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Trends and Developments in Antarctic Icebreaking Ships

Rob Hindley[1], Robert Tustin[2], Chi-Hyun Sung[3]
[1] Lloyd's Register EMEA, Helsinki, Finland
[2] Lloyd's Register EMEA, Southampton, United Kingdom
[3] Lloyd's Register Asia, Busan, South Korea

ABSTRACT

A recent resurgence has been seen in the specification, ordering and building of ice capable ships for Antarctic service. These ships are replacements of existing Antarctic Treaty state ships used to resupply Antarctic research bases. Similar mission demands allow for the fleet of specialist Antarctic icebreaking ships to be studied as a distinct and unique sub-set of the global ice-classed fleet. Trends can be seen between earlier and more recent generations of ships, aligned with changing missions of the ships used in the Antarctic. To draw out these trends a comparison of has been made of ship principal dimensions as well as ice-going performance. A particular emphasis is made on changing mission profiles and an increasing multi-role mission for Antarctic shipping. Trends from procurement and specification practices for recent projects for Antarctic icebreaking ships are described along with insights to inform future procurements.

KEY WORDS: Antarctic; Icebreaker; Specification

INTRODUCTION

Background

The functioning of the Antarctic Treaty System relies to a significant extent on the maintenance of science activities in the Antarctic, including scientific base stations, as well as environmental protection and emergency response capability, all of which require access to (and use of) specialist shipping. The premise of this paper is that because of similar mission demands by Antarctic treaty signatories the fleet of specialist Antarctic icebreaking ships can be categorized, and studied, as a distinct sub-set of the global ice-classed fleet.

Dick & Laframboise (1989) provided an empirical review of the design and performance of icebreakers, which explored characteristics of icebreakers by the use of trend lines, developed from a database of ships existing in 1989. In the first part of this paper we utilize the approaches taken by Dick & Laframboise to look at similar trends for the sub-set of existing Antarctic icebreaking ships and look at the most recent additions to this sub-set fleet in service as well as those currently being designed. For the most recent ships, in addition to characteristics and trends of use to the designer, an overview of trends in procurement processes is offered.

Objective

The objective of this paper is to analyze trends in the design of Antarctic icebreaking ships to understand the implications of evolutions of mission requirements and procurement policies on the design of the latest ships for Antarctic employment.

TREND LINE DEVELOPMENT

Antarctic Ship Data-sets

Data of ships known to be deployed to Antarctic waters for support of Antarctic science has been collated. Ships included have the following characteristics:

- Antarctic research and/or resupply mission
- Ice strengthening for re-supply mission

This screening of ships was undertaken to capture a set of ship data which is consistent, based on an Antarctic mission, and avoids outliers that, in a relatively small data-set, may bias trends unnecessarily. In undertaking this a number of ship types known to have operated in the Antarctic have been excluded, notably: cruise ships operating in the Antarctic – as this ship type is unique in its own right and deserves separate analysis; icebreakers on occasional duty – for example icebreakers such as the *Kapitan Khlebnikov* chartered by tour operators; and finally ice-strengthened general cargo ships used on an ad-hoc basis to supplement resupply activities to Antarctic bases.

Data Sources for the Antarctic Ship Data-set

The majority of data has been collated from two sources:

1. Principal particulars necessary for the trend lines associated with ship proportions have been collated from public domain sources, e.g. Lloyd's Register's Register Book; operator data sheets

2. Data required related to ice performance has been collated primarily from Riska (2013)

Public information sources, such as ship owner webpages have been used to validate these figures. Values associated with bow form (e.g. stem angle) have generally been scaled from drawings in publications and should therefore be considered estimates.

Appendix of Antarctic Ship Data-set

The complete listing of the Antarctic ship data-set analyzed for this paper is included in the appendix. The appendix contains relevant information from which the data used in the graphs have been derived. In order to present the data in a concise manner, derived values are not repeated (e.g. lightweight from deadweight and displacement).

COMMENTARY ON TRENDS AND CHARACTERSTICS

Generations of Antarctic Icebreaking Ship Development

An overview of the data-set allows us to consider three phases of Antarctic icebreaking ship designs, with each phase corresponding to a nominal ship life of 25 to 30 years.

Early Antarctic ships: pre 1970 year of delivery

Access to the Antarctic for science, and strategic purposes, has always required ships. Although early Antarctic ships were often not purpose built – or built for other ice covered environments - the 1950s and 1960s saw the first purpose built ships for Antarctic service to enable access and supply to newly established science research stations. Although history gives useful context we have omitted these early ships from our trend analysis because ship design and ship missions have evolved significantly since these early Antarctic icebreaking ships were introduced.

First Generation: 1970s-2000, peaking in early 1990s

The first generation of Antarctic ships, as we have defined them, began in the 1970s where existing early ships were replaced with purpose built units, aimed at resupplying science bases on the Antarctic content and ensuring countries with claims to the continent were able to fulfill their Antarctic Treaty obligations. The data-set analyzed starts with ships of this first generation (delivered after 1970).

Second Generation: 2000 – present

The second generation is identified as ships delivered after 2000 to the present. Here the line is drawn arbitrarily, but aligns with the replacement of tonnage for first generation ships.

Mission Profiles

Analyzing the Antarctic ship data-set using the generations defined above it is possible to draw conclusions on the changing mission profiles of the ships, and to use this as a way of further analyzing trends.

First generation ships may generally be characterized as *resupply* ships with limited facilities for on-board oceanographic research. Ice going capability is aligned with the need to re-supply Antarctic bases on an itinerary. In particular for ships resupplying more than one station, commencement of resupply is dependent on early-season entry through the Antarctic pack ice.

With the signing of the environment protocol, in the final act of the 11th Antarctic Treaty Special Consultative meeting in 1991, these ships placed more emphasis on missions associated with Protocol (Article 15) provisions for “prompt and effective response to such [environmental] emergencies which might arise in the performance of scientific research programmes, tourism and all other government and non-government activities ...".

The second generation of Antarctic ships may be characterized as multi-role, with a varying emphasis on southern ocean science / research capability in addition to resupply.

To explore this point we have plotted deadweight versus displacement in Figure 1 for the data-set of ships. Figure 1 categorizes ships into *resupply* or *research* primary missions where ships with a deadweight / displacement higher than the trend line slope of 0.38 are those was a *resupply* primary mission, whereas ships with a deadweight / displacement ratio lower than the trend line slope are categorised with a *research* primary mission.

There is a generally consistent ratio for the first generation fleet. This characterizes the cargo carrying nature of these ships. A number of second generation ships are below the trend line, and this indicates a greater emphasis on ocean science compared to cargo carrying. For second generation ships the balance between cargo carrying and research varies with the individual needs of the southern ocean operators with, for example, some national administrations operating two or more vessels, where the role of *resupply* and *research* is distributed between the two ships.

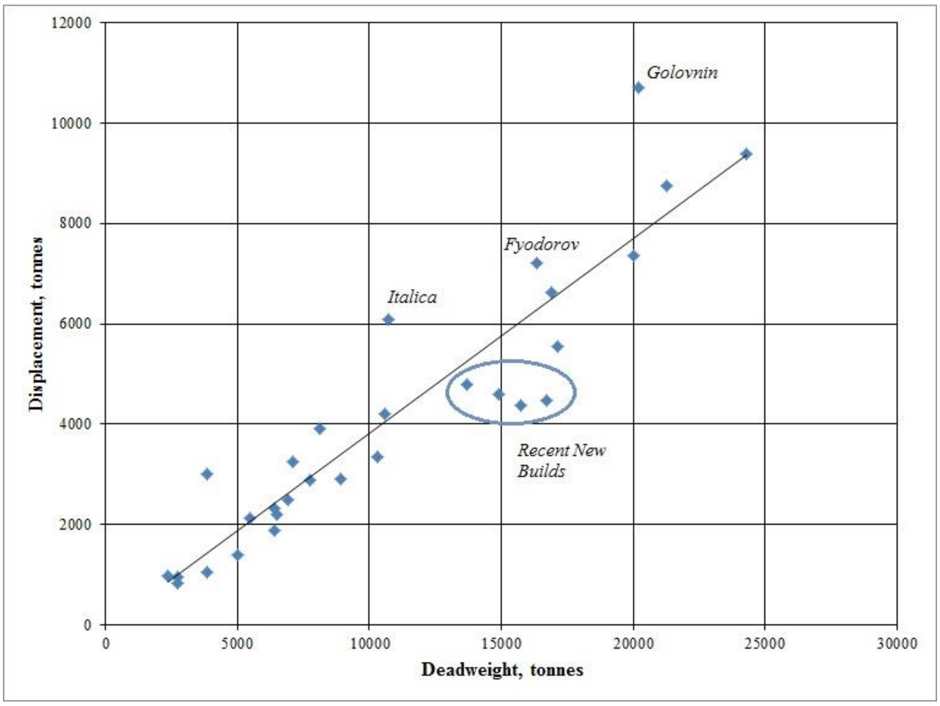

Figure 1. Deadweight vs. Displacement for Antarctic icebreaking fleet

Dimensions

Figure 2 presents a review of ship principal dimensions. Figure 2a shows the entire data-set of Antarctic ships. Linear trends can be seen for ratios of length to breadth, depth and draft albeit with significant data point scatter. Figure 2b presents the same data, but ships are categorised based on their primary mission of *research* or *resupply*. It can be seen that the gradient of the dimension ratios for the *resupply* ships are shallower than those for *research* ships, generally reflecting the increased open water performance characteristics (open water speed) for *research* ships, and the increased cargo carry capacity for *resupply* ships.

Hull Form

Dick & Laframboise discuss hull form, in particular bow form for icebreaking ships in detail. Rather than re-visiting this subject we have focused on the trends between the first and second generation ships and differences in hull form arising from the development of the mission profile for replacement vessels of the second generation associated with an increased emphasis on research missions.

From the data-set it can be seen that stem angle is lower for first generation *resupply* ships when compared with replacement ships of the second generation – which typically have a dual *resupply* and *research* role. A lower stem angle is characteristic of a bow more optimized for ice-performance than open water (*resupply* ships generally have had the need to break ice to carry out their resupply).

