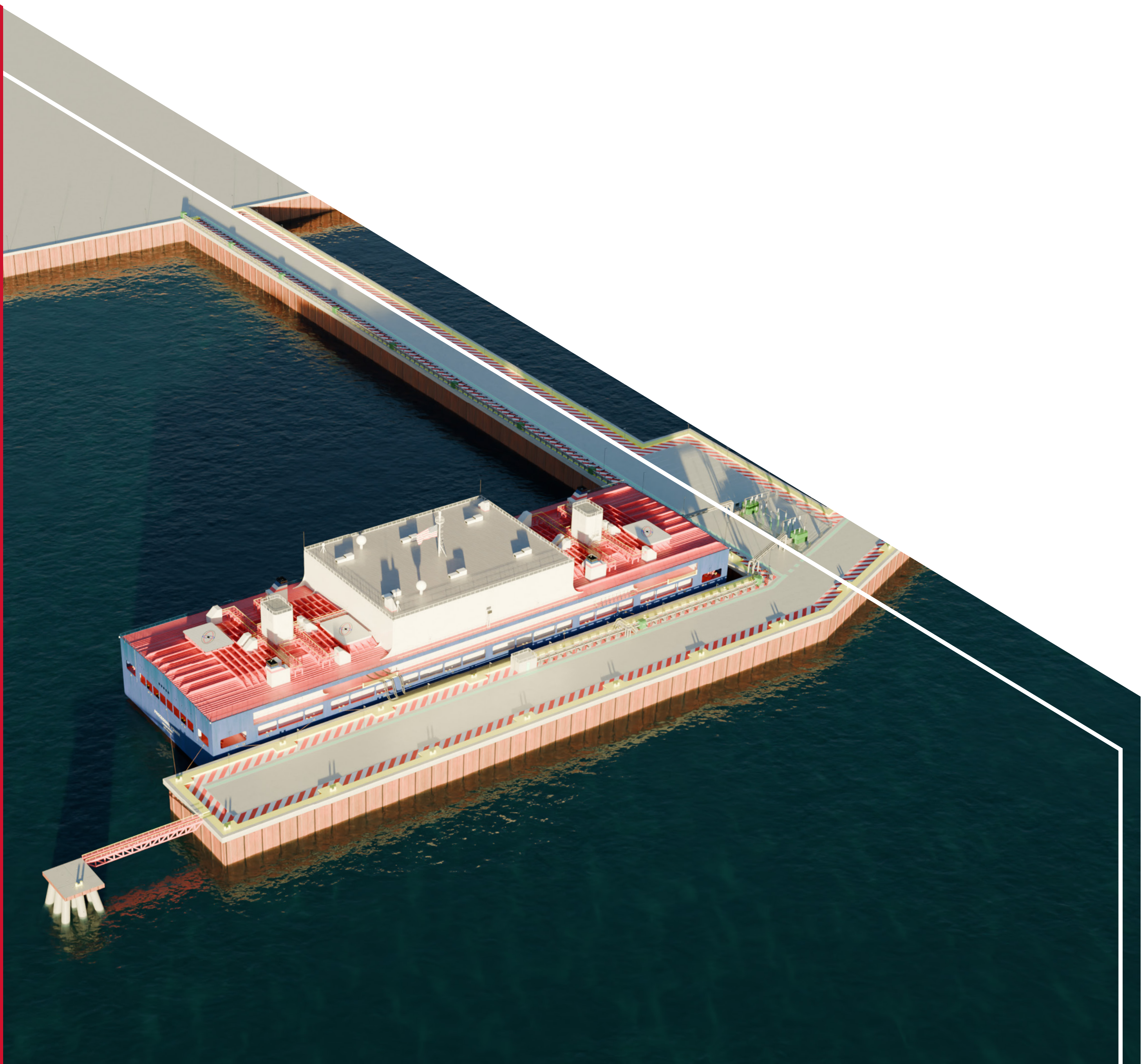
PATHWAYS TO A
LOW CARBON FUTURE

FLOATING NUCLEAR POWER DATA CENTER

IN PARTNERSHIP WITH



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BACKGROUND

Data centers have high electrical power demands and the rapid growth of new data centers supporting artificial intelligence (AI), cloud computing and crypto currencies are accelerating this power demand. The latest generation of computer processors are faster, require more power and produce increased levels of residual heat.

Concurrently, with this increasing power demand from data centers, electric vehicle charging, and other shifts to electrification in other industries, the existing power utilities are striving to expand to greener and more sustainable low-carbon energy and shutting down older fossil fueled power generation plants. This expansion of renewable power generation can result in limited grid power supply options for new data centers. Utilities, local regulators and the public are often reluctant to support large new connections to the grid. Often new connections come with conditions requiring capacity reductions during high grid demand periods.

Many new data centers are considering green options including bring your own power (BYOP) as part of their development plans to mitigate some of the issues with the limitation of existing utility grid infrastructure. Bring your own power can include solar panels, wind turbines, fuel cells, battery energy storage systems and on-site electricity generators powered by natural gas or biofuels. These systems help data centers enhance their power reliability, give some measure of grid independence and support overall corporate sustainability goals.

Also, part of the move to green data centers is the overall drive to improve efficiency, with a focus on power usage effectiveness (PUE) – the ratio of total power usage to the power used directly for computing. Improvements in PUE, generally coming from both software management tools, as well as advanced server cooling technologies such as direct-to-chip liquid cooling, and for some systems the use of an external cool water source to dissipate the generated heat. Other green data center characteristics include modular and scalable designs to meet rapid deployment and construction effectiveness.

Floating nuclear-powered data centers as described in this report seem to be an excellent match to the desired characteristics of the next generation of data centers, solving many of the issues associated with the upcoming expansion of the next generation of data centers. This design is a modern, efficient, high-density data center, which can employ advanced server cooling technologies, it is modular and remotely constructed, and comes with its' own dedicated grid-independent, fully fueled and carbon free power source.

INTRODUCTION

The scope of this report is to describe the concept design of a floating nuclear power data center. The design is an extension of the floating nuclear power plant (FNPP) described in Ref. [5], but it includes in its general arrangement volumes and systems sufficiently flexible to allow hosting a range of different servers, from large AI graphics processing units to much lighter data storage units.

The design is based on the Nautilus EcoCore cooling system (Ref.[7]) already employed for the Stockton Port floating data center (Ref.[6]) which takes advantage of the water surrounding the barge to improve server cooling efficiency. Since its four nuclear power plants also use this water as a heat sink, the design is intended to be generally deployable on waters that have sufficient current to dissipate most of its power rating.

Ref. [1 to 4] are assumed to form the basis of the regulatory requirements for classification and nuclear license, where the nuclear systems are to have a license from an approved Nuclear Regulator such as the Nuclear Regulatory Commission, and the barge structure and marine systems receive ABS Class. It is also assumed that the data center will be moored to a jetty to allow high-speed data connection, backup power access and straightforward personnel boarding.

