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# Victualling for Future Royal Australia Navy Platforms - Alternative Technologies

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**ABSTRACT**

Rapid Prototyping, Development and Evaluation (RPDE) are investigating alternative victualling methods for submarines and surface ships of the Royal Australian Navy (RAN). Emerging food processing technologies were identified and considered in the context of the RAN victualling system and naval food culture. Technologies such as cook chill - heat treated refrigerated food (HTRF) - have a shelf-life up to 2 months and are currently available. Other technologies, such as high pressure processing (HPP) and microwave assisted pasteurisation (MAPs) promise 'fresh-like' foods with extended shelf-life under chilled storage. While other developing technologies such as microwave assisted thermal sterilisation (MATS) and high pressure thermal processing (HPTP) aim to produce extended shelf-life foods which are fresh-like and shelf-stable. Although the technology readiness levels (TRLs) of the emerging technologies estimated to be ~ 6, key decision dates of some future naval platforms are still about 5-10 years away. These technologies might then reach maturity within this timeframe. Opportunities, risks and mitigation strategies are also discussed.

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## Executive Summary

Rapid Prototyping, Development and Evaluation (RPDE) is investigating alternative victualling methods for submarines and surface ships of the Royal Australian Navy (RAN). As a quick response to RPDE, the Defence Science and Technology Organisation (DSTO) has provided a snapshot of emerging food processing technologies, including the apparent risks and opportunities presented by alternative technologies in the context of the RAN victualling system and Naval food culture.

Naval victualling is best considered as a system, with changes in one system component affecting other parts of the system. In addition to thinking of victualling as a system, it is important to understand the context in which the system operates. Understanding RAN food culture can assist the choice and introduction of systems that are not only fit for purpose, but can also be successfully introduced into RAN service. Food processing technologies which were chosen for consideration here are cook chill HTFR, HPP/HPTP and MAPs/MATS. As both HPTP and MATS are emerging technologies, a watching brief outlining the developing maturity (TRLs), industry up-take, and hence availability and cost, should be maintained up to the key decision dates of the major projects. Nutrition and health aspects of RAN crew and reduction of waste are also issues for consideration. These might be substantially improved through the introduction of electronic menu-managements systems. Functional foods are also considered in the context of specific requirements for submariners. As introduction of new approaches can be difficult, social marketing techniques could be used to facilitate acceptance of new food processing techniques and victualling systems for the RAN.

TRLs of the emerging technologies described are currently at mid-level, i.e. ~ 6. As some future naval platforms are still 5-10 years away from key decision dates, it is possible that some of these technologies may mature in that time. The opportunities, risks and mitigation strategies for future naval victualling are also discussed.

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# Abbreviations

| | |
|---|---|
| CFI | Centre for Food Innovation |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| FDA | Food and Drugs Administration |
| FDM | Fused Deposition Modelling |
| HACCP | Hazard Analysis of Critical Control Points |
| HPP | High Pressure Processing |
| HPS | High Pressure Sterilisation |
| HPTP | High Pressure Thermal Processing |
| HTRF | Heat Treated Refrigerated Food |
| MAP | Modified Atmosphere Packaging |
| MARPOL | Maritime Pollution |
| MATS | Microwave Assisted Thermal Sterilisation |
| MOTS | Military off the Shelf |
| PATS | Pressure Assisted Thermal Processing |
| PEF | Pulsed Electric Field |
| QL | Quick Look |
| RAN | Royal Australian Navy |
| RPDE | Rapid Prototyping, Development and Evaluation program |
| SFE | Supercritical Fluid Extraction |
| SLS | Selective Laser Sintering |
| SSL | Short Shelf Life |
| SWAP | Size, Weight and Power |
| TRL | Technology Readiness Level |
| TTPs | Training, Techniques and Procedures |
| UTAS | University of Tasmania |
| WH&S | Work Health and Safety |
| WSU | Washington State University |

# 1. Introduction

As the Australian Government considers future naval platforms, viable capability options for the design of the platforms' communication, propulsion, navigation and weapon systems are being identified, debated and assessed. The potential impact of emerging technologies is also being closely analysed, and decision makers advised. The endurance of future naval platforms is a key component of the capability, yet the feeding system – which affects endurance – is often overlooked in the early project definition phase. Options for naval feeding systems or 'victualling' are also best considered early in the project life, as the food processing technologies available may impact both the optimal design of the platform, including galley and storage areas, and the ultimate endurance of the platform. In short - clever platform design can increase Defence capability.

The current work has been compiled in response to the Rapid Prototyping, Development and Evaluation (RPDE)[1] Quicklook 100 (QL 100) task which is investigating alternative victualling methods for submarines and surface ships in the Royal Australian Navy (RAN). This snapshot gives an indication of technology maturity, feasibility and risks/opportunities, and a summary of other potential issues which may impact RAN feeding systems. It has been provided in response to the RPDE QL 100 task lead's request for information within a timeframe of three weeks.

As Defence projects move closer to key decision dates, updated information on emerging technologies and feeding systems will become available, and more detailed analysis and advice can be provided on request.

# 2. Royal Australian Navy Victualling System

The ability to feed the crew and manage both solid and liquid waste affects the endurance of a naval platform. Representing RAN victualling[2] as a system helps to understand and analyse the potential impact of emerging technologies.

The purpose of RAN victualling could be described as '*to sustain an embarked ship's company by providing timely, nutritious, appetising and appealing meals, within the specified RAN resource budgets for the embarkation period*'.

[1] RPDE, a Joint Defence-Industry Initiative, was established to help resolve difficult and challenging capability problems.

[2] The terms 'feeding' and 'victualling' are used interchangeably throughout this document

A number of different systems are co-ordinated to achieve this aim:

- menu planning
- processing & packaging of foods
- purchasing & delivery of foods
- stowage of foods
- meal preparation
- serving & consumption of meals
- cleaning, storage and disposal of waste.

Using a mind-map to represent RAN victualling also helps identify the many interrelationships within and between the system components. There are many valid ways to represent naval victualling. In Fig. 1 key clusters are identified around galley design, food culture, logistics, and extended endurance (waste and shelf-life). The current work will take a closer look at the cluster around 'extended endurance', and make brief comment on the other key clusters. To help understand the context in which the victualling system must function, we also take a brief look at the food culture of the RAN (Section 2.1).

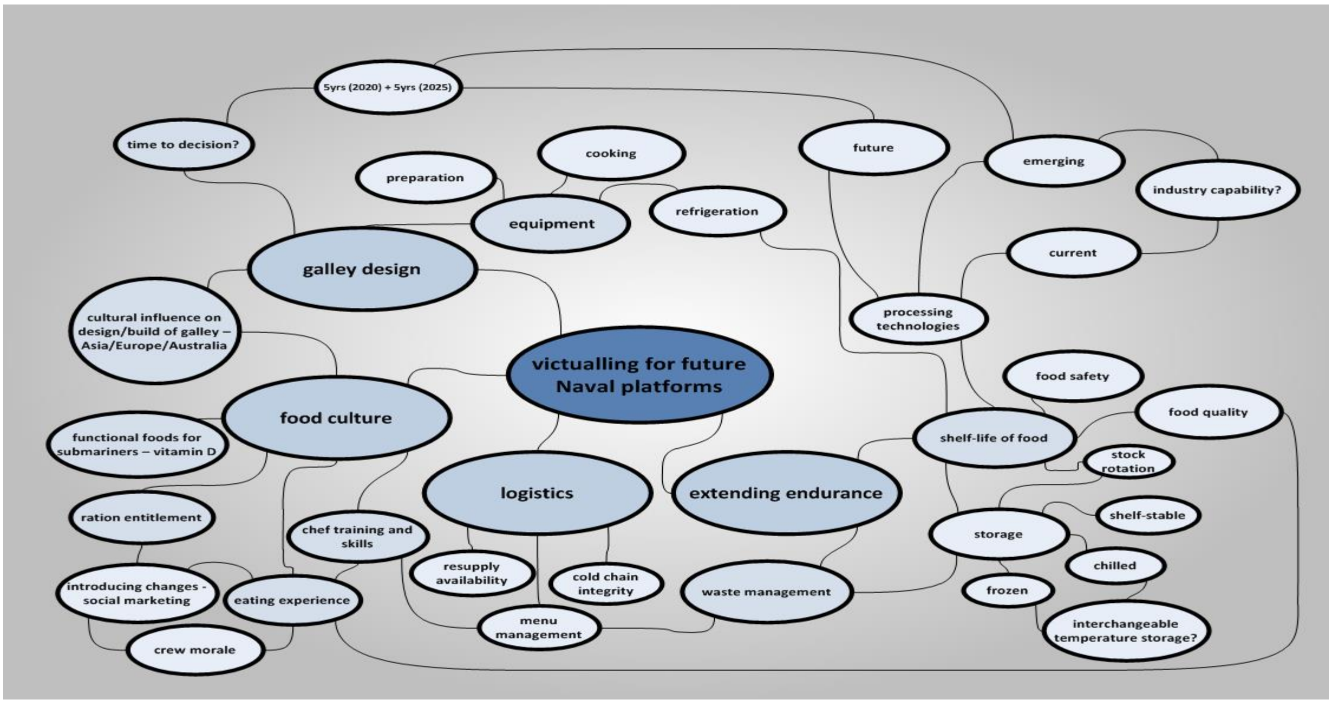


*Figure 1 Mind-map representing naval victualling*

## 2.1 Food culture and the RAN

Food quality comprises many attributes, such as appearance, aroma, flavour, texture[3], safety and nutritional content. It can be quite subjective and specific to individuals and different culture groups. The 'eating experience' is not only made up of food quality but also the individual's expectations [1]. Other contributions to the perceived and actual eating experience are the amount, variety, contrast and novelty within the meal, timing and frequency of meals and the environmental and social influences around the design and location of the eating area [2]. Enhancing the eating experience is complex and can be specific to cultural groups, such as the RAN, and RAN subgroups such as submariners.

As background for the current work, many initial discussions took place around naval victualling. Although food culture is only one of the four clusters of the mind-map representing this work (see Fig. 1) the highly subjective nature of culture makes it particularly difficult to study and understand. Having a good cultural fit, or not, with the intended target audience can often mean the success or failure of a product or system. Although the RAN feeding culture may be challenging to suitably capture, making the effort to do so could significantly improve naval victualling, especially with respect to understanding any differences there may be between the surface ship and submarine fleet. The condensed timeframes for the current work have allowed only cursory consideration of the cultural aspects of naval victualling, and further work in this area is warranted.

The authors gained the following early insights[4]:

- RAN cooks take pride in preparing fresh cooked meals for the crew. The cooks are highly skilled and may resist the introduction of technologies that do not require their skills, such as pre-portioned heat and serve meals.
- The concept of ration entitlement may prevail on some vessels. The introduction of electronic menu-planning which enables the preparation of meals tailored to nutritional and kilojoule values for activities undertaken (i.e. a reduction in portion size or frequency of meals) may not be accepted[5].
- Submarine crews tend to work a 6 hours on/6 hours off watch cycle, receiving a meal at the end of each watch.
- There is limited free time and space for rest and recreation, and the time spent eating meals may provide an important relaxation component.
- Submariners are subjected to extended periods without sunlight which puts them at risk of vitamin D deficiency [4, 5]. Food containing vitamin D [6] or specifically

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[3] The attributes of appearance, aroma, flavour and texture are often grouped together and referred to as the 'organoleptic qualities' of foods.

[4] The insights given are based on preliminary conversations only, and deeper and broader discussion is required for a good understanding of RAN food culture.

[5] Early studies involving submariners found that food intake significantly exceeded energy expenditure, indicating the potential for crews to acculmulate excess body fat, with long term adverse health consequences [3] Forbes-Ewan, C.H. and B.L. Morrissey, *Interim report on the food intake and energy expenditure of submariners*. 1989, Defence Science and Technology Orgainisation. p. 11.

designed to contain vitamin D - 'functional foods' - could be developed for submariners.

The authors understand that the predominant practise for RAN vessels is to cook fresh food for each meal, with the use of some canned items and pre-prepared items such as soups and sauces. Understanding the expectation for fresh cooked meals, helps to understand what types of food processing technologies will suit the RAN culture and expectations. Those technologies that produce 'fresh-like' foods are considered for the current work, rather than conventional techniques which produce dried, frozen or high temperature/time processed foods.

## 2.2 Extending the endurance of RAN platforms

Aspects of the naval victualling system which contribute to vessel endurance are the amount or volume of food that can be stored on-board for a deployment, the shelf-life of the food itself, and the management of the waste generated from the system. Only the latter two of these three aspects are considered in this quick-look report.

### 2.2.1 Increasing the shelf-life of food

Many factors throughout the food supply chain affect the shelf-life of food. Growing conditions, postharvest practices, storage and handling, food processing technologies and packaging options can all be designed, and carefully controlled, to enhance shelf-life. This section gives an overview of industrial food processing technologies that could impact the naval victualling system. Included are processing technologies which are currently available in the food industry, and those that are emerging but may be of use in future naval platforms. For this overview, it is assumed that the RAN will source foods from industry, rather than invest in production technology itself. Many of the newer technologies become economically viable only when employed for large scale feeding. However, co-investment opportunities involving Defence and Australian industry could be investigated for promising technologies that would be particularly suited to naval victualling.

Foods can be preserved, and the shelf-life extended, through many techniques and processes [7]. Drying, heating, chilling, freezing and the addition of various preservatives such as sugar, salt, antioxidants, and foods acids, have all been used for centuries to inhibit microbial growth, and hence, extend the shelf-life. Processing techniques can be used individually or in combination, creating products which are not only safe to eat, but are also good to eat [8].

Food safety cannot be compromised. For Australian Defence rationing, rigorous food safety standards apply. What may be subject to compromise during food processing, is a trade-off between extending the shelf-life and retaining the quality of the food. Food processing can affect one or more of a particular food's organoleptic (sensory aspects such as taste, texture, aroma and appearance) and nutritional aspects. The target consumer group (RAN crew for naval victualling) are key in ascertaining if the trade-off in quality and/or nutritional aspects of the processed foods[6] is acceptable in the context of achieving extended shelf-life and improved handling and logistics.

What follows is a brief overview of processes and technologies which could be considered for future naval platforms. This section is presented as a snapshot of current, emerging and future food technologies, and is not an exhaustive analysis of all processing techniques available. For example mature technologies such as drying, freezing and retorting/canning technologies have not been included. Although advances in these conventional technologies are being achieved, the authors' understanding is that the RAN food culture is likely to be more receptive to 'fresh-like' foods rather than dried, frozen, or foods treated with high temperature/time combinations. Foods processes by these conventional techniques generally have a significantly different texture and flavour to those which are freshly cooked. These technologies have been available for some time and their limited use in naval victualling is thought to result from the Naval food culture, discussed briefly earlier (section 2.1). This may be contrasted with Army combat ration packs where canned and retorted food have been used extensively to provide the extended shelf-life required.

#### *2.2.1.1 The cook chill technique*

The process of 'cook chill' has been in use for many years (TRL 9). However the quality and variety of foods produced by this process today, has overcome the initial resistance to its introduction. In addition to supplying large-scale feeding operations of the mining industry, airlines and hospitals, many restaurants are now purchasing cook chill products to supply some or all of the meal components for high quality dining experiences.

There are two major classifications of cook chill based on differing shelf-life [9]. