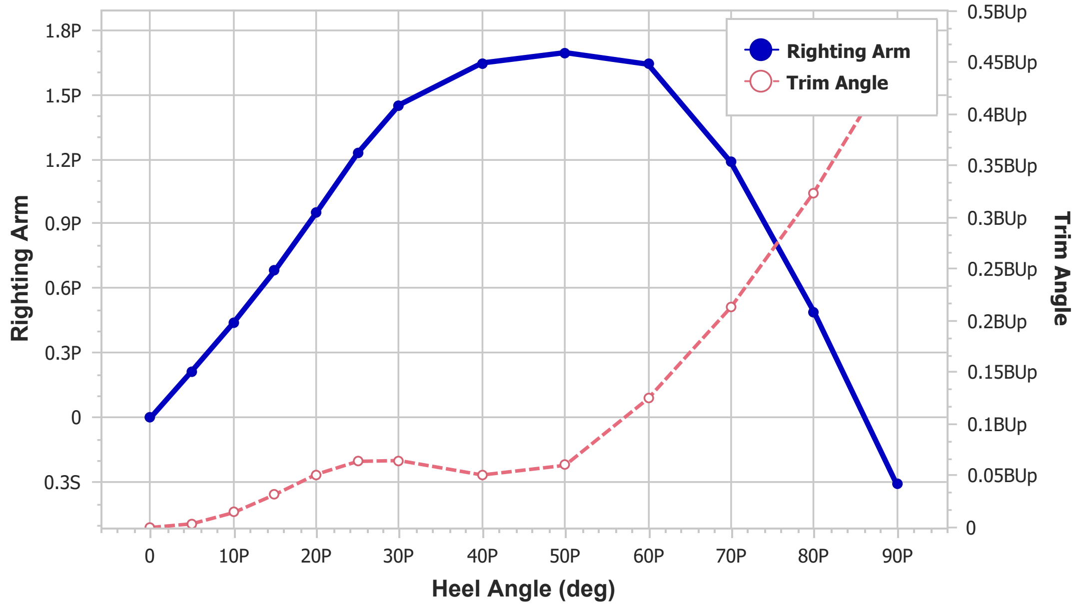
1. For the static equilibrium condition listed in this report, the center of mass of any fluid loads (if present) depends on the tank free surface type specified in the load case. Fluid loads for which the tank free surface type is Actual CG Shift include the true CG shift due to any heel and trim in the equilibrium condition, while fluid loads with a tank free surface type of Virtual CG Shift use the initial upright CG regardless of equilibrium heel/trim.

2. If this report includes a righting arm analysis, fluid loads with a tank free surface type of Actual CG Shift includes the true CG shift for each heel angle, while fluid loads with a tank free surface type of Virtual CG Shift include the virtual rise of the initial CG based on the type of virtual shift chosen.

Initial Righting Arm Report

Default Project
Upright Equilibrium Stability Analysis with Righting Arm (with fixed load or flotation plane)
Default Company
1/27/2024 1:17:36 PM Orca3D Version 3.0.13 WIP (1/8/2024)
C:\Users\2N\Documents\2N Students\Pressel\2704\Orca\Celestyal_Crystal.3dm

Fixed-plane Condition



HeelAngle (deg)	Trim Angle (deg)	Righting Arm (m)	Righting Moment (N-m)	Righting Energy (m-rad)
0.00	0.00BUp	0.000P	0.003P	0.000
5.00P	0.00BUp	0.217P	48642376.234P	0.009
10.00P	0.01BUp	0.441P	98597317.037P	0.038
15.00P	0.03BUp	0.683P	152764509.988P	0.087
20.00P	0.05BUp	0.951P	212850680.051P	0.159
25.00P	0.06BUp	1.229P	274902841.890P	0.254
30.00P	0.06BUp	1.452P	324830173.935P	0.371
40.00P	0.05BUp	1.646P	368318192.296P	0.641
50.00P	0.06BUp	1.694P	379076218.017P	0.933
60.00P	0.12BUp	1.640P	366990516.800P	1.224
70.00P	0.21BUp	1.186P	265262722.561P	1.470
80.00P	0.32BUp	0.493P	110254905.639P	1.617
90.00P	0.46BUp	0.309S	69094203.114S	1.633

Initial Hydrostatic Report

Default Project
Upright Equilibrium Stability Analysis (with fixed load or flotation plane)
Default Company
1/26/2024 9:51:30 AM Orca3D Version 3.0.13 WIP (1/8/2024)
Untitled

Hydrostatics Summary

Load Condition Input Parameters

Condition	Weight/Sinkage	LCG/Trim	TCG/Heel	VCG (m)
Fixed-plane Condition	6.100 m	0.000 deg	0.000 deg	None Available

Resulting Model Attitude and Hydrostatic Properties

Condition	Sinkage (m)	Trim (deg)	Heel (deg)	Ax (m^2)
Fixed-plane Condition	6.100	0.000	0.000	0.000

Condition	Displacement (kgf)	LCB (m)	TCB (m)	VCB (m)	Wet Area (m^2)
Fixed-plane Condition	22812644.564	99.076	0.000	3.231	5725.957

Condition	Awp (m^2)	LCF (m)	TCF (m)	VCF (m)
Fixed-plane Condition	4046.084	103.658	0.000	6.100

Condition	BMt (m)	BMl (m)	GM_T (m)	GM_L (m)
Fixed-plane Condition	9.965	369.475	None Available	None Available

Condition	Cb	Cp	Cwp	Cx	Cws	Cvp
Fixed-plane Condition	0.839	0.000	0.931	0.000	2.970	0.901

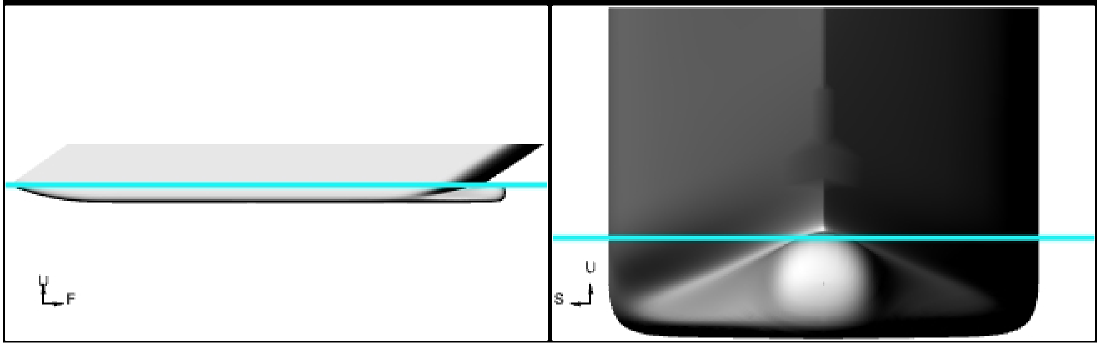
Notes

1. Locations such as the center of buoyancy and center of flotation are measured from the origin in the Rhinoceros world coordinate system.
2. The orientation of the model for an Orca3D hydrostatics solution is defined in terms of "sinkage," "trim," and "heel." The sinkage value represents the depth of the body origin (i.e., the Rhino world origin) below the resultant flotation plane and is sometimes referred to as "origin depth." Heel and trim represent angular rotations about the Rhino longitudinal and transverse axes, respectively, and are taken in that order. For a more detailed description of these terms see the Orca3D documentation.
3. Hull form coefficients are non-dimensionalized by the waterline length.
4. Calculation of Cp and Cx use Orca3D sections to determine Ax. If no Orca3D sections are defined, these values will be reported as zero.
5. For conditions that are part of a stability criteria evaluation, where the associated heeling arm changes the mass properties (such as icing), the results include the effects of the mass properties change.
6. For conditions that include damaged compartments, the wetted surface area includes the wet area of the damaged spaces, and the waterplane area (and inertia) of damaged spaces are excluded.

Initial Hydrostatic Report

Default Project
Upright Equilibrium Stability Analysis (with fixed load or flotation plane)
Default Company
1/26/2024 9:51:30 AM Orca3D Version 3.0.13 WIP (1/8/2024)
Untitled

Fixed-plane Condition



Mass Properties			
Weight	22812644.564	kgf	(Computed from input sinkage)
LCG	None Available	m	
TCG	None Available	m	
VCG	None Available	m	

Resultant Model Orientation					
Sinkage	6.100	m	T_{FP}	6.100	m
Trim	0.000	deg	T_{AP}	6.100	m
Heel	0.000	deg	T_M	6.100	m

Overall Dimensions				
Length Overall, Loa	182.137	m	Loa / Boa	7.005
Beam Overall, Boa	26.000	m	Boa / D	1.300
Depth Overall, D	20.000	m	D / Loa	0.110

Waterline Dimensions				
Waterline Length, Lwl	167.102	m	Lwl / Bwl	6.427
Waterline Beam Bwl	26.000	m	Bwl / T	4.262
Navigational Draft, T	6.100	m	D / T	3.279

Initial Hydrostatic Report

Default Project
Upright Equilibrium Stability Analysis (with fixed load or flotation plane)
Default Company
1/26/2024 9:51:30 AM Orca3D Version 3.0.13 WIP (1/8/2024)
Untitled

Fixed-plane Condition

Volumetric Parameters

Displacement Weight	22812644.564	kgf	Displ-Length Ratio	136.258
Volume	22236.714	m^3		
LCB	99.076	m	FB / Lwl	0.505
TCB	0.000	m	TCB / Bwl	0.000
VCB	3.231	m		
Wetted Surface Area	5725.957	m^2		
Moment To Trim	4946525.758	N-m/cm		

Waterplane Parameters

Waterplane Area, Awp	4046.084	m^2		
LCF	103.658	m	FF / Lwl	0.532
TCF	0.000	m	TCF / Lwl	0.000
Weight To Immerse	41508.781	kgf/cm		
I (transverse)	221588.669	m^4		
I (longitudinal)	8215916.833	m^4		

Sectional Parameters

Ax	0.000	m^2	Ax Location / Lwl	0.000
Ax Location	0.000	m		

Hull Form Coefficients

Cb	0.839	Cx	0.000
Cp	0.000	Cwp	0.931
Cvp	0.901	Cws	2.970

Static Stability Parameters

Mt	7.096	m	Ml	366.606	m
BMt	9.965	m	BMl	369.475	m
$GM_{Tuncorrected}$	None Available	m	$GM_{Luncorrected}$	None Available	m
Trans FS Correction	0.000	m	Longl FS Correction	0.000	m
$GM_{Tcorrected}$	None Available	m	$GM_{Lcorrected}$	None Available	m

Initial Hydrostatic Report

Default Project
Upright Equilibrium Stability Analysis (with fixed load or flotation plane)
Default Company
1/26/2024 9:51:30 AM Orca3D Version 3.0.13 WIP (1/8/2024)
Untitled

Fixed-plane Condition

Surface Meshing Parameters			
Density	1.000	Min edge length	0.000 m
Maximum angle	0.000	Max edge length	0.000 m
Maximum aspect ratio	0.000	Max dist edge to srf	0.000 m
Minimum initial grid quads	0	Jagged seams	False
Refine mesh	True	Simple planes	True

General Info				
Fluid Density	1025.900	kg/m^3	Up Direction	Positive_Z
Fluid Type	Seawater		Forward Direction	Negative_X
Mirror Geometry	False			

Notes

1. For the static equilibrium condition listed in this report, the center of mass of any fluid loads (if present) depends on the tank free surface type specified in the load case. Fluid loads for which the tank free surface type is Actual CG Shift include the true CG shift due to any heel and trim in the equilibrium condition, while fluid loads with a tank free surface type of Virtual CG Shift use the initial upright CG regardless of equilibrium heel/trim.

2. If this report includes a righting arm analysis, fluid loads with a tank free surface type of Actual CG Shift includes the true CG shift for each heel angle, while fluid loads with a tank free surface type of Virtual CG Shift include the virtual rise of the initial CG based on the type of virtual shift chosen.

I. Final Ship Data

Final Righting Arm Report

Default Project
Upright Equilibrium Stability Analysis with Righting Arm (with fixed load or flotation plane)
Default Company
01-Feb-24 3:18:59 PM Orca3D Version 3.0.13 WIP (08-Jan-24)
C:\Users\Rafail\Downloads\Celestyal_Crystal.3dm

Hydrostatics Summary

Load Condition Input Parameters

Condition	Weight/Sinkage	LCG/Trim	TCG/Heel	VCG (m)
Free-float Condition	22741794.000 kgf	0.000 deg	0.000 deg	10.698

Resulting Model Attitude and Hydrostatic Properties

Condition	Sinkage (m)	Trim (deg)	Heel (deg)	Ax (m^2)
Free-float Condition	6.083	0.000	0.000	0.000

Condition	Displacement (kgf)	LCB (m)	TCB (m)	VCB (m)	Wet Area (m^2)
Free-float Condition	22741740.688	99.061	0.000	3.222	5718.544

Condition	Awp (m^2)	LCF (m)	TCF (m)	VCF (m)
Free-float Condition	4046.308	103.664	0.000	6.083

Condition	BMt (m)	BMl (m)	GM_T (m)	GM_L (m)
Free-float Condition	9.993	370.741	2.517	363.265

Condition	Cb	Cp	Cwp	Cx	Cws	Cvp
Free-float Condition	0.838	0.000	0.931	0.000	2.971	0.901

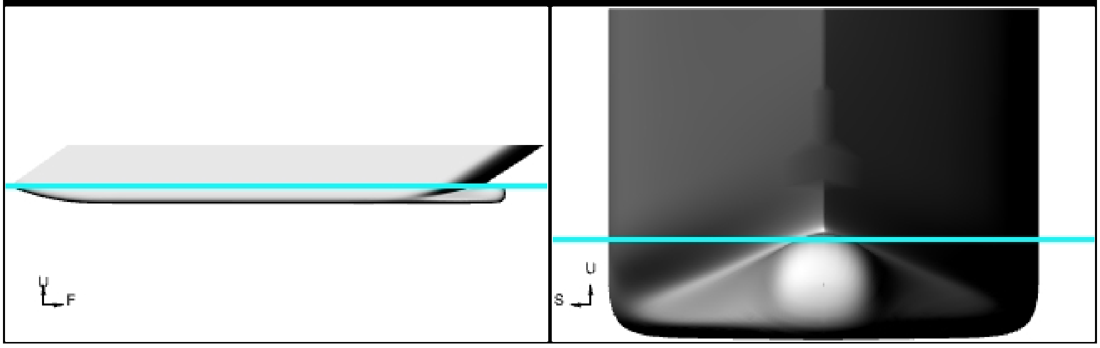
Notes

1. Locations such as the center of buoyancy and center of flotation are measured from the origin in the Rhinoceros world coordinate system.
2. The orientation of the model for an Orca3D hydrostatics solution is defined in terms of "sinkage," "trim," and "heel." The sinkage value represents the depth of the body origin (i.e., the Rhino world origin) below the resultant flotation plane and is sometimes referred to as "origin depth." Heel and trim represent angular rotations about the Rhino longitudinal and transverse axes, respectively, and are taken in that order. For a more detailed description of these terms see the Orca3D documentation.
3. Hull form coefficients are non-dimensionalized by the waterline length.
4. Calculation of Cp and Cx use Orca3D sections to determine Ax. If no Orca3D sections are defined, these values will be reported as zero.
5. For conditions that are part of a stability criteria evaluation, where the associated heeling arm changes the mass properties (such as icing), the results include the effects of the mass properties change.
6. For conditions that include damaged compartments, the wetted surface area includes the wet area of the damaged spaces, and the waterplane area (and inertia) of damaged spaces are excluded.

Final Righting Arm Report

Default Project
Upright Equilibrium Stability Analysis with Righting Arm (with fixed load or flotation plane)
Default Company
01-Feb-24 3:18:59 PM   Orca3D Version 3.0.13 WIP (08-Jan-24)
C:\Users\Rafail\Downloads\Celestyal_Crystal.3dm

Free-float Condition



Mass Properties			
Weight	22741740.688	kgf	(Specified as input)
LCG	99.061	m	(Computed from input trim)
TCG	0.000	m	(Computed from input heel)
VCG	10.698	m	(Specified as input)

Resultant Model Orientation					
Sinkage	6.083	m	T_{FP}	6.083	m
Trim	0.000	deg	T_{AP}	6.083	m
Heel	0.000	deg	T_{M}	6.083	m

Overall Dimensions				
Length Overall, Loa	182.137	m	Loa / Boa	7.005
Beam Overall, Boa	26.000	m	Boa / D	1.300
Depth Overall, D	20.000	m	D / Loa	0.110

Waterline Dimensions				
Waterline Length, Lwl	167.178	m	Lwl / Bwl	6.430
Waterline Beam Bwl	26.000	m	Bwl / T	4.274
Navigational Draft, T	6.083	m	D / T	3.288

Final Righting Arm Report

Default Project
Upright Equilibrium Stability Analysis with Righting Arm (with fixed load or flotation plane)
Default Company
01-Feb-24 3:18:59 PM Orca3D Version 3.0.13 WIP (08-Jan-24)
C:\Users\Rafail\Downloads\Celestyal_Crystal.3dm

Free-float Condition

Volumetric Parameters

Displacement Weight	22741740.688	kgf	Displ-Length Ratio	135.650
Volume	22167.600	m^3		
LCB	99.061	m	FB / Lwl	0.505
TCB	0.000	m	TCB / Bwl	0.000
VCB	3.222	m		
Wetted Surface Area	5718.544	m^2		
Moment To Trim	4846070.656	N-m/cm		

Waterplane Parameters

Waterplane Area, Awp	4046.308	m^2		
LCF	103.664	m	FF / Lwl	0.532
TCF	0.000	m	TCF / Lwl	0.000
Weight To Immerse	41511.078	kgf/cm		
I (transverse)	221527.232	m^4		
I (longitudinal)	8218438.486	m^4		

Sectional Parameters

Ax	0.000	m^2	Ax Location / Lwl	0.000
Ax Location	0.000	m		

Hull Form Coefficients

Cb	0.838	Cx	0.000
Cp	0.000	Cwp	0.931
Cvp	0.901	Cws	2.971

Static Stability Parameters

Mt	7.132	m	Ml	367.880	m
BMt	9.993	m	BMl	370.741	m
$GM_{Tuncorrected}$	2.517	m	$GM_{Luncorrected}$	363.265	m
Trans FS Correction	0.000	m	Longl FS Correction	0.000	m
$GM_{Tcorrected}$	2.517	m	$GM_{Lcorrected}$	363.265	m

Orca3D - Marine Design Plug-in for Rhinoceros Page 3 of 5

Final Righting Arm Report

Default Project
Upright Equilibrium Stability Analysis with Righting Arm (with fixed load or flotation plane)
Default Company
01-Feb-24 3:18:59 PM Orca3D Version 3.0.13 WIP (08-Jan-24)
C:\Users\Rafail\Downloads\Celestyal_Crystal.3dm

Free-float Condition

Surface Meshing Parameters			
Density	1.000	Min edge length	0.000 m
Maximum angle	0.000	Max edge length	0.000 m
Maximum aspect ratio	0.000	Max dist edge to srf	0.000 m
Minimum initial grid quads	0	Jagged seams	False
Refine mesh	True	Simple planes	True

General Info				
Fluid Density	1025.900	kg/m^3	Up Direction	Positive_Z
Fluid Type	Seawater		Forward Direction	Negative_X
Mirror Geometry	False			

Notes

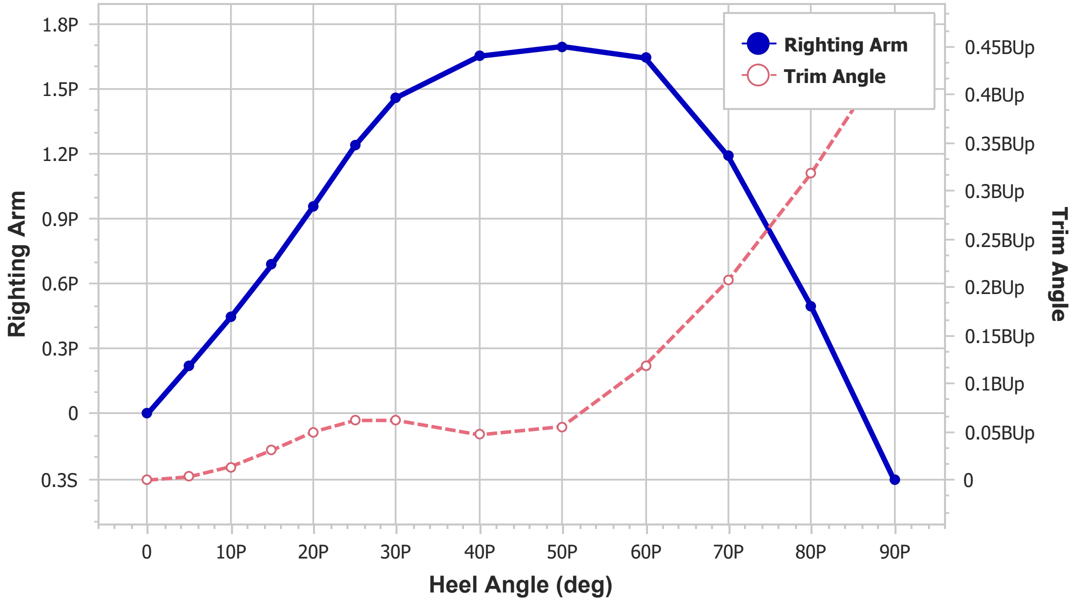
1. For the static equilibrium condition listed in this report, the center of mass of any fluid loads (if present) depends on the tank free surface type specified in the load case. Fluid loads for which the tank free surface type is Actual CG Shift include the true CG shift due to any heel and trim in the equilibrium condition, while fluid loads with a tank free surface type of Virtual CG Shift use the initial upright CG regardless of equilibrium heel/trim.

