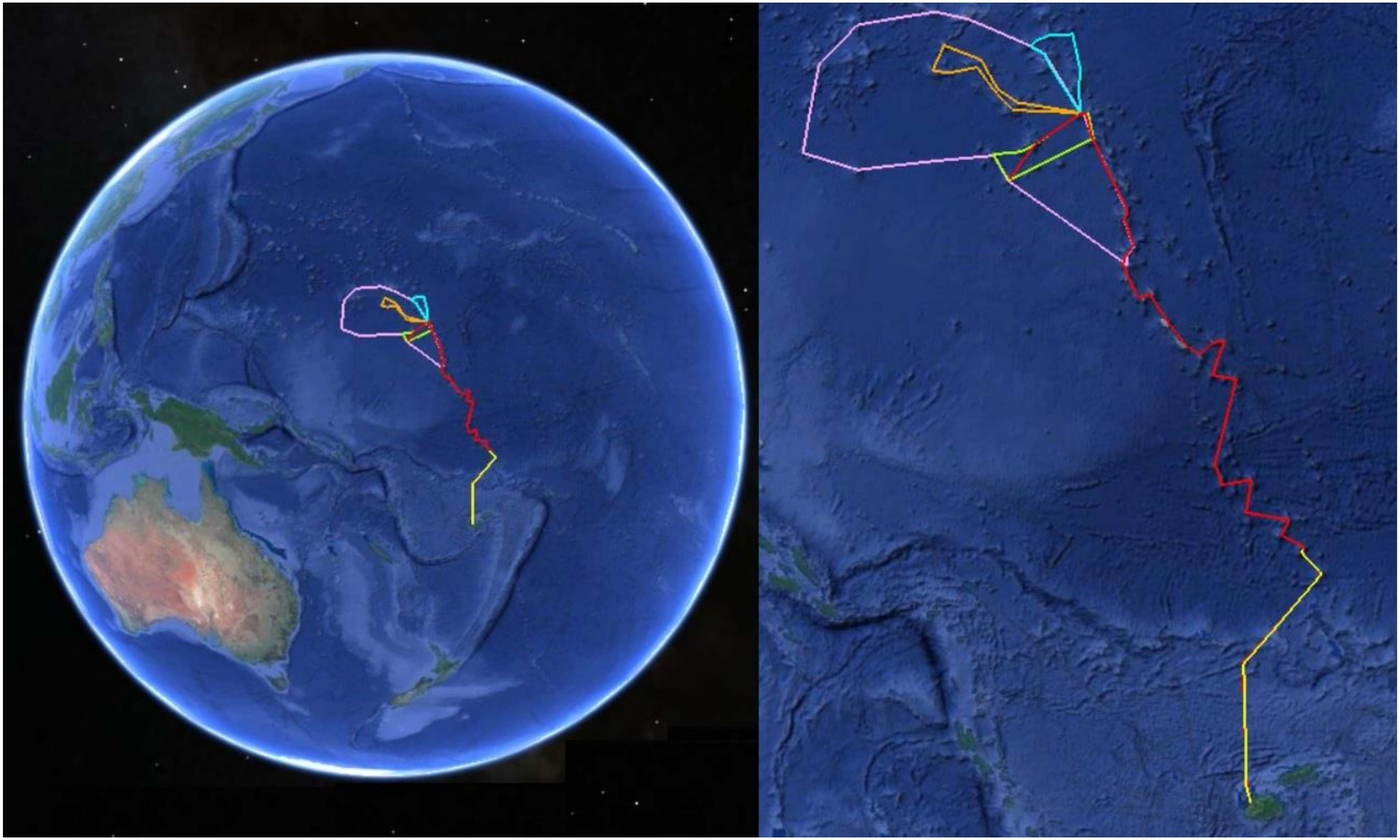
Cerulean Project
Design Review Team Findings Report

Micronesian Center for Sustainable Transport
(November, 2019)

A joint collaboration between RMI Government and USP

Contents

Map of Cerulean Project Proposed Operational Area & Prospective Routes



List of Abbreviations

CJR – Captain John Rounds

DWT – Deadweight Tonne

EPIRB – Emergency Position Indicating Radio Beacon

GT – Gross Tonne

HE/L – Hochschule Emden/Leer

IBC – Intermediate Bulk Container

IVL – Island Ventures Limited

LOA – Length overall

LOD – Length on-deck

MCST – Micronesian Center for Sustainable Transport

SOLAS – (The International Convention for the) Safety of Life at Sea

Introduction

The Design Review Team Findings report consolidates and presents the information collected through consultations between the MCST Cerulean Project Staff and the Design Review Team since the project inception in May. The multi-dimensional analysis summarizes the various discussions and information collated in the Options Analysis Matrix used by the team to evaluate route, transport work, and design parameters and priorities. The information contained within represents the cumulative contributions of the design review team to specify a realistic operational scenario for the Cerulean Vessel, and this report is intended to serve as a snapshot of the current project direction and outline of how various determinations have been made. As the Business Case & Operational Plan is formalized alongside the Costings Review, Design Review Team input will continue. As such this report should be considered a working document.

Members of the Cerulean Design Review Team:

Captain John Rounds, Kiribati National Shipping Line

Captain John Rounds has decades of experience around the Pacific Islands in the maritime sector, having served as Deputy Secretary for Transport in the Fiji Government, Director of Fiji's Maritime Safety Authority, and Shipping Advisor for the Secretariat of the Pacific Community (SPC). He is currently CEO of the Kiribati National Shipping Line. Capt. Rounds' focus on expanding outer island service to the atolls of Kiribati and incorporating efficient design and cost-effective operations leaves him appropriately positioned to provide crucial guidance in the context of the Cerulean Project to help address the specific maritime transport needs of small island states.

Captain Brad Ives and Evyatar Resheph, Island Ventures, Ltd.

Captain Brad Ives is the President of Island Ventures, Ltd. and the Senior Captain of the SV Kwai. He has over 25 years' experience in traditional sailing and commercial seafaring. SV Kwai is his third project, which involved converting an old ship to a sailing ship. In the 1970's, he was the captain and part owner of the SOFIA, a 90' Baltic Trader converted for world voyaging, carrying cargo in the West Indies and later trade goods, from sugar to ebony elephants, through the Pacific and Indian Oceans. In 1978, he purchased the EDNA, a 100' ex-fishing vessel in Denmark, refitted in Portugal, and operated as a sailing cargo vessel for nine years, trading mostly in construction materials. The same year, he earned the US Coast Guard Master of Sail License for up to 300GT, now upgraded to 500GT. Brad has extensive experience building boats as well, installing engine, electrical, plumbing and navigational systems aboard yachts. Island Ventures Ltd is supported by Evyatar Resheph as captain when the ship is operating, with Brad serving as general manager and relief skipper.

Prof. Cptn. Michael Vahs, Siegfried Warner, and Sascha Strasser, Hochschule Emden/Leer

Michael Vahs, has been the professor for ship operations and simulations at Hochschule Emden-Leer (University of Applied Sciences) since 2000. Graduating in Maritime Transport from "Hamburg Polytechnical Institute" in 1989, he undertook a career in the merchant marines on various ships up to the Captain's position. After three years of studying Maritime Education and Training, he was appointed to his current position. His field of research has been strongly related to green shipping – in particular, the development and operation of sail systems for cargo ships.

Dr. Tristan Smith, University College of London

Tristan Smith's field of research includes low carbon shipping, the development and implementation of technologies, and operational practices for the reduction of CO_2 emissions from shipping. Dr Smith was lead author for the 3rd IMO GHG report. His research interests cover all aspects of shipping economics, logistics and operations, with a specific focus on the development of techno-economic models for the shipping industry and the design of robust and effective policy and instruments for CO2 emission reduction. His analytical work at University College of London will be called upon as needed to supplement the expertise provided by the core design review team members as the Cerulean Project proceeds.

Each of these team members brings crucial experience to the evaluation of the Cerulean Project scope, and all have expressed a dedicated interest in the successful deployment of a new generation of low-emission maritime vessels in the service of Pacific Island Countries.

This team was identified for its potential contributions early in the planning process, and the feedback each has provided in the evaluation process has been indispensable. Aspects of the information and data collected concerning each route has been shared with Swire management through the monthly reporting mechanism. This report represents a consolidated presentation of the developing discussion around the vessel parameters.

The various categories of transport work and potential routes identified have been detailed in the Cargo & Route Assessment Report submitted previously, this report focuses specifically on the design elements thus far identified as appropriate by the Design Review Team members. Where specific technology or design elements have been ruled out of consideration, these aspects of the decision-making process are noted. The Cerulean Vessel Design Specification Sheet provided in Annex 1 incorporates findings into a simplified form now being completed by Design Review Team members for pending use in the preliminary and full-build design process.

Vessel Design Parameters

The tables below present the findings of the Design Review Team in a consolidated form, based upon the working documents utilized in the review process thus far.

The original starting point for considering the overall design parameters was the *SV Greenheart* design concept[1]. There was a consensus amongst the design team from the outset that this design, while well-intentioned, lacked sufficient understanding of the practical and physical constraints of cargo handling in remote island scenarios. Many of the innovative features (e.g. fully electric, battery storage, main drives, shallow draft with quadrant keels, use of TEU containers as the base cargo storage unit) were considered to compromise both performance and safety. It was therefore determined at an early stage to use the Greenheart design as a reference point but that a full set of new lines would be needed.

1. Vessel Capacity & Size
a. LOA/LOD
• **HE/L** – The Cerulean Vessel should be 30-40m LOA, which would require 30-32m perpendicular. The Kwai is heavily loaded when they conduct their trips. Their cargo distribution could probably be made a bit easier. • **IVL** – A maximum length of 130ft (39.62m) would be reasonable – the Cerulean Vessel should be narrow and lean for efficient sailing.

[1] http://greenheartproject.org/en/

- **CJR** - Maybe less than 40m. With the other vessels of over 300t, 36m is ideal, as the wave length is around 18m, so for the sake of comfort, at least two wavelengths will be needed (36m bow-to-stern, LOD).

Discussions with Swire indicate a design with variable length parameters for later scalability would be desirable in order to provide a smaller craft to service shorter routes on regular intervals, or having a longer vessel for larger markets/longer routes. An example of this approach may be seen with the Scruffie '*Electric Clipper*[2] designs amidst the various potential design configurations identified. *A vessel of no more than **40m LOA**, of approximately **36m LOD** is recommended.*

b. GT

- **HE/L** – The relation between DWT and GT (a virtual number derived from the volume of the ship multiplied by various factors) leaves no concern of exceeding the 500GT limit. We can expect to fall under 300GT, particularly in consideration of what can we get for US$1.5m. As a prototype and new-build design, this makes it difficult to budget. We can go low-budget with an existing hull design, where the shipyard has built it before and the workshop plans, material list, etc. already exist. For the shipyard, it will be a new design and build. There are two possibilities; find a standard ship type that's been produced and can be generally converted to what is in mind for this project with the sail drive, or not. If there is such a type of ship, it can be assumed it would not be suited for what we have in mind. To approach this properly, the design phase should involve a design office which needs to work upon the specifications we determine, based upon the general layout. In this, HE/L can assist. That's where it becomes more complex – bringing this forward without a professional design office is not recommended.

  The design office needs to be identified as an immediate priority – the work of Dykstra Naval Architects is exemplary, high-cost, high-skilled firm. If Swire has ship design offices in partnerships that may offer decent rates, they may have recommendations on who may handle this task. The full-build design process will take US$200-400k depending on how much detail is worked in, and how much will be left to the shipyard. The contract design may allow different shipyards to make offers on the design. Then we can get a sense of the market situation. They'll give the best offer knowing they're working in competition. For $1.5m, we may be underfinanced for this purpose and scale, where the build design is not standardized yet. This limit – is it a point to adjust with Swire? Swire needs to know how to handle this situation if we do not fulfill all requirements under this budget. The next step is to engage a design office – the option of a competition is still possible. Some of the considered designs are an option – the best way to do this would be to come out with a functional description on size parameters, function parameters, and don't be too concerned about the technical details on how this can be worked out. That's part of the responsibility of the ship design office and shipyard to work out.

[2] http://www.gosailcargo.com

- **IVL** – The SV Kwai is listed at a 179GT minimum, but it can exceed 200t when fully laden. It is recommended GT stay beneath 200t.
- **CJR** – Do not exceed more than 500t, as it invokes the international registry requirements. 200GT is rather small, and may empty its cargo holds before completing the full length of the longer route, but as a demonstration and research vessel, it should be more than adequate in serving its transport work purposes.