Other trends can be derived from two cases where first generation ships have been replaced by second generation ships with increased ice performance, similar stem angles, but with lower deadweight to displacement ratios (*S.A. Agulhas II* replaced *S.A. Agulhas*; *Admiral Tryioshni*kov replaces *Akademik Fyodorov*). This shows the trend that even for second generation ships with a primary *resupply* mission there is more of a consideration, or emphasis, also placed on the *research* role in open water.

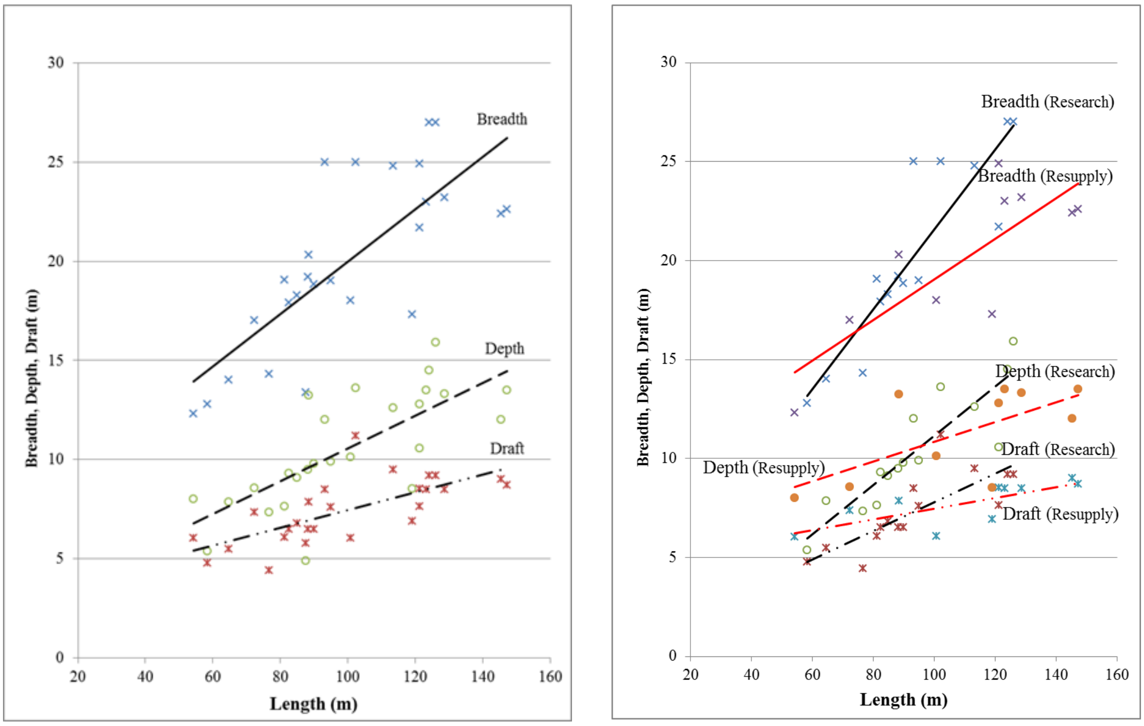

Figure 2. (a) & (b) Antarctic icebreaking ship dimensions

Propulsion

In comparison with the icebreaking fleet analyzed by Dick & Laframboise in 1989 there are no further significant highlights or trends to comment on with respect to propulsion type. We may account for this due to the less extreme mission profile of these Antarctic ships, none of which are dedicated icebreakers.

From the database the distribution between diesel-electric and diesel-mechanical propulsion has changed significantly between the two generations: just 40% of first generation ships are diesel-electric compared to 90% of the later generation ships. This change is probably a result of a number of factors, both from the reduction in cost of electric drives as well as the flexibility such propulsion configurations provide for multi-role ships. There are no significant trends in selection of open and nozzle propulsion units across either generations of ships or primary mission. A small trend in increased use of controllable pitch propellers (CPP) can be seen with the second generation of ships. Flexibility of propulsion that a CPP provides can also be achieved through the combination of fixed pitch propeller and electric propulsion. As such it is suggested that the recent trend to retain CPP even with electric propulsion is related to the requirement to reduce underwater radiated noise for research / science purposes.

Power and Performance

In the data-set principal dimensions and installed power were available for all cases. To determine the bollard pull for all ships the following relationship was used, utilizing installed power and propeller diameter, see Riska (2014):

$$T_B = Ke\,(P_D\,D_P)^{2/3} \qquad [kN] \qquad (1)$$

Where P_D is the installed shaft power and D_P is the propeller diameter. The propulsor efficiency factor, Ke, was determined from Riska (2014), with corrections for propulsion type. These are consistent with the approach taken to the formulations for the powering requirement in the Finnish Swedish ice class rules (2010). Where available the bollard pull values from Riska

(2013), or public domain data sheets, were used for confirmation.

For consistency of presentation we have also normalized the quoted ice performance figures to an ice thickness at a speed of 2 knots. Our approach has been to utilize the ice resistance method presented by Lindquist (1989) to estimate required resistance at the quoted speed and ice thickness and to equate this to the actual thrust available at 2 knots. For the occasional case where ice performance has not been found in the literature, an estimate has been made using the bollard pull and the Lindquist method in combination with an idealized second order polynomial net thrust curve as described in Riska (2014).

While we believe that the values in the data-set for bollard pull and ice-going performance are reliable and are of satisfactory accuracy for determining trends, we would caution against the use of these derived values outside of this context.

Figures 3 and 4 present an evaluation of installed propulsion power and ship performance for the data-set of Antarctic icebreaking ships. The general shape of the trend curve is consistent with that presented by Dick & Laframboise for the wider icebreaking fleet i.e. that propulsion power has a strong dependency on breadth. A small difference is presented between primarily *research* and *resupply* ships and this reflects the trade-off between design points for open water and operation in ice. Figure 4 presents a plot of bollard pull divided by breadth against the quoted ice performance given as a level ice thickness normalized to 2 knot ahead speed. This presentation is consistent with Dick & Laframboise but we have plotted a trend line as opposed to a line of minimum performance. If such a (minimum performance) line would be plotted in this case it would be significantly steeper when compared with the performance line of icebreakers presented by Dick & Laframboise. This steepness indicates that the majority of Antarctic vessels are not “pure” icebreakers and their ice performance is only part of their mission profile (and then to a varying degree in each case).

Capacity and Weight

The trend lines presented in Dick & Laframboise do not, understandably, present a study of weight or capacity: Again being more concerned with ships which primarily, and often solely, perform only icebreaking functions cargo carrying capacity is of little importance. This is not the case for Antarctic ships and consequently we have presented curves of gross tonnage against lightweight for the ships in the data-set. Gross Tonnage (GT) has been used as a value to describe internal volume and has the advantage of being a readily accessible figure for nearly all vessels in the data-set and a straightforward value to develop for a new design.

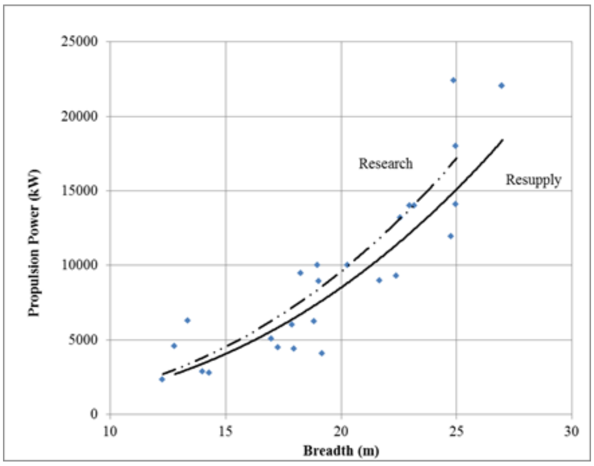

Figure 3. Propulsion power vs. breadth

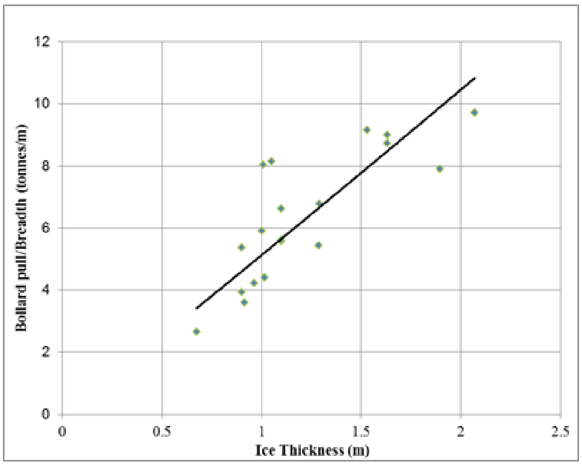

Figure 4. Ice performance

Generally this analysis aligns with Watson's (2002) suggested approaches for estimating steel weight using the old Lloyd's Register Equipment Numeral, which is a function of L, B, T, D and size of superstructure. Lightweight has been plotted, instead of steel weight, due to lack of publically available steel weight data for the majority of ships in the data-set. Figure 5a presents this data. To investigate the effect of ice class on the lightweight, the ships in the database were divided into three strength categories, based on ice class as follows:

- Heavy – ships with an ice class comparable to PC3 and above
- Medium – ships with an ice class comparable to ice class PC5 – PC3
- Light – ships with an ice class below those of "medium"

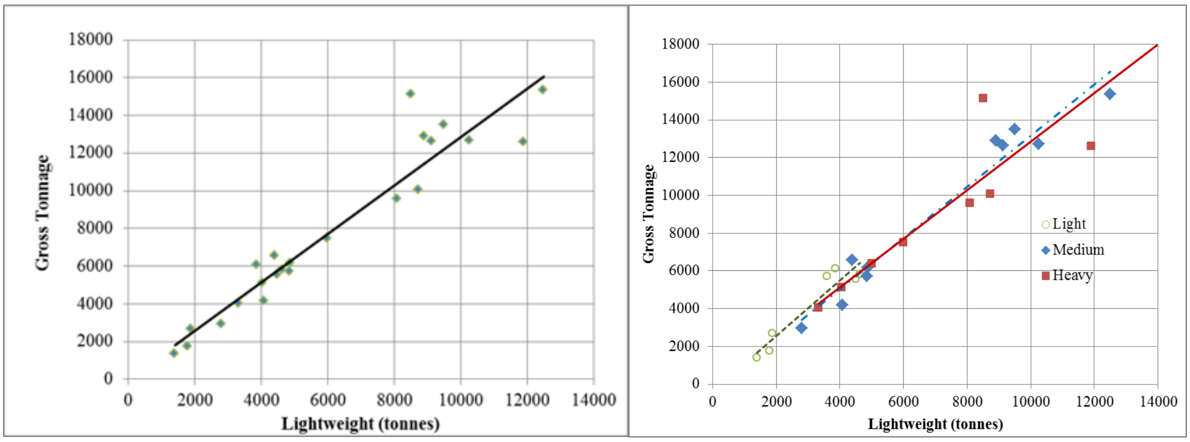

Figure 5. (a) & (b) Antarctic fleet gross tonnage vs. lightweight

The majority of the ships in the data-set were not built to the IACS Polar Class Rules (IACS, 2016). In order to establish a Polar Class for evaluating trends for existing ships built to other ice strengthening standards a comparison of the existing ship bow and midbody structural capacity has been made with that of the capacity of the same structure dimensioned to Polar Class rule requirements. Where Lloyd's Register has had access to the existing ship (or in some cases sister ship) structural plans this has formed the basis of the assessment. Where this has not been available, a standard structural configuration and assigned ice class rule minimum scantlings have been assumed for the comparison.

Trend lines for these ice class (heavy, medium, light) subsets of data are plotted in Figure 5b.

Note that there is not a significant change in slope between the strength categories which in this case is probably due to a reduction in deadweight to accommodate increased steel weight between the categories. Further investigation is warranted here but this relies to access to steel weight data for the ships which is not yet available to be presented in this paper.

PROCUREMENT TRENDS FROM RECENT PROJECTS TO BUILD ANTARCTIC ICEBREAKING SHIPS

Each recent procurement of a second generation Antarctic icebreaking ship has had unique and be-spoke characteristics defined by:

- **Objective for procurement for the new ship:** usually associated with an enhanced mission for supply and research activities to be carried out by a second generation ship, such as, added capability in scientific research aspects and/or enhanced cargo carrying capacity for re-supply missions
- **Procurement processes applied for the new ship:** usually associated with government policies, noting that all projects are for service for an Antarctic Treaty state, including policies for local content as well as requirements for competitive tendering for provision of services by third party providers and suppliers

Three recent examples of procurement objectives for recently contracted Antarctic icebreaking ships are:

Procurement objective – United Kingdom New Polar Research Vessel (NPRV)

- Replacement of two ageing ships with a single, larger, ship with updated, and enhanced, scientific research facilities and sufficient cargo carrying capacity to substitute for two replaced ships

This objective formed part of a science case, NERC (2014), in a public consultation process on the procurement.

Procurement objective – Australian Supply and Research Vessel (ASRV)

- Replacement of a single aged ship with a larger ship with higher cargo carrying capacity and improved operational availability

Procurement objective – Polar Research Institute of China (PRIC) Icebreaking science vessel (IBSV)

- Additional ship with improved ice-going and scientific research capability to support an expected enhanced presence – with additional Antarctic stations and personnel – of the Chinese state in Antarctica

Table 1 presents a summary of characteristics for these second generation ships and compares with existing first generation ships.

PROCUREMENT PROCESSES FOR RECENT ANTARCTIC ICEBREAKING SHIPS

Lloyd’s Register, in a consulting capacity, typically focusing on Rules, Regulations and Certification aspects, have been involved in a number of the recent procurement projects for Antarctic icebreaking ships. Each procurement process for these recent projects has been involved three basic phases;

1. **An initial phase involving 3rd parties** – either a concept design and outline specification preparation by third party designers, or alternatively a definition or development of a

statement of requirements by a third party consultant. At this initial phase the third parties involved have been contracted by the owning or chartering Government research organization responsible for the deployment of the ships to the Antarctic.

2. **A validation and tendering phase –** involving science and research body consultations, including, in some cases, public consultations on initial phase work. Following on from this consultation phase a competitive tendering process is launched for bidding parties to be short-listed to:
   a) Design the Antarctic icebreaking ship which typically involves preparation of a basic design package where in-country build is envisaged, as part of government local content policies, with a specialist designer contracted to prepare a design package for bidding in-country shipyards to bid for the build; OR
   b) Design and construct the Antarctic icebreaking ship which may involve specialist designer and shipyard consortia to bid to meet tender qualification requirements; OR
   c) Design, construct, operate and maintain the Antarctic icebreaking ship which typically involves a consortia of a specialist designer, shipyard and owner/operator to bid to meet the tender qualification requirements

3. **A bid evaluation, short-listing and contract award phase –** involving bid evaluations for compliance with tender requirements, including verification of compliance with Government procurement policies. Following from these evaluations there is a short listing of bidders followed by final negotiations and contract award.

Note that the second phase may involve multiple tenders depending upon the scope of work forming part of each tender. Notwithstanding the procurement practices and policies of the countries and organizations involved it should be noted each recent project has adopted the same basic phases.

INSIGHTS TO INFORM PROCUREMENT OF ANTARCTIC ICEBREAKING SHIPS IN FUTURE

Whilst we cannot offer specific examples from individual procurement projects of Antarctic icebreaking ships there are, however, valuable insights that can be generalized from these recent cases that may inform parties involved in future procurements of Antarctic icebreaking ships as follows:

Less detail in requirements definition may be appropriate - in the case of replacements for aged existing ships the requirements definition for a tender document for the second generation replacement ship has often been very much more detailed, extensive and prescribed than the contract technical specification for the first generation ship to be replaced. There may be a case, at least at the initial conceptual and tendering phases, to consider *less* definition for future procurements in order allow bidders to offer design solutions that may possibly represent an improvement to those that might be prescribed in more detailed requirements definitions.

More emphasis on feasibility studies to examine design trade-offs and compromises at very early stages prior to launch of procurement process - in all procurements there appears to have been insufficient emphasis on feasibility studies at very early concept and requirements definition phases and in some instances there was no consideration of funded feasibility studies prior to launching the procurement process.

Where conflicting requirements and standards have been specified without the consideration of any design trade-offs needed this has led, in some cases, to late stage design compromises which possibly could have been avoided with earlier feasibility studies. There may then be a strong justification, prior to launching a tendering process at the very initial conceptual design phase, to fund feasibility studies to consider design trade-offs that may emerge from specification of conflicting requirements and standards.

Pre-procurement funding of conceptual design studies to examine alternatives - Replacement second generation ships have often materialized as a larger sibling of an older ship to be replaced.

	Xue Long	*James Clark Ross*	*Shackleton*	*Aurora Australis*	*NPRV*	*ASRV*	*PRIC*
Antarctic Station (**ice performance case**)	Great Wall, **Zhongshan**	Signey, Rothera, **Halley**	Signey, Rothera, **Halley**	Casey, **Mawson, Davis**	Signey, Rothera, **Halley**	Casey, **Mawson, Davis**	Great Wall, **Zhongshan**
L / B / T (m)	147.2 / 22.6 / 8.7	90 / 18.85 / 6.5	72.4 / 17 / 8.55	88.4 / 20.3 / 7.85	121 / 24 / 7.5	144.2 / 25.6 / 9.2	117 / 22 / 8
Displacement (t)	21 250	7 700	5 455	8 130	16 700 abt	24 300 abt	15 000 abt
Ice performance @2 knots (est.) (m)	1.05m	0.9m	0.93m	1.29m	1.1m	1.79m	1.5m
Non-crew berths	128	31	50	116	60	116	49
Cargo	17 000m3 abt	1 500m3 general cargo 300t cargo AF	3 000m3 general cargo	1 790m3 hold+18 TEU 1000m3 DO	2 200m3 hold 660m3 cargo AF	6 500m3 hold 1 900m3 DO	40 TEU 750t DO
Deadweight (t)	10 225	2 900	1 800	3 893	4 475	ND	ND
Ship's FO	1 800 m3 (abt)	1 200t	1 380 m3	1 200m3	1 800 m3 (abt)	ND	ND
Propulsion Power (kW)	13 200	6 250	5 100	10 000	11 000	26 600	15 000
Propulsion type	Diesel Mech. 1xCPP in Nozzle	Diesel Electric 1XFPP	Diesel Mech. 1xCPP in Nozzle	Diesel Mech. 1xCPP	Diesel Electric 2xCPP	Diesel Mech +PTI 2xCPP in Nozzle	Diesel Electric 2xAzimuth
Station keeping	No	DP1	DP2	DP1	DP2	DP2	DP2
Positioning thrusters	None	2: retractable azimuth	1: retractable azimuth, 4: tunnel	2: retractable azimuths,1: tunnel	4: Gill thrusters	6: tunnel	2: tunnel
Endurance, days Range, nm	ND (No Data) 20,000	57 days 16,500 (abt.)	130 days 40,000	90 days 25,000	60 days 19,000	90 days 16,000	60 days 20,000
Stabilization / ice heeling systems	No / Yes	Intering type tank (passive / active)	Roll reduction tanks (semi passive)	Intering type tank (passive / active)	Intering type tank (passive / active)	Intering type tank (passive / active)	Roll reduction tanks (semi passive)
Science deck area (m^2)	NA	370+150	NA	310	650	ND	500
Science Lab area (m^2)	100 #	330	90	ND	ND	500	580
Labs (+ containers)	3 #	6 (+5)	2	8	7	4 (+24)	6 (+8)
Helideck	Yes + hanger	No	Yes	Yes + hanger	Yes + hanger	Yes	Yes+ hanger
Helideck location	Aft	NA	Aft	Aft	Fwd	Aft	Aft of midship
Tenders / Support craft	NA	NA	NA	10m tender	Cargo tender, workboat	2 x 35t barge, 4 x tender	workboat
Cranes (over 5t)	2x50t cargo cranes (double cranes)	20t / 10t cargo crane 20 t / 30t A frames	1x50t crane 10t telescopic crane	1x25t crane 1x7t crane	1x50t cargo crane 1x30t A frame	2x 55t crane 1x15t crane	1x50t cargo crane A frame & U frame
Winch number	2 #	2	None	6	10 abt	ND	11 abt
Underwater noise	Not Considered	Considered	Not Considered	Not Considered	ICES209 (part)	ICES209 (part)	Considered
Drop keel	No	No	No	No	No	Two	No
Moonpool	No	No	No	No	Yes	Yes	Yes

Table 1. Characteristics of recent Antarctic Icebreaking projects (retrofits marked #)

On the other hand the second generation replacements are incorporating added or enhanced roles as well as new technologies and technological improvements to existing equipment, including, as recent examples, adoption of azimuthing podded propulsions systems and deployment of autonomous vehicles for scientific research tasks.

There may then also be a justification, for adoption of new technologies and improvements to technology that have occurred since the build of a first generation parent, to fund pre-procurement conceptual design studies to identify whether alternative hull forms, layouts and arrangements could offer an improved design and performance in a second generation replacement.

CONCLUSIONS

Because of similar mission demands the fleet of specialist Antarctic icebreaking ships can be categorized, and studied, as a distinct sub-set of the global ice-classed fleet.

In the first part of this paper design trends have been examined. Second generation of Antarctic ships from this analysis may be characterized as multi-role, with more design emphasis on science / research capability in open water and less design emphasis on icebreaking performance for resupply operations.

In the second part of this paper procurement practices for recent projects have been described. Insights to inform future procurements offered include feasibility studies to support study of design trade-offs in multi-role ships, as well as pre-procurement conceptual design studies to address new technologies and alternative design concepts.

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APPENDIX: DATA-SET OF ANTARCTIC ICEBREAKING SHIPS

Ship	Admiral Irizar	ASRV	Aurora Australis	Admiral Max'ano	Almirante Oscar viel	Antarctica I	Xue Long	PRIC Icebreaker	L'Astrolabe	L'Astrolabe II
Country	Argentina	Australia	Australia	Brazil	Chile	Chile	China	China	France	France
Year	1978	In build	1990	1974	1969	In build	1993	In build	1986	2017
Length (m)	113.4	144.2	88.4	87.5	81.15	95	147.2	117	58.32	68
Breadth (m)	24.8	25.6	20.3	13.39	19.05	21	22.6	22	12.8	16
Depth (m)	12.6	13.1	13.25	4.903	7.62	10.6	13.5	11.8	5.36	6.8
Draft, **T** (m)	9.5	9.2	7.85	5.77	6.09	7.2	8.7	8	4.782	5.3
Displacement, **D**, (m)	14900	24300	8130	0	6400	10310	21250	15080	2740	3840
Cb	0.54	0.7	0.56	0	0.66	0.7	0.71	0.72	0.75	0.65
Stem angle, **γ** (deg)	22	16.5	20	ND	53	0	25	20	37	ND
GT (t)	10065	20200	6574	2493	4179	ND	15352	ND	1753	3628
Deadweight, **DW** (t)	4600	9400	3910	1760	2320	3340	8760	ND	950	3000
Endurance (nm)	20160	16000	25000	ND	12000	25900	22000	ND	ND	10080
Compliment	135+45	32+117	24+116	ND	78	64+56	38+128	ND	12+50	60
Shaft **P**ower (kW)	11950	26600	10000	6270	8950	8000	13200	15000	4600	6400
Bollard **P**ull (t)	138	305	138	0	102	101	184	ND	ND	ND
Machinery	DE	DE	DM	DM	DE	DE	DM	DE Th	DM	DM
Propeller **N**o	2	2	1	1	2	2	1	2	2	2
Propeller **Dia**meter (m)	4.3	5.65	5.11	ND	3.658	ND	5.7	ND	ND	ND
Propeller **T**ype	FPP	CP	CPP	ND	FPP	FPP	CPP	FPP	CP	CP
Nozzle	Open	Nozzle	Open	ND	Open	Open	Nozzle	Open	Open	Open
OW Speed, **Vow** (kt)	17.2	16	16.8	ND	15	15	17.9	ND	14.2	ND
Ice thick @2kts (m)	1.1	1.79	1.29	ND	0.9	1	1.05	1.5	ND	ND
Ice **Class**	ND	PC3	ASPPR 2/3	Strength'd	Class 1	PC5	ULA	PC3	1A Super	PC5
Polar Class, **PC**	PC3	PC3	PC4	PC7	PC6	PC5	PC5	PC3	PC6	PC5

ND – No Data; DE – Diesel Electric; Th – azimuth thruster; DM – Diesel Mechanical; FPP / CPP – fixed/controllable pitch propeller; In build – preliminary data only