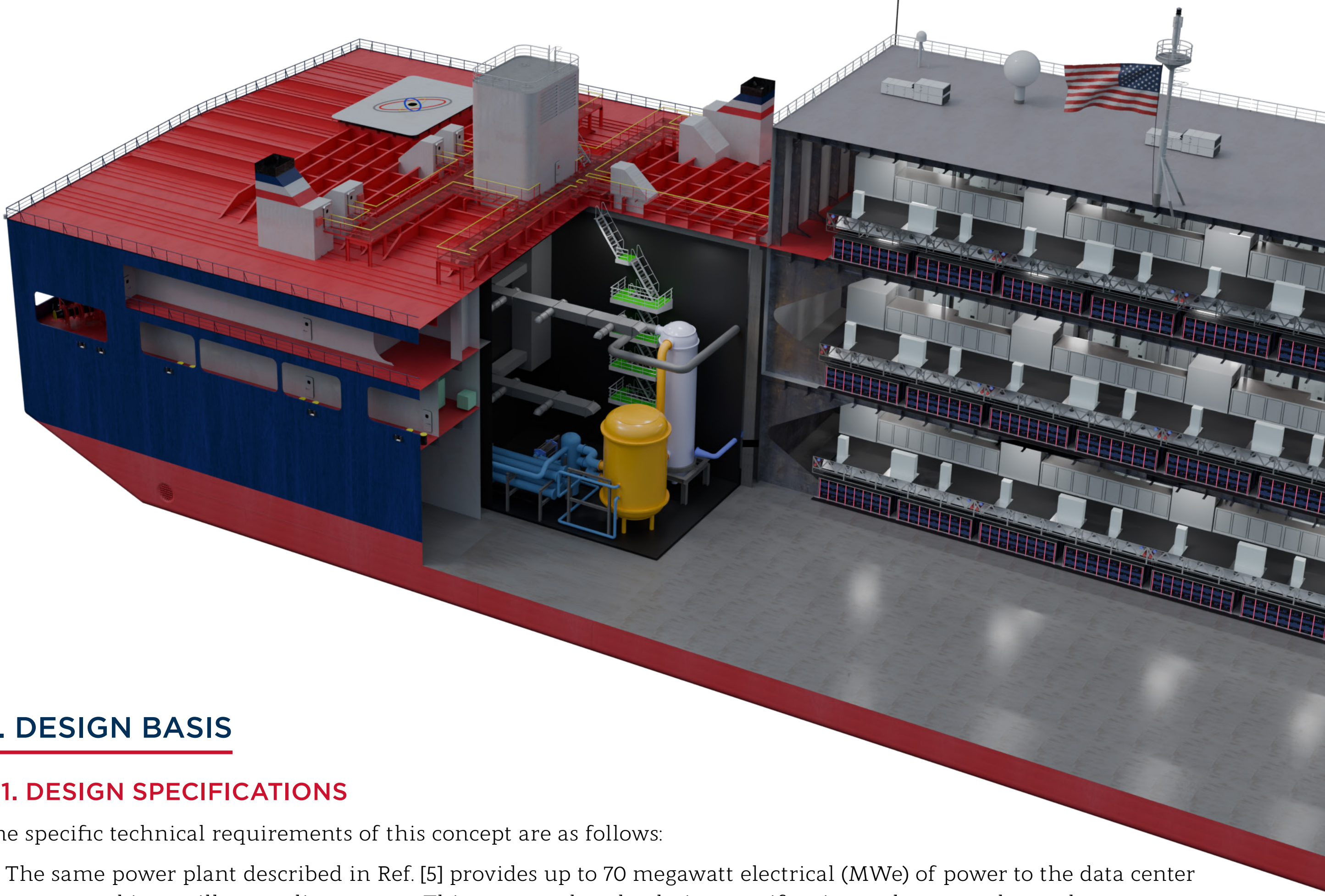
1. SCOPE OF STUDY

1.1. STUDY GOALS

The scope of this study is to develop a high-level design of a floating nuclear power data center intended as an independently powered unit to be deployed on large river estuaries or coastal waters that are strategically located to serve the information technology (IT) infrastructure.

As for the FNPP, the design assumes a sheltered, pier-moored installation which allows straightforward access to personnel, backup power and fast fiberoptic cable connections. For this reason, no anchoring facilities are part of the design. In this respect, it should be noted that placing this installation offshore would be significantly challenging as none of the forementioned aspects could be dealt with in a satisfactory manner. Data center connectivity through satellite links would be hampered by latency and an underwater data cable would be a significant expense. Similar considerations are also true for personnel access to the installation (probably implying the need for resident personnel and, consequently, more extensive accommodation facilities) and power backup arrangements.

No environmental impact analysis of this design was carried out. However, it is noted that the environmental impact of the installation of this barge will have to be considered in detail once a specific location is chosen to ensure that the heat released to the surrounding waters is efficiently dissipated without undue harm to the local surroundings. Similarly, no analysis was performed of the security provisions needed to ensure facility security.



2. DESIGN BASIS

2.1. DESIGN SPECIFICATIONS

The specific technical requirements of this concept are as follows:

1. The same power plant described in Ref. [5] provides up to 70 megawatt electrical (MWe) of power to the data center servers and its ancillary cooling system. This ensures that the design specifications relevant to the nuclear power generation of that design are also applied and met here.
2. The data center design needs to be flexible enough to adapt to a variety of server typologies. This implies that the data center volumes and floorspace are determined by the total power available and the cooling system chosen, rather than by the characteristics (size, power requirements, heat release) of the servers.
3. The design, beam and length of the barge should be such that it may be transported widely across the United States during sequential construction and outfitting and brought to its final location. The dimensions should allow mooring to be possible in a reasonably large number of locations.
4. The design needs to be cost-competitive and should be designed with economy as a critical factor.
5. Plant and IT personnel would only need day accommodation since it is expected that crew would alternate on board and otherwise live on shore. For this reason, minimal onboard transition accommodation for crew during barge relocation is included in the design.
6. Connection of the data center to the country's IT infrastructure is ensured through high-speed fiber cable connection.

2.2. DESIGN ASSUMPTIONS

Since servers and associated cooling systems technologies are mature and commercialized widely, the assumptions needed to define the characteristics of the data center module of this design are only limited by their current fast-paced development. In order to achieve a reasonable result, it was agreed that the design should be based on the Nautilus cooling system (Ref. [7]) since this is a proven modular design that is easily adapted to fit the basis FNPP barge beam.

It should be noted that more powerful and efficient cooling systems are being developed to serve the high-end of the server power spectrum. Some of these are designed to use liquid to cool the relevant server components directly and therefore would need less volume than the one required by the Nautilus EcoCore system. Since no sufficient detail is available on these systems at this time, they were nevertheless not considered for this specific design.

2.3. COOLING SYSTEM TECHNOLOGY

The Nautilus EcoCore system is a modular air cooling system that uses an external water source as ultimate heat sink. This system is already in use on a floating power barge (Ref. [6]) and consists of a basic block designed to cool a pool of servers with a total required power equal to 2.5 megawatt (MW). The specifics of such servers is not important, as long as the total heat released by them over the area of the room they occupy is not above the maximum heat rejection per unit area of the Nautilus EcoCore block. Nautilus EcoCore blocks are often assembled together to extend the cooling capacity to integer multiples of 2.5 MW.

Each Nautilus EcoCore block is composed by nine basic units: one cooling distribution unit (COOL2500 – comprising four compressors/evaporators/condenser modules designed to handle the high-performance cooling demands of AI and high-density environments), two power units (PWR-LV-2500 – providing electricity to the COOL2500), one reserve unit (RES-LV-1250 ensuring redundancy of the power distribution system), four hot aisle units (AISLE-HT – distributing cooled air and conveying heated air back to the COOL2500), and one accessory space unit (AISLE-CL – used to close the air distribution loop and host ancillary systems).

Each Nautilus EcoCore unit measures 13.75 meter (m) by 2.44 m, so the dimensions of each Nautilus EcoCore 2.5 MW block are 13.75 m by 21.96 m, covering 301.95 meters squared (m^2) of floor area. This corresponds to a rated heat rejection per unit area equal to 8.6 kW/m^2 (max 11.03 kW/m^2). This cooling capacity is delivered at a PUE of 1.15 or less, which means that if the total power needed by the Nautilus EcoCore 2.5 MW block cooling system plus the servers it cools is 2.5 MW, the power available to the servers alone is approximately 2.174 MW. The system is designed to work producing a maximum of 2° C temperature increase in the ultimate heat sink water, and each Nautilus EcoCore 2.5 MW block weighs 272.2 metric tons (MT).