2. If this report includes a righting arm analysis, fluid loads with a tank free surface type of Actual CG Shift includes the true CG shift for each heel angle, while fluid loads with a tank free surface type of Virtual CG Shift include the virtual rise of the initial CG based on the type of virtual shift chosen.

Final Righting Arm Report

Default Project
Upright Equilibrium Stability Analysis with Righting Arm (with fixed load or flotation plane)
Default Company
01-Feb-24 3:18:59 PM Orca3D Version 3.0.13 WIP (08-Jan-24)
C:\Users\Rafail\Downloads\Celestyal_Crystal.3dm

Free-float Condition



HeelAngle (deg)	Trim Angle (deg)	Righting Arm (m)	Righting Moment (N-m)	Righting Energy (m-rad)
0.00	0.00	0.000	0.000	0.000
5.00P	0.00BUp	0.219P	48897281.497P	0.010
10.00P	0.01BUp	0.444P	99101534.226P	0.039
15.00P	0.03BUp	0.688P	153495387.448P	0.088
20.00P	0.05BUp	0.958P	213735438.450P	0.160
25.00P	0.06BUp	1.236P	275733143.601P	0.256
30.00P	0.06BUp	1.459P	325306792.609P	0.373
40.00P	0.05BUp	1.650P	367913646.795P	0.644
50.00P	0.06BUp	1.694P	377860644.223P	0.936
60.00P	0.12BUp	1.641P	365992321.962P	1.227
70.00P	0.21BUp	1.188P	264888050.232P	1.474
80.00P	0.32BUp	0.495P	110504031.378P	1.621
90.00P	0.45BUp	0.306S	68228034.352S	1.638

Final Resistance Report

Default Project
Holtrop Resistance Analysis
Default Company
31-Jan-24 2:08:19 PM Orca3D Version 3.0.13 WIP (08-Jan-24)
C:\Users\Rafail\Downloads\Celestyal_Crystal.3dm

Prediction Parameter	Value
Method	Holtrop 1984 (mod)
SpeedCheck	OK
HullCheck	Check
DesignMarginPercent	0.000
WaterType	UserDefined
WaterDensity	1025.90000 kg/m^3
WaterViscosity	1.1883E-06 m^2/s
FormFactor	0.477
CorrAllowance	0.000426
PropulsiveEfficiency	50 %

Vessel Data	Value
LengthWL	167.178 m
BeamWL	26.000 m
MaxMoldedDraft	6.083 m
DisplacementBare	22741740.460 kgf
WettedSurface	5718.544 m^2
MaxSectionArea	152.718 m^2
WaterplaneArea	4046.308 m^2
LCBFwdMidships	-0.463 %Lwl
BulbAreaAtFP	27.427 m^2
BulbCentroidHeight	2.860 m
TransomArea	0.035 m^2
HalfEntranceAngle	44.400 deg
SternTypeCoef	20.000

Parameter Check	Value	Minimum	Maximum	Type
PrismaticCoef	0.868	0.55	0.85	Check
LwlBwlRatio	6.430	3.9	14.9	OK
LambdaCoef	1.063	0	0.99	Check
BwlDraftRatio	4.27421	2.1	4	Check

Final Resistance Report

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Holtrop Resistance Analysis
Default Company
31-Jan-24 2:08:19 PM Orca3D Version 3.0.13 WIP (08-Jan-24)
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Speed (kt)	Fn	Cf (x 1000)	Cr (x 1000)	Rbare(N)	PEtotal (kW)	Rtotal (N)
8.000	0.102	1.640	1.199	162219.5	667.6	162219.5
10.000	0.127	1.594	1.187	248948.1	1280.7	248948.1
12.000	0.152	1.558	1.246	361081.4	2229.1	361081.4
14.000	0.178	1.528	1.430	514881.3	3708.3	514881.3
16.000	0.203	1.503	1.759	732894.0	6032.5	732894.0
18.000	0.229	1.482	2.225	1039528.8	9626.0	1039528.8
20.000	0.254	1.463	2.846	1470308.6	15127.8	1470308.6

Speed (kt)	Fv	Rbare (N)	PEtotal (kW)	PPtotal (kW)	Prediction Check
8.000	0.248	162219.5	667.6	1335.2	OK
10.000	0.310	248948.1	1280.7	2561.4	OK
12.000	0.372	361081.4	2229.1	4458.2	OK
14.000	0.434	514881.3	3708.3	7416.6	OK
16.000	0.496	732894.0	6032.5	12065.1	OK
18.000	0.558	1039528.8	9626.0	19252.1	OK
20.000	0.620	1470308.6	15127.8	30255.7	OK

Prediction Checks

1. The Holtrop prediction method has a defined upper limit of 0.80 for the length-based Froude number (Fn). Extrapolating speed beyond this value is not recommended.

Notes

PPtotal represents the total propulsive power. Its precise definition depends on how the user specified the propulsive efficiency. If the user input the quasi-propulsive efficiency, then PPtotal is the total delivered power. If the user specified overall propulsive efficiency then PPtotal is the brake power.

Final Resistance Report

Default Project
Holtrop Resistance Analysis
Default Company
31-Jan-24 2:08:19 PM Orca3D Version 3.0.13 WIP (08-Jan-24)
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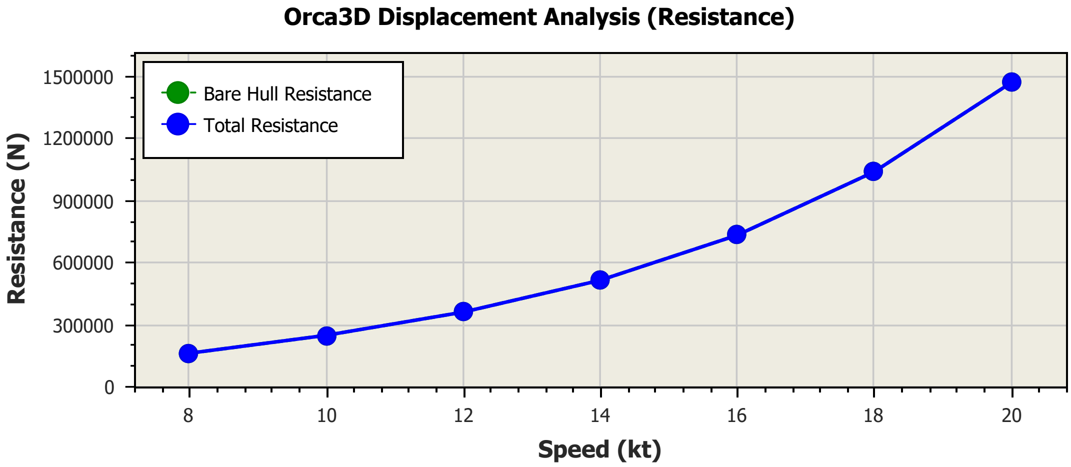

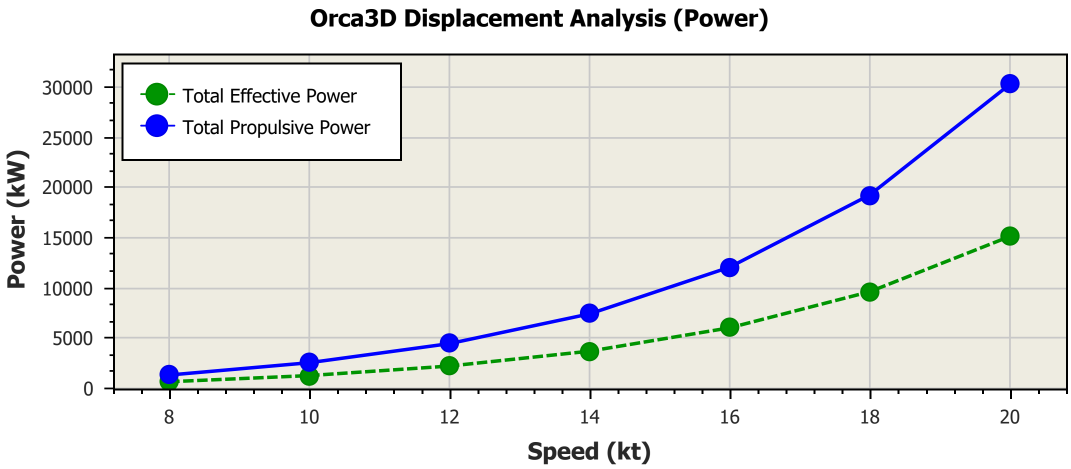

Final Resistance Report

Default Project
Holtrop Resistance Analysis
Default Company
31-Jan-24 2:08:19 PM Orca3D Version 3.0.13 WIP (08-Jan-24)
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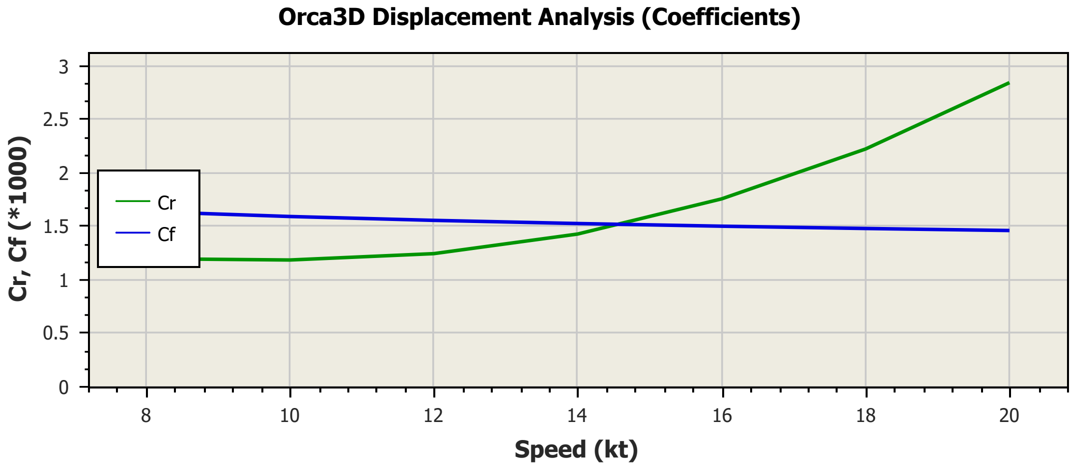

J. Detailed Ship Renovation Data

Deck	Converted Item Name	Remodel Type	Existing Item Name	Room IDs	Number of Patients	Existing Item Area [ft^2]	Total Rooms	Total Final Area [ft^2]	Weight Change [MT]
2	Security Office	Administrative	1A Cabin	2011, 2012, 2013	0	129	3	387	-0.025
2	Reception/ Quarterdeck	Administrative	1A Cabin	2014, 2015, 2016	0	129	3	387	-0.03
2	Court Room	Administrative	1A Cabin	2008, 2009, 2010	0	129	3	387	-0.02
2	Administrative Office	Administrative	1A Cabin	2000	0	129	1	129	-0.015
2	Administrative Office	Administrative	1A Cabin	2001	0	129	1	129	-0.015
2	Administrative Office	Administrative	1A Cabin	2002	0	129	1	129	-0.015
2	Administrative Office	Administrative	1A Cabin	2003	0	129	1	129	-0.015
2	Administrative Office	Administrative	1A Cabin	2004	0	129	1	129	-0.015
2	Administrative Office	Administrative	1A Cabin	2005	0	129	1	129	-0.015
2	Administrative Office	Administrative	1A Cabin	2006	0	129	1	129	-0.015
2	Administrative Office	Administrative	1A Cabin	2007	0	129	1	129	-0.015
2	Waiting Area	Administrative	None		0	590	1	590	0
2	Administrative Space	Administrative	None		0	1045	1	1045	0
2	Crew Spaces	None	None		0	5900	1	5900	0
3	Single Inpatient Room	Inpatient	XB Cabin	3025	1	118	1	118	-0.01
3	Single Inpatient Room	Inpatient	XB Cabin	3026	1	118	1	118	-0.01
3	Single Inpatient Room	Inpatient	XB Cabin	3027	1	118	1	118	-0.01
3	Single Inpatient Room	Inpatient	XB Cabin	3028	1	118	1	118	-0.01
3	Single Inpatient Room	Inpatient	XB Cabin	3029	1	118	1	118	-0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3000	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3001	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3002	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3003	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3004	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3005	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3006	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3007	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3008	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3009	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3010	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3011	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3012	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3013	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3014	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3015	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3016	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3017	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3018	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3019	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3020	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3021	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3022	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3023	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3024	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3200	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3201	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3202	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3203	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3204	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3205	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3206	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3207	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3208	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3209	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3210	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3211	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3212	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3213	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3214	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3215	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3216	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3217	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3218	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3219	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3220	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3221	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3222	2	150	1	150	0.01
3	Double Inpatient Room	Inpatient	XC Cabin	3223	2	150	1	150	0.01
3	Crew Spaces	None	None		0	9968	1	9968	0
3	Nursing Station	Hospital	1A Cabin	3100, 3101	0	130	2	260	-0.02
3	Nursing Station	Hospital	1A Cabin	3111, 3112	0	130	2	260	-0.02
3	Nursing Station	Hospital	1A Cabin	3116, 3117	0	130	2	260	-0.02
3	Nursing Station	Hospital	1A Cabin	3129, 3130	0	130	2	260	-0.02
3	Consultation Room	Hospital	1A Cabin	3102	0	130	1	130	-0.02
3	Consultation Room	Hospital	1A Cabin	3103	0	130	1	130	-0.02
3	Consultation Room	Hospital	1A Cabin	3108	0	130	1	130	-0.02
3	Consultation Room	Hospital	1A Cabin	3109	0	130	1	130	-0.02
3	Consultation Room	Hospital	1A Cabin	3110	0	130	1	130	-0.02
3	Consultation Room	Hospital	1A Cabin	3118	0	130	1	130	-0.02
3	Consultation Room	Hospital	1A Cabin	3119	0	130	1	130	-0.02
3	Consultation Room	Hospital	1A Cabin	3127	0	130	1	130	-0.02
3	Consultation Room	Hospital	1A Cabin	3128	0	130	1	130	-0.02
3	On Call Room	None	1A Cabin	3144	0	130	1	130	0