Ship	Polarstern	Maria S Merian	Italica	Shirase I	Shirase II	Lance	Kronprins Haakon	BAP Carrasco	Akademik Fyodorov	Vasiliy Golovnin	Admiral Tryiosh’ov
Co	Germany	Germany	Italy	Japan	Japan	Norway	Norway	Peru	Russia	Russia	Russia
Yr	1982	2005	1981	1982	2009	1978	2017	2017	1987	1988	2012
L	102.2	88.2	119	124	126	54.19	90	84	128.61	145.38	123.24
B	25	19.2	17.3	27	27	12.3	21	18	23.2	22.4	23
D	13.6	9.5	8.54	14.5	15.9	8.01	10.5	9.2	13.31	12	13.5
T	11.2	6.5	6.914	9.2	9.2	6.031	7.8	5.95	8.5	9	8.5
D	15720	6380	10710	17140	20000	2370	10580	5000	16340	20200	16890
Cb	0.53	0.56	0.73	0.54	0.62	0.57	0.7	0.7	0.62	0.67	0.68
γ	25	39	ND	21	19	ND	ND	ND	26	ND	27
GT	12614	5573	5825	ND	ND	1380	10900	5716	12660	13514	12711
DW	4370	1890	6080	5540	7350	980	4200	1400	7200	10700	6630
E	19000	7500	ND	ND	ND	21000	15000	ND	ND	ND	15000
C	44+80	23+23	27	174+60	175+80	13+25	17+35	50+60	90+160	ND	59+80
P	14116	4100	4486	22065	22066	2354	11000	0	14000	9300	14000
BP	197	ND	ND	243	236	28	158	ND	137	ND	152
Mach	DM	DE Th	DM	DE	DE	DM	DE Th	DE Th	DE	DE	DE
PropN	2	2	1	3	2	1	2	2	1	1	2
Dia	4.2	ND	ND	4.9	5.2	2.75	ND	ND	5.1	ND	4.25
PropT	CPP	FPP	FPP	FPP	FPP	CP	FPP	FPP	FPP	FPP	FPP
N	Nozzle	Open	Open	Open	Open	Open	Nozzle	Open	Open	ND	Open
Vow	16	18	14	19.5	19.5	ND	20	ND	16	16	16
Ice	1.8	ND	ND	1.63	1.63	ND	1.29	ND	1	ND	1.1
Class	Arc3	1A	ND	ND	ND	1A	PC3	PC7	ULA	ULA	Arc7
PC	PC2	PC7	ND	ND	ND	PC7	PC3	PC7	PC5	PC5	PC4

Ship	Hesperides	SA Agulhas	SA Agulhas II	Araon	Oden	Ernest Shackleton	James Clark Ross	Endurance	NPRV	Nathaniel B Palmer	Lawrence M Gould
Co	Spain	South Africa	South Africa	South Korea	Sweden	UK	UK	UK	UK	USA	USA
Yr	1991	1977	2012	2009	1989	1995	1991	1990	In build	1992	1997
L	76.75	100.72	121.25	95	93.2	72.4	90	82.5	121	84.94	64.7
B	14.3	18	21.7	19	25	17	18.85	17.9	24	18.288	14.02
D	7.35	10.11	10.55	9.9	12	8.55	9.8	9.3	11	9.1	7.85
T	4.42	6.058	7.65	7.61	8.5	7.359	6.5	6.5	7.5	6.8	5.49
ᴅ	2720	7110	13690	8900	12930	5460	7770	6500	16730	6910	3840
Cb	0.54	0.63	0.66	0.63	0.63	0.61	0.68	0.66	0.74	0.63	0.75
ɣ	ND	35	22	33	21	30	36	30	15	28	35
GT	2682	6112	12897	7507	9605	4028	5732	5129	5000	6174	2966
DW	830	3250	4780	2900	4910	2130	2890	2200	4480	2500	1040
E	12000	15000	15000	20000	ND	40000	16400	ND	19000	15000	12000
C	55+37	44+94	45+100	25+65	22+44	22+50	28+52	35+95	28+62	22+39	16+37
P	2800	4414	9000	10000	18000	5100	6250	6000	11000	9500	2886
BP	ND	48	118	107	243	72	74	79	120	147	50
Mach	DE	DM	DE	DE Th	DM	DM	DE	DE	DE	DM	DM
PropN	1	1	2	2	2	1	1	1	2	2	2
Dia	ND	3.35	4.5	3.5	4.5	3.6	4	3.5	4.5	4	2.65
PropT	FPP	CPP	CPP	FPP	CPP	CPP	FPP	CPP	CP	CPP	CPP
N	Open	Open	Open	Open	Nozzle	Nozzle	Open	Nozzle	Open	Nozzle	Nozzle
Vow	15	14	16	16.65	17	14	15.5	15	14.5	15	12
Ice	ND	0.675	1.285	1.1	2.07	0.963	0.9	1.015	1.1	1.01	0.914
Class	ND	Class 1*	PC5 / Ice10	Polar10	IB Polar 20	Ice05	1AS	Ice05	PC4/PC5	A2	A1
PC	ND	PC6	PC4	PC3	PC2	PC3	PC5	PC3	PC4	PC4	PC5