The Nautilus EcoCore 2.5 MW block is designed to be installed above the servers' area. The minimum clearance needed from the servers floor to the ceiling above the cooling system is 9.2 m to ensure sufficient volume for efficient air recirculation.

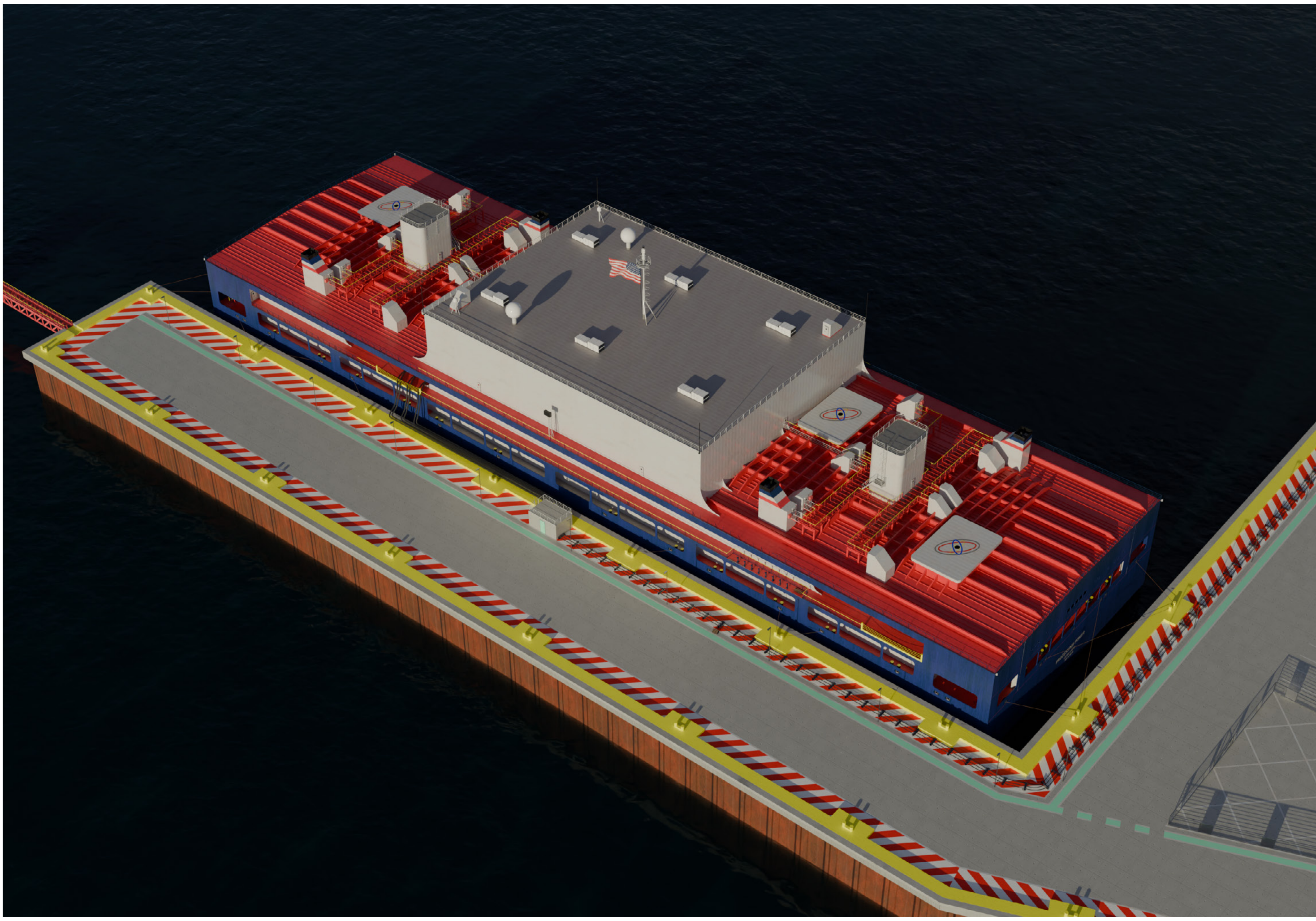
2.4. SERVER CHARACTERISTICS

Each Nautilus EcoCore 2.5 MW block is capable to cool effectively a pool of 160 servers racks each needing approximately 13.6 kilowatts (kW) of power. Assuming each rack can host five servers, this corresponds to 2.72 kW per server, which is at the lower end of the average AI computing needs. Assuming these racks have a 24" (0.61 m) by 36" (0.91 m) footprint and are distributed evenly over the floor under the Nautilus EcoCore 2.5 MW block, this corresponds to a floor area ratio (server footprint/cooling area) equal to three, which is an indication of a relatively dense floor usage.

These characteristics represent a mid-density rack configuration with advanced air cooling and was selected to match the cooling characteristics of the modular Nautilus EcoCore units which are well suited to the overall design concept. Alternate configurations using high-density 50+ kW racks and using even more advanced cooling technologies (direct-to-chip liquid cooling, or processor immersion cooling) could be considered, along with other mixed configurations employing a range of low-, mid- and high-density server racks.

For the development of this data center, a high-end AI cloud server configuration was also considered. This is the Nvidia DGX H100/H200. These servers need 10.2 kW of power each and measure 14" (0.356 m) in height, 19" (0.482 m) in width, and 35.3" (0.897 m) in depth. This corresponds to a form factor equal to 8U making it possible for each rack to host a maximum of five servers. Each server weighs 130.45 kg, resulting in a total of 0.8 MT per rack and a local deck loading of approximately 1.4 MT/m^2 assuming the same rack footprint as above. Since the required power (and produced heat) per rack is approximately 51 kW. Staying with the current EcoCore cooling units and the current reactor power, only about 45 such racks can be cooled by each Nautilus EcoCore 2.5 MW block. This corresponds to a floor area ratio (server footprint/cooling area) equal to 12, which is a sparse floor usage. The total server weight per Nautilus EcoCore 2.5 MW block is approximately 36 MT.

Alternative arrangements with a denser floor usage of high-end 51 kW per rack servers are possible but would entail a significant increase in the overall power and cooling capability. Alternate small modular reactor/generator packages with higher powers and cooling systems with greater capacity and efficiencies using immersion cooling may be possible but were beyond the scope of this study. An alternate configuration with a total power generation of about 200 MW, if the reactors and cooling modules could be modularized, would result in a data center categorized as a hyperscale and would be of similar capacity to what is planned for the next generation of Microsoft, Alphabet (Google, YouTube), Amazon, and Meta (Facebook), and Apple land-based data centers. Note that the cooling requirements would also be significantly greater for such an alternative arrangement requiring a closer look at the site location and perhaps considering offshore locations with larger potential for heat dissipation. In this case, it would also be necessary to arrange a high-speed underwater fiber cable connection, as well as sufficient onboard accommodation for a permanent crew and possibly a helipad.



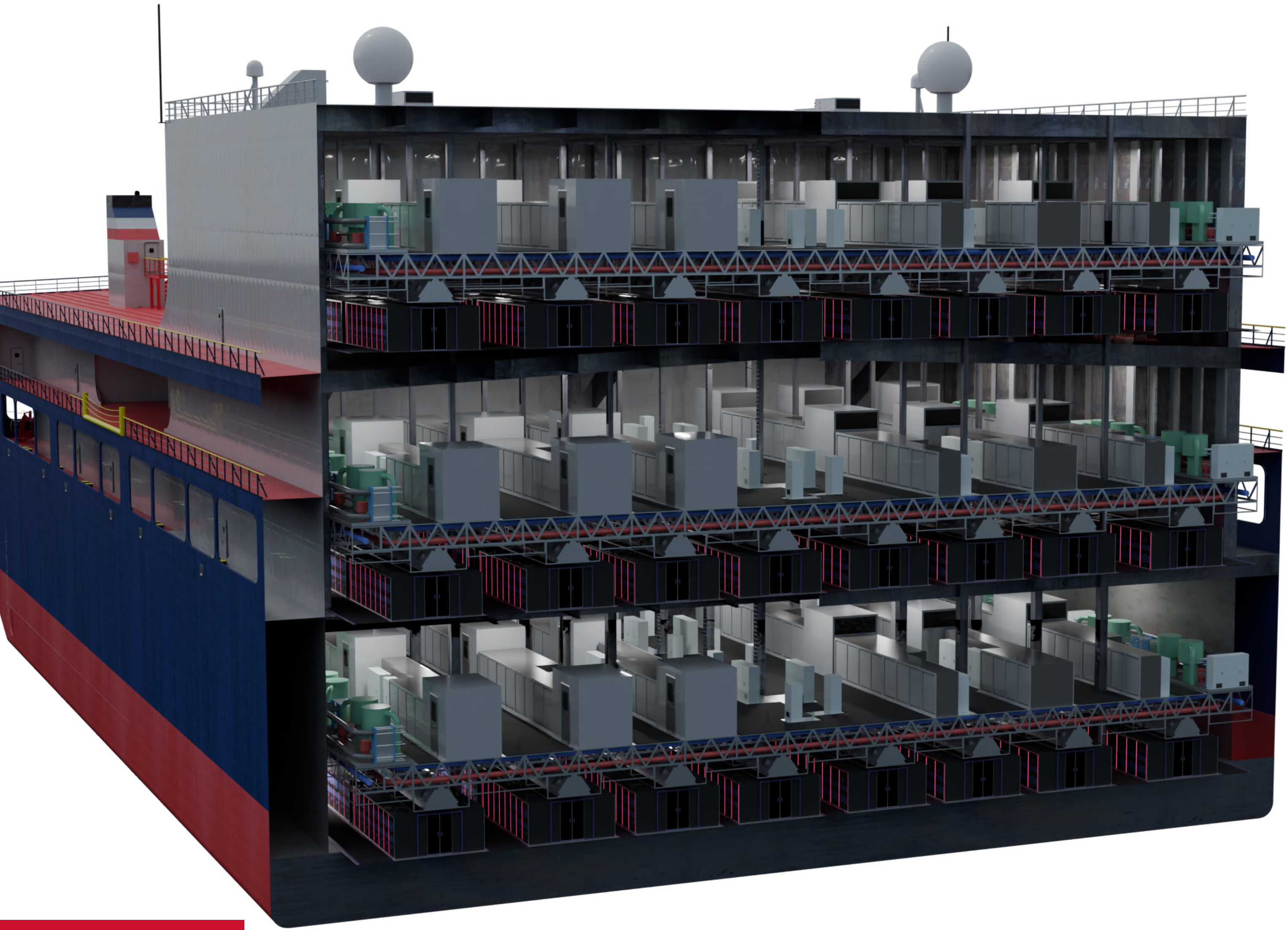
2.5. ONBOARD POWER MANAGEMENT

In the current design, it is assumed that the data center power demand is entirely managed by the on-board reactors and power conversion systems. Electric power can also be sourced via shore connection, but this is not mandatory for the operation of the barge. Assuming there is no shore connection to facilitate the power flow in or out from the barge, the generated electric power needs to match the demand from the data center servers.

Data center power demand can fluctuate depending on the geographical location, data connection, and the time of the day. In extreme cases, such as a remote data center that does not coordinate its computational load with other data centers, the computational load and hence the power demand of the data center can drop by double-digit percentages during the day (for example after midnight). This drop can also last for a few hours. During this time, the power will be reduced to match the power demand from the data center servers.

Modern advanced small modular reactor design can achieve a load adjustment response rate of up to 10 percent of rated power per minute. This means that in an ideal situation within a few minutes the reactor can be adjusted to the required power levels. To facilitate this transition in reactor power without the support of external/shore power supply, the data center servers can also be regulated so that their aggregated power demand follows that of the reactor generating power during the reactor's derating process. This can be achieved by scheduling the computational tasks and throttling internet traffic via the data link between the barge and shore.

Furthermore, battery energy storage systems can be considered to perform peak-shaving operations when the power demand from the data centers fluctuates. Specifically, the battery system can store the excess power of the reactors during long periods of lower power demand from the data center. The battery energy storage system could consist of containerized battery systems, each have a 20-feet container footprint. This will allow for placing these battery containers on deck. Other form factors could also be explored, such as cabinet type battery systems that can be located under the deck. The safety management of these battery systems will be a very important factor to consider should they be placed on the floating nuclear data center.



2.6. WASTE HEAT AND ENVIRONMENTAL IMPACT

This data center design is based on the fundamental assumption that the heat generated by reactors and servers can be discharged in the water/air surrounding the barge. This is effectively equal to the large majority of the rated thermal power of the BWXT Advanced Nuclear Reactors (BANR), i.e. 4 x 50 megawatt thermal (MWt) = 200 MWt or approximately 700 MBtu/hour (although a smaller portion of this heat will be dissipated through air ventilation or if air cooling system for the servers is selected). This requires the floating data center to be in a location with adequate water/air current flow.

The minimum natural current flow under the keel needed to dissipate the above mentioned heat depends on the amount of water used to cool servers and steam in the power plant condensers. In turn, this depends on the maximum allowed temperature change between inlet and outlet seawater (often referred to as Delta-T). This is generally around 10° C for open waters, but it can be lowered to as little as 2° C in inland and coastal waters. The lower the Delta-T, the larger the amount of water needed to dissipate the produced heat, and therefore the larger the minimum current flow under the keel.

In summary, the integration of a nuclear power plant into a floating data center introduces significant heat dissipation challenges that must be taken into account during the early stages of project planning. As mentioned, a 200 MWt nuclear data center producing 70 MWe power can generate up to 200 MW of residual thermal heat (nuclear waste heat plus server cooling) that must be safely and efficiently released into the surrounding environment. Without careful planning, this heat discharge could significantly impact the local air and water temperatures (>5° C Delta-T increase in some cases), posing risks to equipment performance, marine ecosystems and regulatory compliance. By carefully evaluating the site location, heat sink size/capacity, discharge angle and water/air flow dynamics, one can minimize environmental risks while ensuring stable operating conditions.

3. FLOATING NUCLEAR DATA CENTER DESIGN

3.1. GENERAL ARRANGEMENT

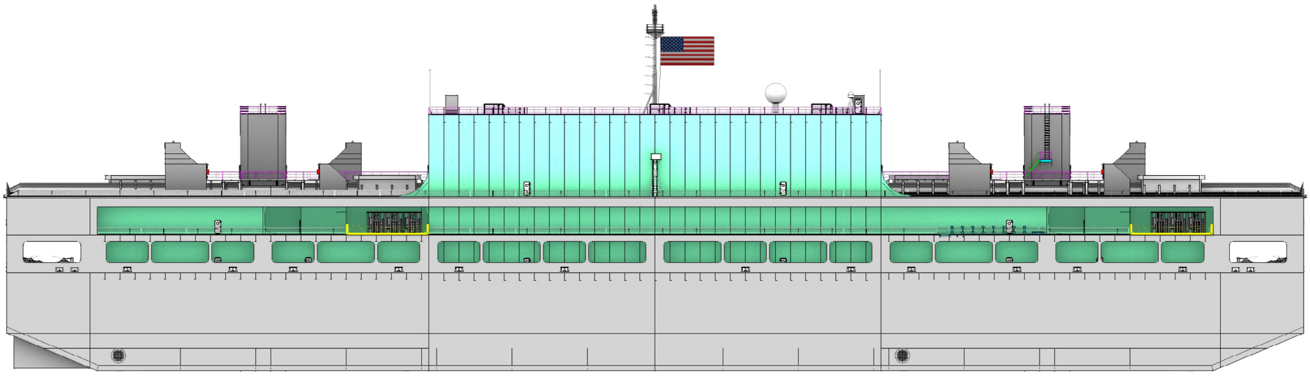


Figure 1: Outboard profile.

The proposed layout of this data center is derived from that of the FNPP, retaining the modular construction of the power plant, but adapting it to match the volumetric needs of the data center (see Figure 1). The data center is arranged at MS, between the aft two and the fwd two BANR power plant modules and the principal change in the FNPP original setup is the increase of the nuclear reactor room clearance height from 7 to 10 m. This allows the deck structure to be continuous between nuclear power plants and data center, retaining the minimum clearance needed by the cooling system.

The data center comprises three main volumes, each hosting eight 2.5 MW Nautilus EcoCore blocks, with the top volume arranged as a hull superstructure. This is equivalent to 24 x 2.5 MW = 60 MW of nominal power demand, which uses up 85 to 90 percent of the combined 70 MW rated power capacity of the four BANR power plants. The remaining power is dedicated to peak demands (the 2.5 MW rating of the Nautilus EcoCore blocks is based on their nominal cooling rate and 1.15 PUE, but the system is capable of a somewhat higher max cooling capacity at the expense of additional power) and ancillaries not explicitly taken into account in the preliminary power sizing.

This arrangement allows the data center to fit well in the original 50 m FNPP beam, adding approximately 60 m length to its 112 m length overall (LOA), split in two large compartments separated by a transversal bulkhead at MS. The resulting 172 m LOA is deemed to be manageable. The associated width of the eight 2.5 MW Nautilus EcoCore blocks also allows the retaining of the two external longitudinal bulkheads which provide continuous walkways to connect the fwd and aft accommodation and mooring facilities. This is an essential feature for safety and operability of the barge.

The reactor compartments retain the B/5 longitudinal bulkheads that provide collision protection, but this feature is not carried over to the central portion of the barge to ensure an open plan arrangement for the server areas. This also means that the CL longitudinal bulkheads needed for the radiological shielding are substituted by pillars in the central portion of the barge. Radiological shielding of the data center is ensured by transversal bulkhead at each end of the two power plants, creating a cofferdam similar to that separating each reactor room from the neighboring power production plants. Structure continuity is ensured by sets of large longitudinal brackets.

It is not entirely clear what stability standard should be used for this barge. Since it is essentially an unmanned barge, it could be argued that only the International Maritime Organization (IMO) Intact Stability Code, Part B – Chapter 2 – 2.2 Pontoons would apply. This is a simple check of 15 degree positive stability range, and a 30 m/sec wind heel to not more than half the freeboard. However, since the consequences of a stability accident on this installation can be significantly more severe than those on the average unmanned barge, it was decided that this design should be checked against the full IMO Intact Stability Code General Criterion and Weather Criterion, as well as the MARPOL damage stability criteria.

Because of the large beam, relatively dense subdivision, and very high freeboard, both of the above stability standards can be met easily by this design. However, it is noted that to meet the IMO Intact Stability Code General Criterion and relieve some of the natural hogging bending moment created by the weight of the reactors at the two ends of the barge, it is necessary to use ballast in the double bottom tanks under the data center, resulting in an operational draft of 6.2 m.

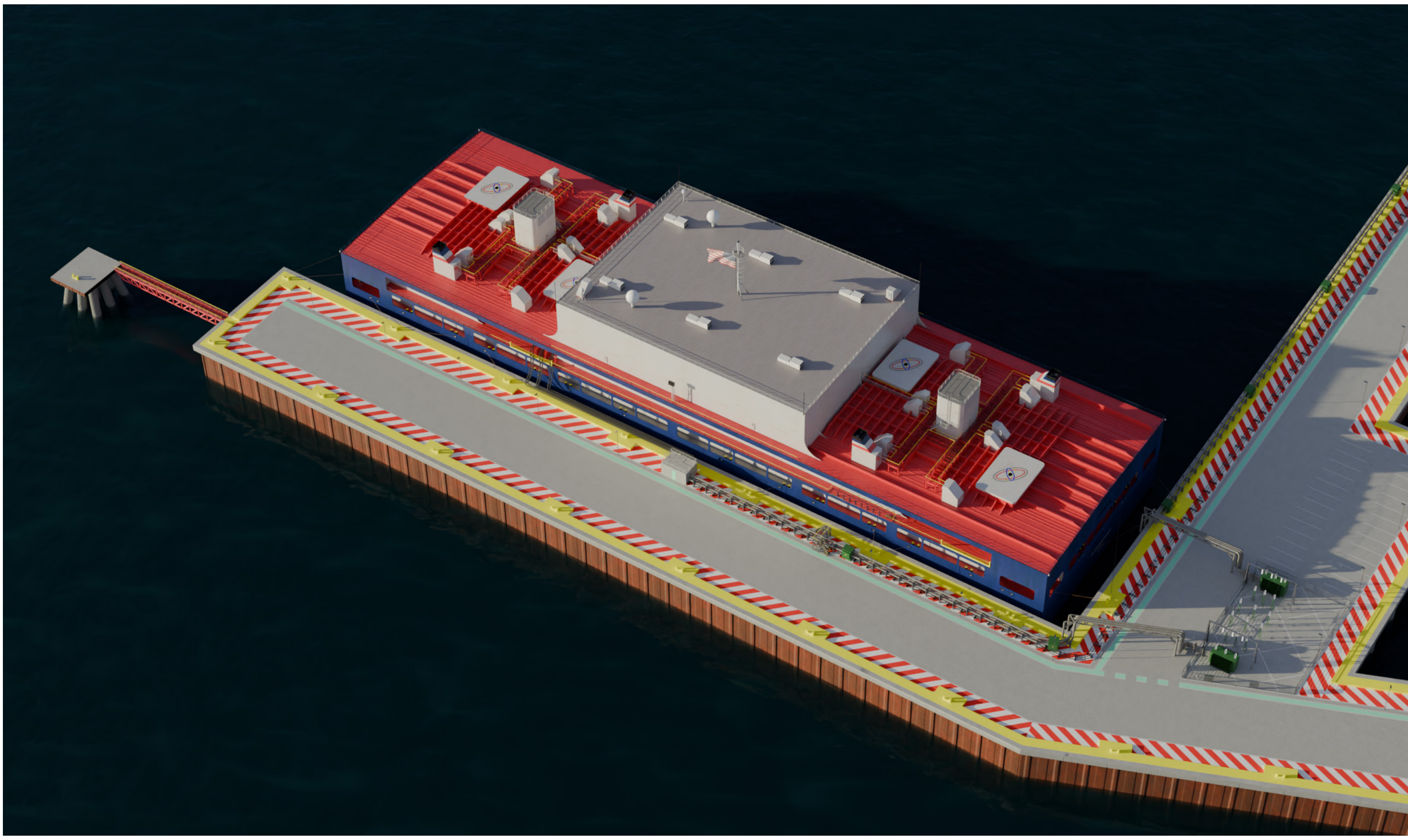
3.2. STRUCTURAL LAYOUT

Structurally the barge is constructed of two different types of sections, the nuclear power plant sections fwd and aft and the data center section amidships. The nuclear power plant section is derived from the FNPP design with modifications to accommodate the data center section.

The nuclear power plant structural arrangement centers around the key consideration of having to keep all steel structure on the exterior of the reactor compartments as to not interrupt internal insulation and radiological shielding. Consequently, a layout was adopted that employs box transversal bulkheads situated at the end of each room, offering a two-meter-wide cofferdam that allows for the necessary structure to be situated on the external wall of each reactor room, while also creating space for insulation, inspection, instruments, and radiological shielding (Figure 2). Similarly, three cofferdams extend the length of the nuclear power plant sections, one at CL, and two at 15 m port and starboard. These cofferdams are two stiffener spaces wide (approximately 1.5 m) and connected with diaphragm plates with manhole cutouts at every frame to allow access.

In addition to the double bottom and main deck, two partial decks at 13 and 18 m above baseline (BL) extend continuously along the length of the barge throughout the wing sections, outward of the B/5 limit. These decks provide support for mooring arrangements, emergency generators and associated fuel, as well as a ring walkway around the entire barge. These decks also provide support for two flats in the power generation rooms where the control rooms and turbomachinery are located. Neither of these flats are present in the reactor rooms. Thus, they are not longitudinally continuous and not considered as providing longitudinal strength.

The data center structural arrangement is primarily influenced by the need to provide sufficient volume and vertical clearance above the servers to allow for sufficient ventilation and air circulation and the need to maximize structural continuity with the nuclear powerplant sections. In order to allow for sufficient ventilation above and around the servers 10 m clearance was required above each deck. To accommodate this the inner bottom is a 3 m above baseline (ABL), the second deck at 13 m ABL, the main deck is cambered between 23 and 24 m ABL and the top of the superstructure deck is located at 34 m. The other major impact of the ventilation and air circulation requirements of the servers is that each deck should not be subdivided by longitudinal bulkheads like the nuclear data center section. As this would result in a 45 m span between the inner hull longitudinal bulkhead, each deck is formed with a grillage girders structure supported by pillars. These pillars are located every 6 m along the length of the section at CL, 7.5 m port and starboard (P&S) and 15 m P&S reducing girder spans to 7.5 m.



Structural continuity is the greatest challenge associated with the structural arrangement of this barge as all longitudinal bulkhead excluding the shell do not align between the nuclear power plant and data center sections. As a result, significant transitional structure is required to minimize the effects of these misalignments. Large soft toed triangular brackets as shown in Figure 3 will protrude approximately 9 m into the data center section to transfer longitudinal bending stress from the nuclear power plant section CL and 15 m P&S bulkheads to the data center decks whilst trying to minimize stress concentration points and thus fatigue hotspots. Similarly, large triangular brackets will protrude into the nuclear power plant ballast tanks and nuclear power plant mooring deck space in line with the 22.5 m P&S inner hull bulkheads in the data center section. Large radiused brackets will be located between the main deck and the data center superstructure outboard bulkheads. The decks continuous deck in the nuclear power plant and data center sections all align. It should be noted that the main deck camber is retained throughout the data center section to aid structural continuity (level grating will be installed internally to allow for the installation of the servers). The girder and stiffeners of the main deck are located above the deck in the nuclear power plant sections so as not to interrupt internal insulation and radiological shielding. These girder will transition to being located under the deck in the data center section. It should be noted that this barge is likely to spend most of its lifespan in sheltered waters such as rivers, thus experiencing less wave loading resulting in less fatigue wear over its life reducing the potential impact of structural discontinuities.

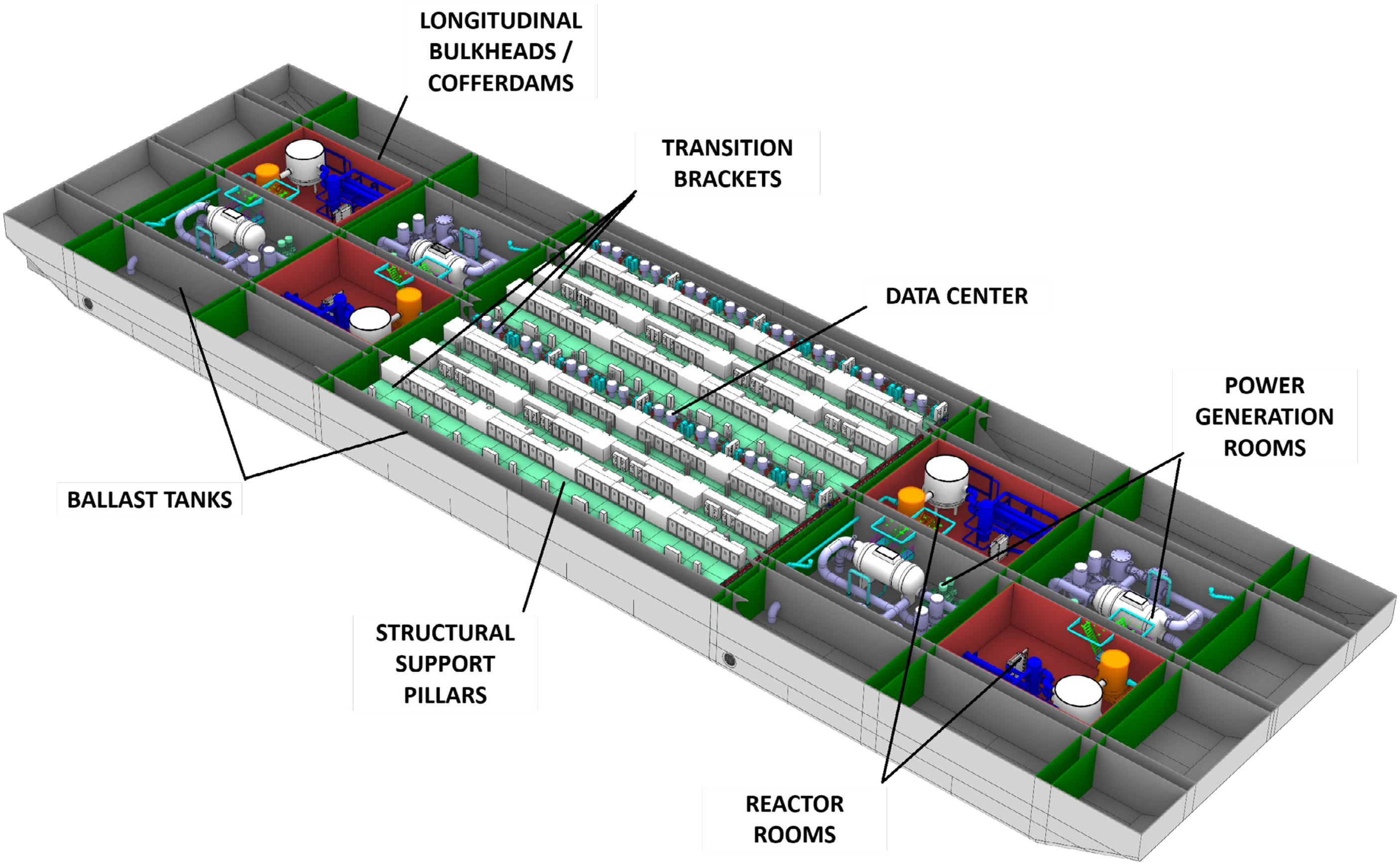


Figure 2: 22.5m ABL cut view depicting the layout and location of rooms and cofferdams.

A longitudinal frame spacing of 0.75 m was chosen, with a non-tight web frame located at every frame and watertight subdivision by a pair of transverse bulkheads forming a cofferdam where appropriate. A vertical stiffener spacing of 800 mm is implemented from above the inner bottom to the main deck for stiffeners on the side shell and on the longitudinal bulkheads. Deck longitudinal stiffeners are spaced 750 mm from CL to the 22.5 m off-centerline longitudinal bulkheads. Outboard of these longitudinal bulkheads, the deck longitudinal spacing transitions to 833 mm, which is continued to the side shell.

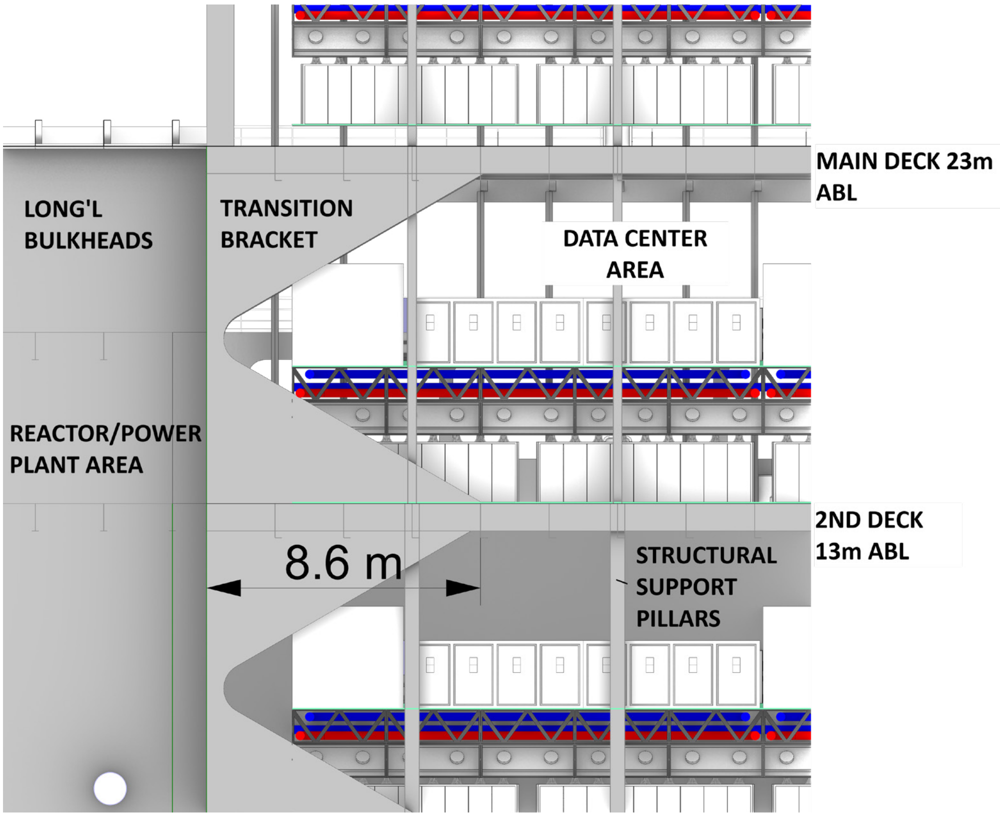


Figure 3: Longitudinal elevation at CL of transitional brackets between nuclear power plant and data center section.

3.2.1. SCANTLINGS

ABS *Rules for Building and Classing Barges* and ABS *Rules for Building and Classing Marine Vessels* were followed for the initial scantling sizing of the FNPP. The vessel was divided into four analysis regions from the keel to the inner bottom at 3 m ABL, from 3 m ABL to 11 m ABL, from 11 m ABL to 16 m ABL and from 16 m ABL to main deck at 24 m ABL for the purposes of sizing scantlings and calculating design pressure heads. Utilizing four regions allowed for a degree of basic tapering in scantlings, while also keeping the analysis simple for this high-level conceptual design.

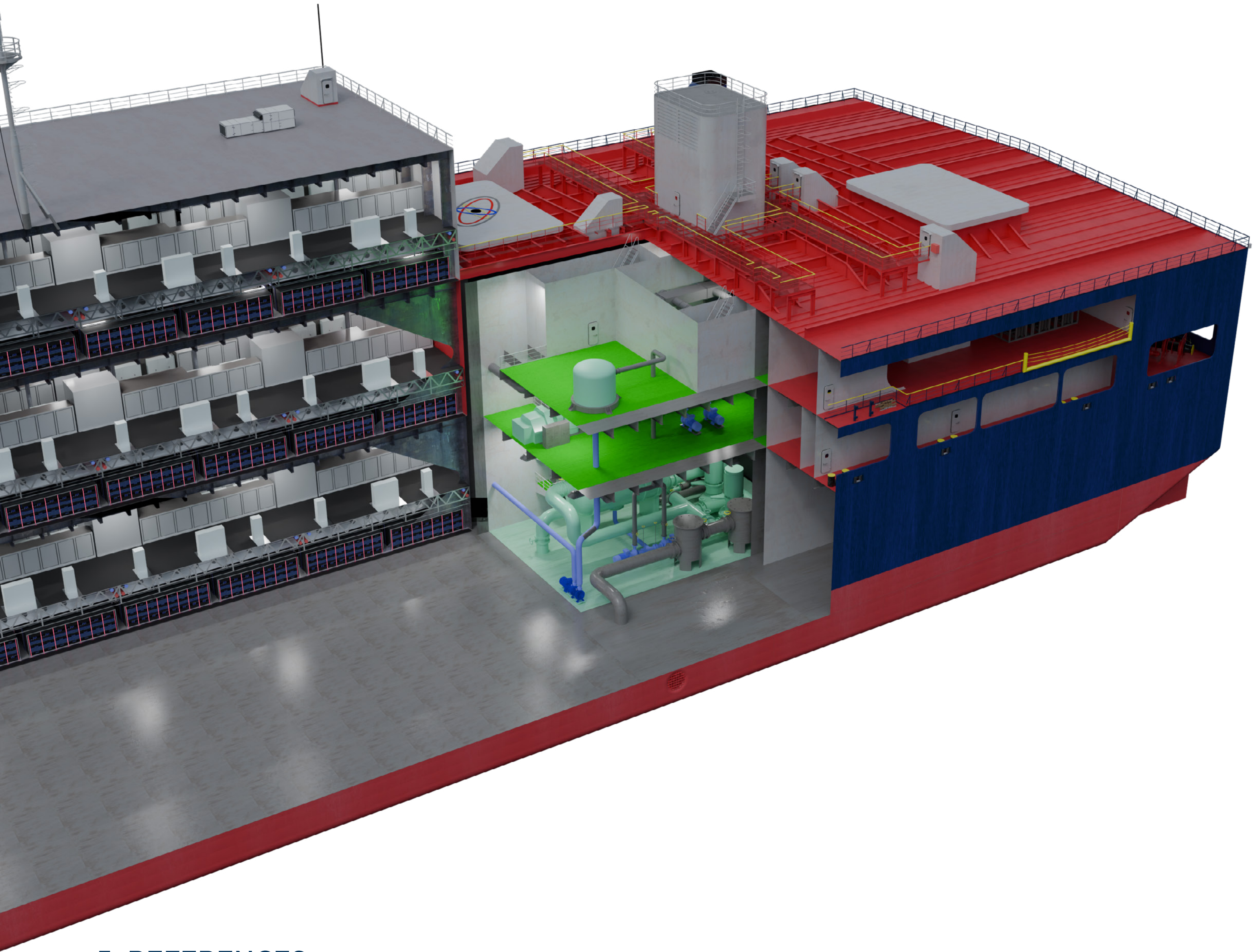
3.2.2. STEEL WEIGHT SUMMARY AND HULL GIRDER SECTION MODULUS