Deck	Converted Item Name	Remodel Type	Existing Item Name	Room IDs	Number of Patients	Existing Item Area [ft^2]	Total Rooms	Total Final Area [ft^2]	Weight Change [MT]
3	On Call Room	None	1A Cabin	3115	0	130	1	130	0
3	On Call Room	None	1A Cabin	3123	0	130	1	130	0
3	Staff Support Room	Hospitality	1A Cabin	3107	0	130	1	130	0
3	Staff Support Room	Hospitality	1A Cabin	3122	0	130	1	130	0
3	Staff Support Room	Hospitality	1A Cabin	3125	0	130	1	130	0
3	Visitor Room	Hospitality	1A Cabin	3106	0	130	1	130	0
3	Visitor Room	Hospitality	1A Cabin	3124	0	130	1	130	0
3	Group Therapy Room	Hospital	1A Cabin	3104, 3105	0	130	2	260	-0.02
3	Quiet Room	Hospital	1A Cabin	3113	0	130	1	130	0
3	Quiet Room	Hospital	1A Cabin	3121	0	130	1	130	0
3	Quiet Room	Hospital	1A Cabin	3128	0	130	1	130	0
3	Staff Office Space	Administrative	1A Cabin	3120	0	130	1	130	-0.015
4	Double Inpatient Room	Inpatient	XC Cabin 4000	4000	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4001	4001	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4002	4002	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4003	4003	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4004	4004	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4005	4005	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4006	4006	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4007	4007	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4008	4008	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4009	4009	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4010	4010	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4011	4011	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4012	4012	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4013	4013	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4014	4014	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4015	4015	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4016	4016	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4017	4017	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4018	4018	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4019	4019	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4020	4020	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4021	4021	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4022	4022	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4023	4023	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4024	4024	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4025	4025	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4026	4026	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4027	4027	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4028	4028	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4029	4029	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4030	4030	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4031	4031	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4032	4032	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4033	4033	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4034	4034	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4035	4035	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4036	4036	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4037	4037	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4038	4038	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4200	4200	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4201	4201	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4202	4202	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4203	4203	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4204	4204	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4205	4205	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4206	4206	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4207	4207	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4208	4208	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4209	4209	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4210	4210	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4211	4211	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4212	4212	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4213	4213	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4214	4214	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4215	4215	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4216	4216	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4217	4217	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4218	4218	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4219	4219	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4220	4220	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4221	4221	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4222	4222	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4223	4223	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4224	4224	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4225	4225	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4226	4226	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4227	4227	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4228	4228	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4229	4229	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4230	4230	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4231	4231	2	150	1	150	0.01

Deck	Converted Item Name	Remodel Type	Existing Item Name	Room IDs	Number of Patients	Existing Item Area [ft^2]	Total Rooms	Total Final Area [ft^2]	Weight Change [MT]
4	Double Inpatient Room	Inpatient	XC Cabin 4232	4232	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4233	4233	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4234	4234	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4235	4235	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4236	4236	2	150	1	150	0.01
4	Double Inpatient Room	Inpatient	XC Cabin 4237	4237	2	150	1	150	0.01
4	Indoor Dining Space	Hospitality	1B Cabin	4134, 4135, 4136, 4137	0	130	4	520	0
4	Indoor Social SPace	Hospitality	1B Cabin	4109, 4110	0	130	2	260	0
4	Nursing Station	Hospital	Medical Center		0	620	1	620	0
4	Nursing Station	Hospital	1B Cabin 4120	4120, 4121	0	130	2	260	-0.02
4	Nursing Station	Hospital	1B Cabin 4143	4143, 4144	0	130	2	260	-0.02
4	Consultation Room	Hospital	1B Cabin 4106	4106	0	130	1	130	-0.02
4	Consultation Room	Hospital	1B Cabin 4107	4107	0	130	1	130	-0.02
4	Consultation Room	Hospital	1B Cabin 4115	4115	0	130	1	130	-0.02
4	Consultation Room	Hospital	1B Cabin 4116	4116	0	130	1	130	-0.02
4	Consultation Room	Hospital	1B Cabin 4122	4122	0	130	1	130	-0.02
4	Consultation Room	Hospital	1B Cabin 4123	4123	0	130	1	130	-0.02
4	Consultation Room	Hospital	1B Cabin 4131	4131	0	130	1	130	-0.02
4	Consultation Room	Hospital	1B Cabin 4132	4132	0	130	1	130	-0.02
4	Consultation Room	Hospital	1B Cabin 4140	4140	0	130	1	130	-0.02
4	Consultation Room	Hospital	1B Cabin 4141	4141	0	130	1	130	-0.02
4	Consultation Room	Hospital	1B Cabin 4145	4145	0	130	1	130	-0.02
4	Consultation Room	Hospital	1B Cabin 4146	4146	0	130	1	130	-0.02
4	On Call Room	None	1B Cabin 4100	4100	0	130	1	130	0
4	On Call Room	None	1B Cabin 4117	4117	0	130	1	130	0
4	On Call Room	None	1B Cabin 4142	4142	0	130	1	130	0
4	Staff Support Room	Hospitality	1B Cabin 4101	4101, 4102	0	130	2	260	0
4	Staff Support Room	Hospitality	1B Cabin 4113	4113, 4114	0	130	2	260	0
4	Visitor Room	Hospitality	1B Cabin 4108	4108	0	130	1	130	0
4	Visitor Room	Hospitality	1B Cabin 4133	4133	0	130	1	130	0
4	Quiet Room	Hospital	1B Cabin 4105	4105	0	130	1	130	0
4	Quiet Room	Hospital	1B Cabin 4118	4118	0	130	1	130	0
4	Quiet Room	Hospital	1B Cabin 4119	4119	0	130	1	130	0
4	Quiet Room	Hospital	1B Cabin 4130	4130	0	130	1	130	0
4	Group Therapy Room	Hospital	1B Cabin 4128	4128, 4129	0	130	2	260	-0.02
4	Group Therapy Room	Hospital	1B Cabin 4138	4138, 4139	0	130	2	260	-0.02
4	Staff Office Space	Administrative	1B Cabin 4111	4111	0	130	1	130	0
4	Staff Office Space	Administrative	1B Cabin 4112	4112	0	130	1	130	0
4	Staff Office Space	Administrative	1B Cabin 4126	4126	0	130	1	130	0
4	Staff Office Space	Administrative	1B Cabin 4127	4127	0	130	1	130	0
4	Staff Office Space	Administrative	1B Cabin 4147	4147	0	130	1	130	0
5	File Room	Administrative	PhotoShop		0	177	1	177	0
5	Dining Area STBD	Hospitality	Reception		0	1695	1	1695	0
5	Dining Area PORT	Hospitality	Duty Free & Agora		0	2183	1	2183	0
5	Outdoor Rec Space PORT	Hospitality	Thalassa Bar		0	1228	1	1228	0
5	Outdoor Rec Space STBD	Hospitality	Thalassa Bar		0	1208	1	1208	0
5	Heads expansion	Hospital	Heads		0	164	1	164	0.25
5	Heads creation	Hospital			0	154	1	154	0.5
5	Dining Area AFT	Hospitality	Olympus Restaurant		0	3568	1	3568	0
5	Single Inpatient Room	Inpatient	XA Cabin	5002	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5003	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5004	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5005	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5006	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5007	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5008	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5009	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5010	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5011	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5012	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5013	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5202	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5203	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5204	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5205	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5206	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5207	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5208	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5209	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5210	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5211	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5212	1	119	1	119	-0.01
5	Single Inpatient Room	Inpatient	XA Cabin	5213	1	119	1	119	-0.01
5	Indoor Rec Space	Hospitality	1B Cabin	5104, 5105	0	130	2	260	-0.01
5	Indoor Rec Space	Hospitality	1B Cabin	5112, 5113	0	130	2	260	-0.01
5	Nursing Station	Hospital	1B Cabin	5108, 5109	0	130	2	260	-0.01
5	On Call Room	None	1B Cabin	5116	0	130	1	130	0
5	On Call Room	None	1B Cabin	5117	0	130	1	130	0
5	Consultation Room	Hospital	1B Cabin	5103	0	130	1	130	-0.02
5	Consultation Room	Hospital	1B Cabin	5111	0	130	1	130	-0.02
5	Visitor Room	Hospitality	1B Cabin	5106	0	130	1	130	0
5	Visitor Room	Hospitality	1B Cabin	5116	0	130	1	130	0
5	Quiet Room	Hospital	1B Cabin	5115	0	130	1	130	0

Deck	Converted Item Name	Remodel Type	Existing Item Name	Room IDs	Number of Patients	Existing Item Area [ft^2]	Total Rooms	Total Final Area [ft^2]	Weight Change [MT]
5	Seclusion Room	Hospital	1B Cabin	5114	0	130	1	130	0
6	Double Inpatient Room	Inpatient	SBJ Cabin	6004	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6005	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6006	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6007	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6008	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6009	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6010	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6011	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6012	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6013	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6014	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6204	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6205	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6206	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6207	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6208	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6209	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6210	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6211	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6212	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6213	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6214	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6038	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6039	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6238	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	SBJ Cabin	6239	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	XD Cabin	6036	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	XD Cabin	6037	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	XD Cabin	6236	2	166	1	166	0.01
6	Double Inpatient Room	Inpatient	XD Cabin	6237	2	166	1	166	0.01
6	Single Inpatient Room	Inpatient	XB Cabin	6015	1	118	1	118	-0.01
6	Single Inpatient Room	Inpatient	XB Cabin	6016	1	118	1	118	-0.01
6	Single Inpatient Room	Inpatient	XB Cabin	6215	1	118	1	118	-0.01
6	Single Inpatient Room	Inpatient	XB Cabin	6216	1	118	1	118	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6017	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6018	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6019	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6020	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6021	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6022	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6023	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6024	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6025	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6026	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6027	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6028	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6029	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6030	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6031	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6032	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6033	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6034	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6035	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6217	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6218	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6219	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6220	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6221	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6222	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6223	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6224	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6225	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6226	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6227	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6228	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6229	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6230	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6231	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6232	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6233	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6234	1	107	1	107	-0.01
6	Single Inpatient Room	Inpatient	XBO Cabin	6235	1	107	1	107	-0.01
6	Consultation Room	Hospital	1C Cabin	6106	0	130	1	130	-0.02
6	Consultation Room	Hospital	1C Cabin	6107	0	130	1	130	-0.02
6	Consultation Room	Hospital	1C Cabin	6113	0	130	1	130	-0.02
6	Consultation Room	Hospital	1C Cabin	6114	0	130	1	130	-0.02
6	Consultation Room	Hospital	1C Cabin	6119	0	130	1	130	-0.02
6	Consultation Room	Hospital	1C Cabin	6126	0	130	1	130	-0.02
6	Consultation Room	Hospital	1C Cabin	6132	0	130	1	130	-0.02
6	Consultation Room	Hospital	1C Cabin	6133	0	130	1	130	-0.02
6	Consultation Room	Hospital	1C Cabin	6137	0	130	1	130	-0.02
6	Nursing Station	Hospital	SG Cabin	6000	0	376	1	376	0

Deck	Converted Item Name	Remodel Type	Existing Item Name	Room IDs	Number of Patients	Existing Item Area [ft^2]	Total Rooms	Total Final Area [ft^2]	Weight Change [MT]
6	Nursing Station	Hospital	SG Cabin	6200	0	376	1	376	0
6	Nursing Station	Hospital	1C Cabin	6111, 6112	0	130	2	260	0
6	Nursing Station	Hospital	1C Cabin	6130, 6131	0	130	2	260	0
6	Nursing Station	Hospital	1C Cabin	6134, 6135	0	130	2	260	0
6	Visitor Room	Hospitality	1C Cabin	6108	0	130	1	130	0
6	Visitor Room	Hospitality	1C Cabin	6115	0	130	1	130	0
6	Visitor Room	Hospitality	1C Cabin	6116	0	130	1	130	0
6	Visitor Room	Hospitality	1C Cabin	6127	0	130	1	130	0
6	On Call Room	None	1C Cabin	6100	0	130	1	130	0
6	On Call Room	None	1C Cabin	6120	0	130	1	130	0
6	On Call Room	None	1C Cabin	6136	0	130	1	130	0
6	Staff Support Room	Hospitality	S Cabin	6001	0	322	1	322	0
6	Staff Support Room	Hospitality	S Cabin	6201	0	322	1	322	0
6	Administrative Office	Administrative	S Cabin	6002	0	322	1	322	0
6	Administrative Office	Administrative	S Cabin	6202	0	322	1	322	0
6	Group Therapy Room	Hospital	S Cabin	6003	0	322	1	322	-0.05
6	Group Therapy Room	Hospital	S Cabin	6203	0	322	1	322	-0.05
6	Quiet Room	Hospital	1C Cabin	6117	0	130	1	130	0
6	Quiet Room	Hospital	1C Cabin	6118	0	130	1	130	0
6	Quiet Room	Hospital	1C Cabin	6125	0	130	1	130	0
6	Quiet Room	Hospital	1C Cabin	6129	0	130	1	130	0
6	Indoor Rec Space	Hospitality	1C Cabin	6101- 6105	0	130	5	650	-0.03
6	Indoor Rec Space	Hospitality	1C Cabin	6121- 6124	0	130	4	520	-0.03
6	Outdoor Rec Space	Hospitality	AFT Deck 6		0	1461	1	1461	0
6	Extra Space	None	1C Cabin		0	130	1	130	0
6	Extra Space	None	1C Cabin		0	130	1	130	0
6	Extra Space	None	1C Cabin		0	130	1	130	0
7	Double Addiction Room	Addiction	SBJ Cabin	7004	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	SBJ Cabin	7005	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	SBJ Cabin	7006	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	SBJ Cabin	7007	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	SBJ Cabin	7008	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	SBJ Cabin	7009	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	SBJ Cabin	7204	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	SBJ Cabin	7205	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	SBJ Cabin	7206	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	SBJ Cabin	7207	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	SBJ Cabin	7208	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	SBJ Cabin	7028	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	SBJ Cabin	7029	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	SBJ Cabin	7030	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	SBJ Cabin	7227	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	SBJ Cabin	7228	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	SBJ Cabin	7229	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7010	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7011	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7012	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7013	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7014	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7015	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7016	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7017	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7018	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7019	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7020	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7021	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7022	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7023	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7024	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7025	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7026	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7027	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7209	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7210	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7211	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7212	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7213	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7214	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7215	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7216	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7217	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7218	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7219	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7220	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7221	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7222	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7223	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7224	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7225	2	166	1	166	-0.02
7	Double Addiction Room	Addiction	XD Cabin	7226	2	166	1	166	-0.02
7	Consultation Room	Hospital	1C Cabin	7103	0	130	1	130	-0.02
7	Consultation Room	Hospital	1C Cabin	7104	0	130	1	130	-0.02
7	Consultation Room	Hospital	1C Cabin	7106	0	130	1	130	-0.02

Deck	Converted Item Name	Remodel Type	Existing Item Name	Room IDs	Number of Patients	Existing Item Area [ft^2]	Total Rooms	Total Final Area [ft^2]	Weight Change [MT]
7	Consultation Room	Hospital	1C Cabin	7112	0	130	1	130	-0.02
7	Consultation Room	Hospital	1C Cabin	7117	0	130	1	130	-0.02
7	Consultation Room	Hospital	1C Cabin	7118	0	130	1	130	-0.02
7	Consultation Room	Hospital	1C Cabin	7124	0	130	1	130	-0.02
7	Consultation Room	Hospital	1C Cabin	7128	0	130	1	130	-0.02
7	Consultation Room	Hospital	1C Cabin	7129	0	130	1	130	-0.02
7	Nursing Station	Hospital	SB Cabin	7002	0	387	1	387	0
7	Nursing Station	Hospital	SB Cabin	7202	0	387	1	387	0
7	Nursing Station	Hospital	1C Cabin	7110, 7111	0	130	2	260	0
7	Nursing Station	Hospital	1C Cabin	7122, 7123	0	130	2	260	0
7	Visitor Room	Hospitality	1C Cabin	7113	0	130	1	130	0
7	Visitor Room	Hospitality	1C Cabin	7114	0	130	1	130	0
7	Visitor Room	Hospitality	1C Cabin	7125	0	130	1	130	0
7	Visitor Room	Hospitality	1C Cabin	7126	0	130	1	130	0
7	On Call Room	None	1C Cabin	7100	0	130	1	130	0
7	On Call Room	None	1C Cabin	7101	0	130	1	130	0
7	On Call Room	None	1C Cabin	7102	0	130	1	130	0
7	Staff Support Room	Hospitality	SB Cabin	7001	0	387	1	387	0
7	Staff Support Room	Hospitality	SB Cabin	7201	0	387	1	387	0
7	Administrative Office	Administrative	SB Cabin	7000	0	387	1	387	0
7	Administrative Office	Administrative	SB Cabin	7200	0	387	1	387	0
7	Group Therapy Room	Hospital	SB Cabin	7003	0	387	1	387	-0.05
7	Group Therapy Room	Hospital	SB Cabin	7203	0	387	1	387	-0.05
7	Quiet Room	Hospital	1C Cabin	7115	0	130	1	130	0
7	Quiet Room	Hospital	1C Cabin	7116	0	130	1	130	0
7	Quiet Room	Hospital	1C Cabin	7121	0	130	1	130	0
7	Quiet Room	Hospital	1C Cabin	7127	0	130	1	130	0
7	Outdoor Rec Space	Hospitality	AFT Deck 7		0	1427	1	1427	0
7	Extra Space	None	1C Cabin		0	130	1	130	0
7	Extra Space	None	1C Cabin		0	130	1	130	0
7	Extra Space	None	1C Cabin		0	130	1	130	0
7	Extra Space	None	1C Cabin		0	130	1	130	0
7	Extra Space	None	1C Cabin		0	130	1	130	0
7	Extra Space	None	1C Cabin		0	130	1	130	0
8	Large Social Area	Hospitality	Muses Lounge & Bar		0	8513	1	8513	0
8	Library Stand	None	Library Stand		0	355	1	355	0
8	Social Area	Hospitality	Kids Corner		0	347	1	347	0.01
8	Conference Area	None	Conference Area		0	520	1	520	0
8	Lab & Pharmacy	Hospitality	Casino & Eros Lounge & Bar PORT		0	2222	1	2222	0.1
8	Kitchen Service	None	Bar		0	805	1	805	0
8	Galley	None	Galley		0	2532	1	2532	0
8	Addiction Dining Area AFT	Hospitality	Amalthia Restaurant		0	4767	1	4767	0
8	Addiction Outdoor Rec Space	Hospitality	AFT Deck 8		0	1066	1	1066	0
9	Staff Dining Area PORT	None	Leda Casual Dining		0	1550	1	1550	0
9	Staff Dining Area STBD	None	Aura Casual Dining		0	1170	1	1170	0
9	Galley	None	Galley		0	2115	1	2115	0
9	Outdoor Social Space	Hospitality	Helios Bar Outer & Swimming Pool		0	5107	1	5107	0
9	Kitchen Service	None	Helios Bar Inner		0	746	1	746	0
9	Beauty Center AFT	None	Beauty Center AFT		0	384	1	384	0
9	Sauna	None	Sauna		0	726	1	726	0
9	Massage Room	None	Massage Room		0	535	1	535	0
9	Gym	None	Gym		0	500	1	500	0
9	Beauty Center FWD	None	Beauty Center FWD		0	681	1	681	0
9	Inner Social Space	Hospitality	Muses Lounge & Bar		0	4687	1	4687	0
10	Staff Area	None	Horizons Lounge & Bar		0	3196	1	3196	0

K. Historical Cruise Ship Renovation Data

Name	Tonnage [MT]	Cost [$M]	Date
Celestial Journey	55	21	2023
Azamara Onward	31	15.9	2022
Oasis of the Seas	225	165	2019
Carnival Radiance	102	200	2020
Legend of the Seas	226	50	2013
Alllure of the Seas	225	165	2020
Explorer of the Seas	138	110	2020
Freedom of the Seas	156	116	2020
Oasis of the Seas	226	165	2019
Quantum of the Seas	168	65	2019
Voyager of the Seas	137	97	2019
Norwegian Spirit	75	100	2020
Pacific Explorer	77	30	2020
Azura	115	25	2020
Azura	115	32	2015
MSC Armonia	58	30	2019
MSC Musica	92	40	2016
MSC Magnifica	95	140	2021
AIDAvita	42	30	2020
TUI Mein Schiff 4	99	20	2020
Star Legend	13	85	2020
Star Pride	13	3	2015
Star Pride	13	4.5	2016
Crystal Symphony	51	10	2020
Crystal Symphony	51	23	2006
Crystal Symphony	51	25	2009
Rhapsody of the Seas	79	54	2012
Enchantment of the Seas	83	60	2005
Independence of the Seas	156	110	2016

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