SOLAS[3] requirements become more stringent with vessels of over 500GT, which will not be exceeded under the budget constraints laid out for the Cerulean Vessel.

c. DWT

- **HE/L** – DWT capacity will depend on the cargo hold measurements, and the load line and floatation of the ship. If we reduce the design to the cargo hold (such as a tanker) we come up with high DWT and low GT. If we add extra space for light cargo and workshops, cabins, refrigerated space, you add volume without the DWT capacity. Over the thumb, in the range of 150-200DWT, we will, adding volume for refrigerating space, light cargo, etc. exported to outer islands, we are still well below 500GT.
- **IVL** – Not certain on the spot what the DWT would be.
- **CJR** – Laden tonnage of approximately 200t would be expected for a 500t vessel. In the context of the Cerulean Vessel, 2/5ths of GT to be expected, yielding a minimum of at least 80t cargo capacity as DWT.

2. Cargo handling, storage, and loading/unloading

- **HE/L** – The ability to handle palletized cargo is very important – the hold should be optimized for palletized cargo. This should influence the design of the hold. A box-shaped cargo hold will make the stowing of the cargo a lot easier. This needs to be included in the requirements, inclusive of a list of the commodities that may be put into the hold (and in what volumes, if possible). Stick with the safe working load of the system to determine what is needed. It helps if there is an understanding of special commodities to be handled. Not everything needs to be handled by ship gear. Specialized gear may be hired if needed (which may happen perhaps once a year), but what is needed regularly? 2-3 metric tonnes? That should be laid down rather than the crane specifications or the derrick of a specific type. Work on the requirements to determine the solution.
- **IVL** – On containerization, cargo handling and storage are limited by the shape of the containers. It wouldn't save money – too much broken storage for it to be of use. Bigger customers would love to work with containers, but they can't be loaded and discharged on the Kwai. Smaller customers on the outer islands have kept us from thinking about transitioning to containers. Pallets are used, and broken up. When leaving Honolulu, 2/3rds of the total cargo is generally below deck. Most goes in the hold after the first

[3] http://www.imo.org/en/KnowledgeCentre/PapersAndArticlesByIMOStaff/Documents/IMO%20safety%20and%20environmental%20regulations%20for%20OSVs%20-%20H%20Deggim.pdf

stop in Kirimati, allowing the crew to clear the deck. In regard to inventory on cargo carried, the Kwai database will be able to provide more details beyond the discussions with Frankie (Kwai's Supercargo) to better understand the profile of goods carried by the Kwai.

- **CJR** – Even with 500t vessels, full-sized containers aren't being used, as they require a 25t crane. Pallets are generally used, with goods lowered into hatches. In Kiribati, shipped boxes can be left loose, creating a security concern – containers can be used for security, but have impact on stability. Cargo shifting within containers can cause issues. The Cerulean Vessel shouldn't need standard TEUs – just ensure cargo is securable. The cargo hold should be sealed for departures, and deck cargo must be securable. At least one tender vessel will be necessary accompanied by a 3t crane – two tender vessels will be beneficial in the event something happens to the first. Nation of flagging will also determine equipment requirements. Biosecurity isn't handled internally by KNSL, but there is a stringent biosecurity regime in Kiribati (concern around coconut beetles is an issue). Fruits and vegetables from other countries are a concern, and this has negative impacts on NCD rates.

It is recommended a review Singapore/RMI equipment requirement lists is made. It is also clear ***palletization should be the standard*** – either out of bamboo or recycled plastic (better for biosecurity than wood). This will also avoid requirements of exceeding liquid cargo volume in excess of 1,000L IBC tanks. With a cargo area designed for standard pallet size, less cargo space will be lost than utilizing 20' container space in curved ship's hull. From a loading perspective, activities can be undertaken with pallet truck, not just forklift trucks, to lift items with a crane and load/unload from the tender, etc.

3. Speed

- **HE/L** – Under average wind conditions, we cannot make a yacht out of this – it will be a cargo ship and see the average service speed at 6 knots most economically. This can be reached with medium wind on the routes we have in mind – beam wind situations are prevalent on the routes being considered. Don't raise the expectations too high – if you want to save fuel and fix propulsion, stay in the lower speed range.
- **IVL** – On the slower side, average speed is about 6 knots. A bigger engine might be required to yield 8-11 knots as a cruising speed, as the fastest speed of the Kwai is around 10 knots.
- **CJR** – Sailing alone might be around 7-8 knots. Usually vessels of 36m would run around 8-9 knots. 10-11 would be expected under motor use supplemented with sails.

It is not expected the vessel will be operating at high speeds (with ***a cruising average of 7 knots*** projected), particularly in order to realize the fuel savings of up to 40% targeted for the Cerulean Vessel over similarly sized craft powered solely through diesel motor propulsion.

4. Seakeeping (Vessel Draught)
• **HE/L** – The RMI vessels are at a draught of 3 to 3.2m. This range is good for bluewater operations, and is better than the Greenheart design for sailing. • **IVL** – Kwai draft is around 3.5 meters – Cooks have their own loading vessels, but use boats in Kiribati to conduct loading/unloading operations. • **CJR** – For dynamic stability, the more sail, the deeper the hull. Anchoring will be necessary and tenders will be needed. Tender design for specific cargo requirements, involving sturdy construction with built-in floatation is going to be a necessary consideration for the vessel. Tenders can be built and pre-positioned at sites along the selected route, or have 1-2 carried on the vessel (which would be cheaper than setting up a tender on each island serviced along the route). Capt. Rounds wants to take a look at the tender designs as well as the main Cerulean vessel when preliminary design material is available. Across the considered routes, many of the outer islands are lacking infrastructure for vessels with all but the shallowest draught, so for bluewater performance and safety alongside access to communities, linking ***tender craft with 3t+ cargo capacity*** to the Cerulean Vessel operations will be integral, as the vessel is expected to have a ***draught up to 3m***.

5. Maneuverability
• **HE/L** – For the sake of simplicity and the budget, a single screw drive system is most appropriate. • **IVL** – Single screw is sufficient, and a double screw configuration isn't worth the cost. With variable pitch capability, the angle on a single screw should be adjustable, and a bow thruster would be unnecessary. • **CJR** – A good captain doesn't need a bow thruster. A single screw would suffice, and a double screw is not worth the cost. A high-speed engine isn't needed – just a reliable marine diesel motor. A bow thruster is only necessary on a vessel that is not sufficiently maneuverable under a single screw configuration. The cost/benefit assessment of investing in a double screw or bow thruster beyond a single screw propeller configuration was considered, but it was deemed unnecessary by all. The Cerulean Vessel design is expected to be sufficiently maneuverable to undertake all necessary activities with a ***single screw propeller configuration***. Analysis of the *Na Mataisau* sail hybrid retrofit in Fiji in 1986 suggested significant additional savings would be achieved with a folding propeller.

6. Safety
• **HE/L** – Derived from the total volume of the ship – we don't have to be concerned about going above the 500GT limit – we'll be under the limit at 35-36m LOA. As far as understood, we should stay with the international safety regulations and seek a simple

solution. Adhere to minimum safety standards required at 500GT level, but any more regulations we can include, the greater the safety of the vessel.

- **IVL** – Included on the Kwai are; standard certified lifejackets, two EPIRB, general alarms, CO2 system in the engine room, and fire alarms. Required US Coast Guard inspections mean the SV Kwai is kept in shape. No failures of safety systems have taken place. Hull punctures have occurred that required repair, but Kwai has always adhered to safety systems.
- **CJR** – SOLAS standards are another reason to keep the total vessel size under 500GT.

There is an understanding that the Cerulean Vessel design will be ***below the 500GT SOLAS threshold***, but this should not prevent installing/carrying equipment in excess of the legislation to be robustly confident of the extent of safeguards included for international operations.

7. Definition & Regulation

- **HE/L** – We should include DNV-GL or Lloyds as a class society. Some can be expensive. We should definitely have them involved. It needs to be built in-class.
- **IVL** – Has to be classed as a cargo vessel, but additional details may be determined by others.
- **CJR** – Build it in-class. If built out of class, the surveyors will be on everyone's back about the standards. This removes many questions that would arise. Based upon experience with other vessels, don't take it to Indonesian standards.

While there is a strong preference to have the Cerulean Vessel built in the Pacific, there are only a handful of shipyards which may be able to build to a standard which will allow Lloyd's or DNV-GL class compliance. The extended timeframe required to build in the Pacific is worth the capacity building, and will set a precedent for future builds. It is non-negotiable on the part of Swire to ensure the vessel is in-class under internationally recognized class standards.

8. Floatation, Initial Stability, and Dynamic Stability

- **HE/L** – There's a relation between sail area and thrust/side forces, as well as safety and stability. These requirements are covered within the regulations, so this will be defined under the class identifications. The exact criteria are to come to pass – the stability criteria have to be fulfilled. What is the permissible sail area in different wind conditions? Operational limits will also be identified in the context of each wind state.
- **IVL** – The Cerulean Vessel would be venturing into largely unknown territory with a catamaran cargo ship. Stay with a mono-hull design, which has higher dynamic stability and cargo capacity.
- **CJR** – Floatation is going to be an issue for the tenders more than the main Cerulean vessel. (Engines on the tender must be fast enough to ride the waves without being subsumed.) Initial stability requirements are outlined by the in-class specifications. All those parameters will be met if built in-class. The bigger the sail, the deeper the draught needed to provide dynamic stability.

While many of the stability and floatation parameters are to be defined during the design and class designation process, the vessel is expected to be a ***monohull***, which provides benefits in terms of cargo capacity and dynamic stability.

9. Environmental Thresholds

d. Sea State Thresholds

- **HE/L** – The class marks and signs for coastal use limits permissions to operate. If you don't have this limitation, this ship must be able to stand all kinds of sea situations – based on the strength of materials and designs, statistically determined. If we don't have limitations to coastal zones, the ship should be suited for the high seas and should be considered only in operational discussions on receiving forecasts and commencing voyages – should be in specifications and otherwise not a major point.
- **IVL** – The Kwai has encountered waves up to about 7 meters. The Cerulean Vessel shouldn't encounter more than sea state 7 on its route.
- **CJR** – Sea state should be able to handle at least sea state 6. (You can't order the weather.) It should normally operate in 4-5.

As per design requirements, for safety of the vessel, it should be able to handle waters of up through ***Sea State 7 (6-9 meter waves)***.

e. Coastal/In-shore/Bluewater Operations

- **HE/L** – These parameters should also be determined by class rules and not limited by coastal rules.
- **IVL** – The Kwai finds itself using other smaller vessels most of the time unless jetties or wharfs are present. A tender on-board should be available. As per the Kwai experience, expect mostly bluewater operations.
- **CJR** – With tenders, the Cerulean Vessel will avoid most coastal situations, but will be in some sheltered positions. (Work with island councils to determine what coastal drop-off/pick-up looks like.) Some vessels will be in some sheltered positions, but others with fringing reefs. If a two-masted vessel – the derricks should be off-set on the forward and the aft, as the configuration will allow joining of the two cranes to cover the load.

The Cerulean Vessel will primarily operate as a ***bluewater craft***.

10. Launching, Docking, and Grounding

- **HE/L** – Haul-out requirements should involve putting in specifications covering the ease of drydocking. Sailing hulls might have great performance, but cargo hold geometry, etc. might create issues. We recommend hull geometry should be designed to make docking easy and accidental grounding can be avoided. Consider a flat bottom keel – look at bilge keels and design. Dykstra, as a sail enthusiast, might say we won't win the

America's Cup with the hull design, but the discussion around the commercial success and priorities will be important. We aren't working on a yacht design.

- **IVL** – No specific requirements come to mind making this process easier. From the perspective of the Kwai, there is no significant distinction between hauling out in Hawaii and Fiji – Fiji should be more flexible.
- **CJR** – Kiribati can handle haul-out of vessel – ships are cradled and pulled up on airbag. Docking protocols are a non-issue in the region.

It is agreed Fiji will be an acceptable location for all docking and haul-out activities, but Kiribati also remains an option. The hull design should not create unnecessary complications in docking or grounding beyond the situations encountered with other vessels operating in the region.

11. Resistance (Hull coatings, Wake Correction Factor, and Wave-making Resistance)

- **HE/L** – Steel construction is recommended from a cost perspective. Hull coating could be put in for the best resistance performance (hull cleaning intervals and docking intervals will allow design office to propose the appropriate hull coating for the O&M and time requirements needed.) These details will be a standard element of final specifications, and HE/L can assist with the scientific elements of this through BS and MSC students. In regard to paint specifications, the RMI dockings last time didn't look too bad, so include the ground coating (Ice paint, for instance), which will allow rough wear and tear. Paint specifications wouldn't raise any headaches as there's enough knowledge on this.
- **IVL** – These nuances shouldn't be an initial concern in the design. No cargo ship has a completely smooth hull.
- **CJR** – Coating should last up to three years. Higher costs involved in 5-year coatings. Slower vessels need a good coating as they're susceptible to the on-take of barnacles and other seaweed, etc. As for wake correction factor, leave it to the designer – the hull form decided upon will determine the conditions to meet.

HE/L has suggested it provide a download area on the HE/L homepage regarding the works on transitioning to low carbon sea transport and bearing on these elements of the design. It is clear, in line with Swire recommendations, from a hull coating and O&M perspective, ***a steel-hulled vessel*** is recommended.

12. Propulsion

f. Wind Propulsion

- **HE/L** – Soft sail would provide the best solution. This is a point where there are many different solutions/preferences/arguments. We could get lost in this discussion – we need a sail system that will give the ship a speed of at least 6 knots substituting at least a set kW value in engine power that can be handled in a set number of minutes by 1-2 crew. This sail rig will need to be described by function, material, durability, etc. We need a collection of requirements that must be fulfilled, inclusive of options and parameters harder to assess (such as material durability). This will be the job of the design office and the shipyard. The performance we expect should be the determining factor. Examples can be provided by HE/L to illustrate what is possible. Describe the sail system and how that can be handled by a single or two people and the speed under sail in various wind conditions. Those parameters can, later on, be tested for fulfilment. Whether hydraulic or electric, that's something to be considered at the beginning. As for Flettner Rotors, Norsepower has said the same 18x3m – leave this for the future. If we get a more conventional, simple design running, then we look at the upgrade in the next generation system. They boast easy handling – like a motor craft. It could be an issue if we don't have the ability to set sails at any time – Kwai's crew is highly motivated. We need to make sure the inconvenience is mitigated. That's a point that could be solved in the future.

The number of masts is dependent on specific design. In general, one mast fwd. and aft of cargo-holds. Two separate cargo-holds for different types of cargo (copra/other) may be designated. Therefore, three mast could be a good option. Height of the masts about ship length or more. Two masts if the vessel size is smaller. Keep in mind that the single sail area should be of a manageable size.

Specifics on mast dimensions, dependent on sail area (wind load) and construction (number of spreaders, mast foundation, A-frame-construction, material: steel/aluminium/wood?) Number of sails is dependent on vessel design and number of masts etc. It is recommended to keep the area of one single sail in a manageable size (especially for manual operation). Foresails are difficult for automation (IndoSail offers one possible solution).

The use of spinnaker and other light wind sails depends on the abilities of the operating crew.

High aspect ratio of the single sail is an important number for sailing close to the wind. Lower ratio will lead to better overall performance. But the function of the hull-rudder-keel system for sailing close to the wind is equally important.

The total area must be determined alongside the design of the vessel (permissible heeling angle as the main limiting factor).

The best system is a system that can be adapted to the different weather conditions (easy and fast way to change the area of the sails). For the southern parts of the island-hop route it would be good to have large sail areas, where in the north the vessel needs smaller and stronger sails due to higher wind speeds.

In TLCSeaT we focus on traditional (low budget a la Kwai), and the IndoSail utility rig.

The rigging system should be easy to operate and to maintain, as well as efficient to use. The best rigging solution comes alongside with the development of the hull design and cargo operation techniques. Important is the balance of aero- and hydrodynamic forces (overall design of the vessel).

For traditional systems there exists a lot of experience on best working solutions. The type of the rigging (schooner, ketch, yawl, use of topsails, etc.) is dependent on hull shape, keel and rudder layout, deck layout (sails must be easy to operate in severe conditions), wind and sea conditions on intended routes as well as the cargo gear and operations techniques.

If sufficient manpower, as well as a highly motivated crew is available, then a traditional solution could be a good option. Make sure that enough crew is available on board for safe operation.

The IndoSail offers the opportunity for automation, besides of manual operation -> increased safety, good performance and higher percentage of sail utility due to easy operation. Less demands on operating crew.

At the same time the system allows for easy and cost effective construction. Low budget rigging construction in combination with simple canvas sails (almost flat sail cut) and high aerodynamic efficiency.

For a working boat these qualities are strong arguments that speak for this solution.

We need to define all functions of the vessel, then we will see which system works best for our purposes.

- **IVL** – An improved rig able to handle sailing into the wind on a sharper angle would be preferred. A soft sail system is recommended.
- **CJR** – The Kwai has a good arrangement, but angling into the wind is an issue because of the old design. A new design would allow better angle of approach into the wind. Regarding fixed sails, there are a few overseas ships using this – but they may be in the way of cargo loading – you'd get more benefit out of the Flettner rotor. On the performance of the Flettner rotor, unless we bite the bullet, we'll never know. It's worth jumping into this tech and bringing the new tech. Hopefully we can get a better form for the hull design. This is a better way to go forward – possibly in combination with a controllable pitch propeller.

While there is interest in the potential of the Flettner rotor, discussions with Swire indicate this may kill the project at its birth. Study on this is recommended before a second prototype is deployed after banking the lessons of the first. ***A soft sail rig*** is to be utilized for wind propulsion on the Cerulean Vessel, but the specific sail plan (mast/sail/rig configuration) has yet to be finalized although ***having at least two masts is strongly preferred***.

g. Motor/Propeller Propulsion

- **HE/L** – The aim of the project should include some solar applications for electricity, as these ships often have lay time in port with low electricity demands and generators can be shut off completely. For the propulsion, the hybrid solutions with hybrids and batteries will lead to high cost and blow the budget. The major aim is a well-functioning sail system at service speed of 5-6 knots. For all situations, the wind is not always under these conditions and the wind will not always provide these conditions. The budget will be saved by not increasing the speed, and time should not be the critical factor in this project. Time critical applications are not the focus of this projects. Simple diesel drive enabling speeds of 6-8 knots as a limit. Otherwise the power requirements get too high and require a larger motor. Siegfried can determine the size of engine required based on line of calculation, but based upon experience, the size of engine would be in the range of 300kW.

- **IVL** – Electricity to run the motor will introduce power loss, and the main benefit would be choosing how generation could be derived at any time. A more efficient motor would be advised.
- **CJR** – How can we make sure the electric motor is robust enough to meet the needs of the vessel, and have crew that can meet the maintenance needs of the new propulsion? What would be a good replacement for ICE? I have a preference for Yamaha's heavy-duty series, but evaluate for biodiesel. The Cerulean Vessel could be upgraded to utilize biodiesel, but biodiesel utilization is largely reliant on local production, which needs to be identified.

On the topic of biodiesel, a discussion with Rotuma and Kiribati copra producers may be pursued – this may enable the option of buying locally along the route in future years, however no cost-effective solution is currently available. Electric main propulsion is not yet robust enough to provide cost-effective performance with the necessary reliability. ***A primary wind-propelled vessel supported by a diesel auxiliary motor of up to 300kW*** is preferred and expected for the initial build.

13. Structural Elements & Hull Strength

- **HE/L** – Leave all of these elements to the class designations and shipyard – there's a relation to costs. To save costs, look for geometry where we use mostly plane elements – part of ship design process, and there have to be some roundings – 2D over 3D roundings. Simple shipbuilding is 2D rather than 3D, but this needs no special input in the first phase, and will naturally come out when we get to the cost profile. Leave to the class regulations which clarify strength requirements, material thickness, girder dimensions, etc. Don't put in any prerequisites in this regard. We have standards and don't need to decide on this at this point.
- **IVL** – Defer to the design process.
- **CJR** – Frame spacing, thickness of plating, strength of the transom at the stern need to be evaluated. The framing is sometimes insufficient – when turned over for storage, it can cause leakage later < this is for the tender vessels. The main vessel will be built to class standards.

These elements are expected to be specified by the contracted design firm, and will be evaluated against class standards when a preliminary build design is provided.

14. Internal Layout, Equipment Locations, and Accommodations

- **HE/L** – The crewing requirement details are needed – passengers, cadets, and total numbers – to determine accommodation and bunks per cabin. Perhaps a passenger cabin, cadet cabin, and crew cabin may be provided. We need a number for each, knowing passengers won't exceed more than 12 at any time. Budget class passengers could be put in trainee spaces if there are no trainees on-board, or the other way around if there are no passengers booked. This is only possible if there are no special passenger requirements. Galley and other rooms needed should be defined – how will a mess room be included, or will it be put in the aft deck? Space can be allocated by the design office. This may include trainee space, workshop/lab areas, etc.

- **IVL** – Regarding the Kwai, there is not much engine room on the ship. Normally there are 10-11 crew, but crew figures and accommodations are in excess of required numbers.
- **CJR** – Any good naval architect will be able to allocate crew accommodations in appropriate places. A crew of 6-8 should be expected. Guttering and downpiping need to collect rainwater for vessel's onboard use to reduce power requirements for water making. A filtration system (UV or otherwise) needs to be included. Appropriately coated tanks for all water must be included as well (ballast, sewage – maceration, etc.) Sludge storage corrodes, so macerate all waste materials and clear it out.)

The considerations around configuration of various equipment, ship systems (such as water and waste management) and crew/passenger amenities are multifaceted and require specific attention from the design firm to ensure all the above needs identified by the Design Review Team are addressed to meet the needs of a crew of 6-8.

15. Energy Efficiency & Power Requirements

h. Energy Generation

- **HE/L** – Regarding solar, well-suited surfaces can be used, (e.g. aft deck roof or observation deck), PV could cover low power demand periods, a storage battery will enhance periods of use. HE/L can provide studies to substantiate generation potential. Wind generation can be included and built into a system with PV, but quality of the turbine is crucial. If an electric engine was to be used for main propulsion, this can also serve as power input for charging a battery system (if wind conditions are good). PV/wind generation will not substitute a diesel generator, but will reduce operational costs. 2 generators with different power are recommended to suit the power demand (high/low). 2nd generator required by regulations (emergency gen).
- **IVL** – Wind turbine would be good to include for supplemental power that can be disengaged when wind speeds are too high. (The Kwai is all diesel.) The battery bank is necessary so the generator isn't needed all the time. The Kwai runs with 16 x 250Ahr batteries. A bigger battery bank would allow larger buffers on energy consumption.
- **CJR** – Engine operations can turn a small generator for power off-take during sharp turns, etc. (Cruising generator.) Solar with an inverter should be included, with 12V deep-cycle batteries for the solar system. Include wind in an appropriate position which doesn't diminish safety for crew – turbines can whistle heavily, and need to be securable in the event of high wind speeds. Additionally, a back-up generator should be included in the event of cloudy/calm days – with cruising generator, turbine, and panels, demands for its use could be quite small.

It is clear the power system should be diversified, inclusive of at least ***solar PV, wind turbine, and both a primary/emergency generator supported by sufficient battery storage***.

i. Energy Demand

- **HE/L** – Speed of the vessel and sail configuration are the two main factors around power demand. If the vessel speed is doubled, eight times the power is required. High speeds require much higher power. The speed is the most important factor, alongside the sail area we can install to cover the propulsion power needs. Power demand needs to be evaluated, with the Kwai potentially serving as a good example. Different operation modes need to be taken into account when specifying the generator sets (port/cargo gear, sea, anchor, etc.)
- **IVL** – 20 tonne capacity for freshwater – installed a water production system – 60 gallon per hour reverse osmosis desalinization system – recommended for cleanliness. It's approximately 3-4hp. Generator running on average for 8hr per day, and the water (3kW generator). Inverter chargers are being used – converting DC/AC – simple control to use.
- **CJR** – Is there going to be air conditioning? Fans, flow-through? How much goes to freezing/chilling units. On-board machinery such as navigation equipment, lighting, water heater, water maker, pumps, etc. all have power demands. 20 tonnes of capacity for freshwater through reverse osmosis sounds reasonable. Freshwater consumption and storage in tanks would reduce corrosion over regular saltwater ballast. Making sure the generator can handle the needs of the hot water heater (which may otherwise primarily be solar-powered), all navigational computers and communications/printing needs, as well as emergency lighting for cabins and decks.

Demand capacity will vary depending upon amenities (see *14. Internal Layout, Equipment Locations, and Accommodations* above), but it is clear ***at least 20t of freshwater capacity*** is advised. A power management system to balance different generation inputs and DC/AC inverter will be required, as well as channeling power through primary and emergency circuits to ensure back-up to the required navigation and safety instruments. Specific electricity demand will be determined during the full-build design phase.

Summary of Key Points

A few additional comments were provided by the design review team worthy of mention in this findings report:

- **HE/L** – The role of vessel function/transport work in the design process – the shipyard will make proposals around the best way to meet these functional requirements. In the first stage, we don't need to make the most effort on how this is technically realized, as we keep the freedom for the shipyard.
- **IVL** – SV Kwai can be improved upon for the sake of efficiency, and the Greenheart design is lacking certain aspects that would benefit a new build. The Kwai crew has no experience

with the Flettner rotor – traditional sailing is what the Island Ventures crew is used to. The Flettner rotor is likely going to be foreign to other seafarers in the Pacific, as well. Mixing cargo equipment and soft sails is an experience SV Kwai crew have learned from. Starting from scratch with a new build, the Cerulean Project can come up with a very nice sailing vessel with good cargo equipment. Loading copra and other items in the Pacific needs a good crane with different angles of stress – something robust without many problems. Of the different types of cranes, the SV Kwai has the best type available – the pulley and top-lift provide the best control of the load. It's a traditional boom crane, wired to slew sideways with a winch to control the back and forth movement. No hydraulic pistons, no extension of the boom – they are still being made, seen on Norwegian vessels.

Design Review Team Findings Summary

- A vessel of no more than ***40m LOA***, of approximately ***36m LOD*** is recommended.
- SOLAS requirements become more stringent, so the vessel will be designed ***below the 500GT SOLAS threshold***, which will not be exceeded under the budget constraints laid out for the Cerulean Vessel, expected to come in ***under 200GT***.
- ***DWT capacity of at least 80t*** is expected. Greater capacity is preferred.
- ***Palletization*** of cargo loads, carrying a ***maximum of 3t*** will be the unitized standard, not exceeding liquid cargo volume in excess of ***1,000L IBC*** tanks as a maximum individual unit.
- The vessel is expected to ***average cruising speed of 6-8 knots*** in order to realize the targeted fuel savings of ***up to 40%.***
- The vessel will be focused on ***bluewater performance*** with a ***draught of no more than 3m***, carrying two tender craft with ***>3t cargo capacity*** and internal floatation.
- All necessary activities will be undertaken with a ***single screw propeller configuration, preferably folding***.
- The Cerulean Vessel is being designed to be ***built in the Pacific to allow Lloyd's or DNV-GL class compliance***.
- The design will be a ***steel-constructed mono-hull*** vessel.
- ***A primary wind-propelled vessel supported by a diesel auxiliary motor of up to 300kW*** is preferred, utilizing a ***soft sail rig*** for wind propulsion with ***at least two masts***. The specific sail plan (mast/sail/rig configuration) has yet to be finalized.
- The power system should be diversified, inclusive of, at minimum, ***solar PV, a wind turbine, and both a primary/emergency generator***.
- ***At least 20t of freshwater capacity*** is advised. A power management system to balance different generation inputs and DC/AC inverter will be required, as well as channeling power through primary and emergency circuits to ensure back-up to the required navigation and safety instruments.

Limits on Design

- Flettner rotors and fixed sails are not going to be considered for the prototype vessel, as they add additional variables not well understood by regional certified seafaring expertise.
- Structural elements are expected to be specified by the contracted design firm, and will be evaluated against class standards when a preliminary build design is provided.
- The considerations around configuration of various equipment, ship systems (such as water and waste management) and crew/passenger amenities are multifaceted and require specific attention from the design firm to ensure all the above needs identified by the Design Review Team are addressed.
- Demand capacity will vary depending upon amenities (see *14. Internal Layout, Equipment Locations, and Accommodations* above), but it is clear specific electricity demand will be determined during the full-build design phase.

Annex 1 – Cerulean Vessel Design Specification Sheet

CERULEAN VESSEL	
Vessel Type: Wind Hybrid general cargo vessel	Registered Flag: Singapore[4]
Design: TBD	Designer:
Launched: 2021	Loading Ramp configuration:
Keel Type:	Keel Description:
Hull Coating:	Deck Coating:
COMMENTS	
Capt. Rounds:	
Hochschule Emden/Leer:	
Island Ventures:	
MCST:	
Swire Shipping:	

CONSTRUCTION	
Builder: TBD	Displacement (tonnage):
Hull Type (Mono or Multi): Mono	Hull Material: Steel
Deck/Cabin Construction Material:	Hull Thickness (mm):
Gross Tonnage (GT): <500t	Deadweight Tonnage (DWT): >80t
Length Overall (LOA) (m): ~40	Length On-Deck (LOD) (m):
Length Waterline (LWL) (m): < 36	Beam (m):
Draught (m): >3-3.5<[5]	
COMMENTS	
Capt. Rounds:	
Hochschule Emden/Leer:	
Island Ventures:	
MCST:	
Swire Shipping:	

CARGO	
Cargo Unit: Palletized (maximum 3 tonne pallets)[6]	Hold Capacity: >80t
Cargo Holds (#)[7]: 2 – dirty and clean cargoes	Hold Capacity:
Hatches (#):	Hold Dimension(s):
Hatch size(s):	Type of Hatch Covers:
Mean distance from water level to top of hatch (fully laden/heavy ballast):	Reefer (Y/N): Yes[8]
Remote controlled Grab (Y/N): No	Reefer Capacity (Volume):
Electro-Hydraulic Grab (Y/N):	Closed Reefer, MA/CA, or AFAM Reefer system:
Hydraulic Attachment Grab (Y/N):	190/230V 3-phase, 380/460V 3-phase, or 24V/48V 1-phase:
Rope Grab (Y/N) (Single/Two-/Four-rope):	Freshwater Tank Capacity: 20 tonnes (20m^3 or 20,000L)
Hand-Tripped Grab (Y/N):	Ballast Configuration:

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[4] Current preferred flag by Swire – other options are available (e.g. – RMI, Kiribati, Tuvalu)
[5] Assumes a deep-draught vessel is preferable for seakeeping, stability, etc.
[6] Pallet weight will determine minimum derrick and lighter vessel needs.
[7] Is there a need to keep bulk cargo and specialty cargo (e.g. – store goods) separate?
[8] Freezer capacity is highly desirable – how should it be integrated into the hold design?

COMMENTS
Capt. Rounds:
Hochschule Emden/Leer:
Island Ventures:
MCST:
Swire Shipping:

ENGINEERING		
Engines	Number (#): >1[9]	Estimated Hours: 0 (new)
	Make:	Model:
	Year: 2020 (new)	Underfloor (Y/N):
	Horsepower per engine: 300KVA	Drive system:
	Reconditioned: No (new)	Freshwater Cooled (Y/N):
	Estimated Cruise Speed: 6-7 knots	Estimated Cruise RPM:
	Estimated Max Speed: 10-11 knots	Estimated Max RPM:
	Fuel: Diesel	Estimated Fuel Consumption per hour (litres):
Type of Heat Exchanger:	Type of Exhaust:	Waste Heat Recovery system (Y/N):
Transmission	Type:	
Fuel Tanks	Number: >2	Construction Material:
	Total Capacity (litres):	
Bow Thruster	Included: No	
	Make: N/A	Model: N/A
Steering	Type:	Stations:
	Emergency:	
Propeller	Number of screws (#): 1	Number of Blades (#):
	Size of blades:	Shape of blades:
	Type (variable pitch, folding, etc.):	Cowlings/Boss?:
COMMENTS		
Capt. Rounds:		
Hochschule Emden/Leer:		
Island Ventures:		
MCST:		
Swire Shipping:		

SURVEY DETAILS	
Current Survey Details:	MSA #:
Passengers (#): < 12	Date of Survey: N/A (newbuild)
Date of 4 Yearly: N/A (newbuild)	Areas Worked: Fiji, Kiribati, RMI, Tuvalu
Survey Company: N/A (newbuild)	Previous Areas Worked: N/A (newbuild)
COMMENTS	
Capt. Rounds:	
Hochschule Emden/Leer:	
Island Ventures:	
MCST:	
Swire Shipping:	

[9] We know at least one motor is needed > configuration of main/auxiliary needs to be determined.

SAIL PLAN	
Rig Configuration:	Rigging material:
Spar Construction Material:	Rigging Age: N/A (newbuild)
Winches-Cabin Top:	Winches-Mainmast:
Winches-Foremast/Mizzenmast:	# of masts:
Mainsail Reefing (Mast or Boom):	# of Headsails:
Sails (Main) (#/Type):	Sails (Fore/Mizzen) (#/Type):
COMMENTS	
Capt. Rounds:	
Hochschule Emden/Leer:	
Island Ventures:	
MCST:	
Swire Shipping:	

ACCOMMODATION	
Headroom (height):	Cabins (#):
Aft Cabin (Y/N):	Cabin Layout:
Double Berths (#): 0	Single Berths (#):
Showers (#):	Shower Location:
Heads (#):	Head Location: 0
Head Type:	Sewage Treatment:
Holding Tank (Type):	Holding Tank Capacity:
COMMENTS	
Capt. Rounds:	
Hochschule Emden/Leer:	
Island Ventures:	
MCST:	
Swire Shipping:	

GALLEY	
Forward, Mid, or Aft:	Deck Level:
Pressure Water (Y/N): Yes	Hot Water (Y/N): Yes
Refrigeration:	Freezer:
Stove Type: LPG	Stove Fuel:
Burners (Y/N): LPG	Grill (Y/N):
Oven (Y/N):	Gimballed Stove (Y/N):
Microwave (Y/N):	Icemaker (Y/N):
Dishwasher (Y/N): N	Washing Machine (Y/N): N
COMMENTS	
Capt. Rounds:	
Hochschule Emden/Leer:	
Island Ventures:	
MCST:	
Swire Shipping:	

ELECTRICAL

Solar Generation: Yes (generation capacity in kW TBD)	Wind Generation: Yes (generation capacity in kW TBD)	Auxiliary: Emergency diesel back-up and/or cruising generator (generation capacity in kW TBD)
VHF/UHF Radio:	SSB Radio:	Speedometer:
Radar:	Autopilot:	Logometer:
GPS:	Chart Plotter:	Depth Sounder:
Rudder Angle:	Wind Speed:	Navigation Interface:
Surveillance Camera(s):	Satellite Phone:	Lighting:
Desalinization: 225L/hr	Water Heater:	Batteries: >4,000Ah capacity
Other Electronics:		
Power Points (#):	Power Point Location(s):	
COMMENTS		
Capt. Rounds:		
Hochschule Emden/Leer:		
Island Ventures:		
MCST:		
Swire Shipping:		

EQUIPMENT		
Anchor 1:	Anchor 2:	Davit/Winch/Crane #1:
Chain:	Chain:	Davit/Winch/Crane #2:
Warp:	Warp:	Compass:
Capstan (#):	Capstan (Manual/Electric): Electric	Barometer:
Lighter craft #1:	Outboard motor #1:	Clock:
Lighter/Tender craft #2:	Outboard motor #2:	Cockpit Dodger/Bimini:
Bilge Pump:	Workshop Equipment:	
COMMENTS		
Capt. Rounds:		
Hochschule Emden/Leer:		
Island Ventures:		
MCST:		
Swire Shipping:		

SAFETY GEAR		
Life boat (#/Location):	Backfire Flame Arrestor:	Flares (#/Location):
Fire Extinguishers (#/Location):	Life Jackets (#/Location):	Lifebuoy (#/Location):
Danbuoy (#/Location):	Harnesses (#/Location):	Drogue (Y/N):
Jacklines (Y/N):	Storm shutters (Y/N):	Ventilation system:
Automatic Identification System:	EPIRB:	Visual Distress Signals (Day/Night):
Horn/Whistle/Bells/Alarms:	Navigation Lights:	Required Certificates:
COMMENTS		
Capt. Rounds:		
Hochschule Emden/Leer:		
Island Ventures:		
MCST:		
Swire Shipping:		