By analyzing a variety of load cases that the barge could commonly operate at, a still-water bending moment envelope was derived and the required hull girder section modulus was obtained from the 2024 ABS Steel Barge Rules. Considering the maximum still water bending moment from the different load cases and the design wave bending moment, a hull girder section modulus of 470,652 cm^2-m is required. With the prospect of the barge being kept in port and experiencing less wave loading and consequently fatigue wear over its life than would be expected from a non-stationary barge, it can be expected that the required section modulus of the barge would be considerably greater than would be actually required. In fact, local scantling considerations ended up being more significant than hull-girder bending loads when sizing of the structures. In other words, the initial steel scantlings resulted in a section modulus in the nuclear power plant sections approximately 13 percent greater than that required by minimum Rule requirements and in the data center section approximately 62 percent greater than that required. This corresponds to a steel weight of approximately 16,300 MT. This corresponds to a combined steel weight for the nuclear sections of approximately 10,760 MT and a data center section steel weight of approximately 5,090 MT. This results in a total steel weight for the barge of approximately 16,300 MT including transitional structure. This calculated steel weight includes all major structural elements including decks, bulkheads, shell, pillars, data center superstructure and all associated girders and stiffeners. A margin has been added to cover local structural details such as small stiffeners and doubler plates.

4. SUMMARY AND CONCLUSIONS

The main conclusions of this study are as follows:

- The maturity of advanced nuclear technologies that may be implemented for a FNPP (and therefore this data center extension) is currently low. Therefore, the level of detail provided in this study is limited to engineering information available from the design of terrestrial applications for engineering postulation and recommendations for future design optimization.
- The modular philosophy adopted for the FNPP design allows a straightforward extension of that design to host a large data center.
- Both designs need to be installed in a location with sufficient current to ensure that the heat transferred to the water from the nuclear power plant (and the servers cooling system) is displaced from the immediate surroundings and dispersed efficiently without increasing the temperature of the inlet cooling water.
- Appropriate arrangements need to be made to ensure the security of these plants. This is outside the remit of the barge design and pertain mostly to the location of its installation.



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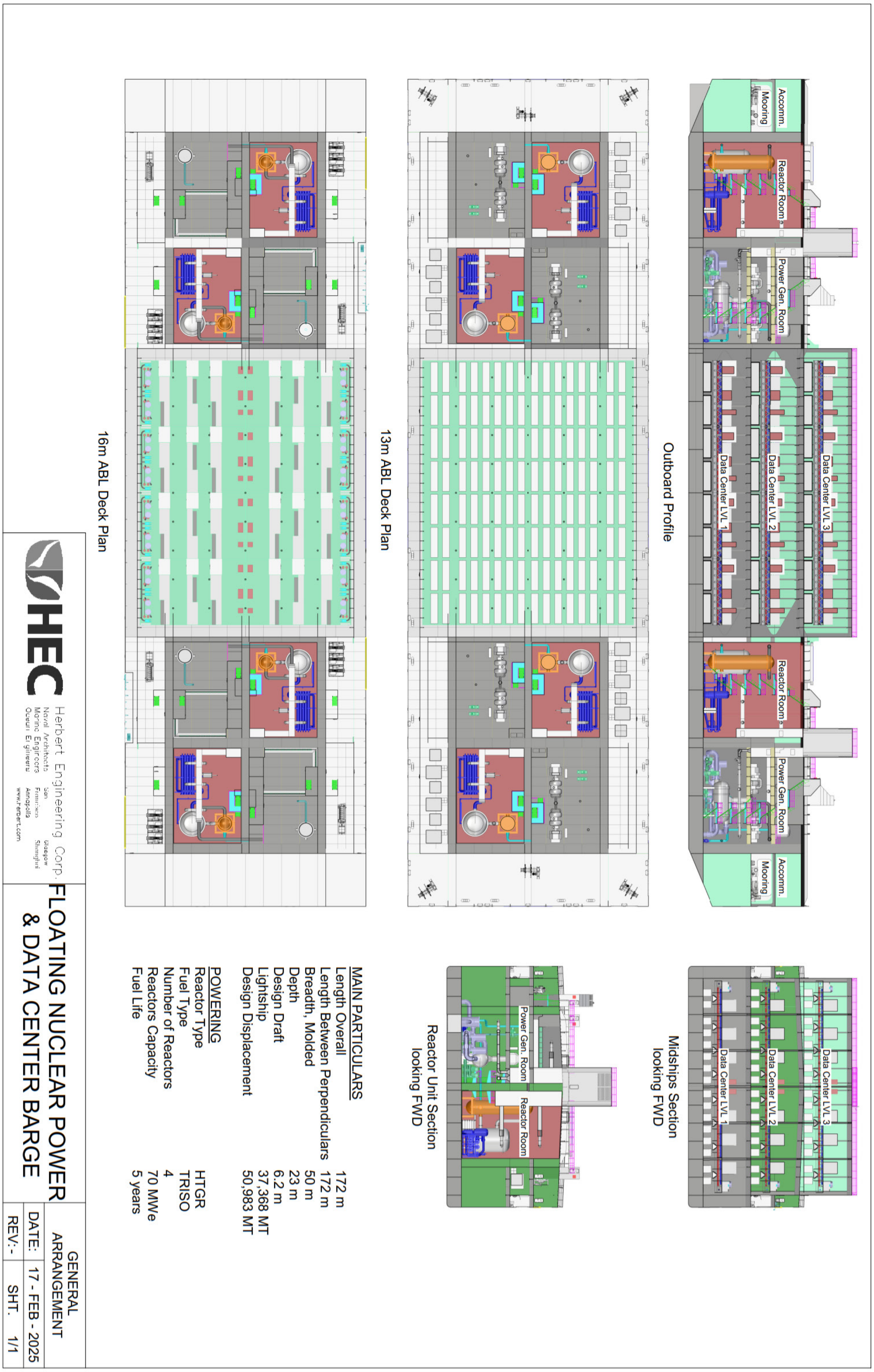
6. ACRONYMS AND SYMBOLS

ABL	above baseline
AI	artificial intelligence
B	ship's beam; the vessel's width
BL	baseline; intersection of the longitudinal symmetry plane with the keel
BANR	BWXT Advanced Nuclear Reactor
CAPEX	capital expenditure
CL	center-line; the vessel's plane of symmetry
CO_2e	carbon dioxide equivalent or CO_2e means the number of metric tons of CO_2 emissions with the same global warming potential as one metric ton of another greenhouse gas
EPZ	emergency planning zone
FNPP	floating nuclear power plant
HALEU	high-assay low enriched uranium (up to 20% of 235U)
HEU	highly enriched uranium (235U above 20%)
HTGR	high-temperature gas reactor
IAEA	International Atomic Energy Agency
IT	information technology
IMO	International Maritime Organization
LEU	low-enriched uranium (up to 5% 235U)
LOA	length overall
LNG	liquefied natural gas
MBTU	mega British thermal unit
MS	midship location
MT	metric ton
MW	megawatt
MWt	megawatt thermal, a unit of power used for the thermal output of a reactor before conversion to electricity
MWe	megawatt electrical, a unit of power used for the electrical output of a nuclear plant
OPEX	operating expense
P&I	protection and indemnity insurance, as provided by a P&I Club
P&S	port and starboard
PUE	power usage effectiveness
TRISO	fully ceramic tri-structural isotropic coated particle-based fuels
UCO	uranium oxycarbide

7. APPENDIX A — DESIGN SKETCH



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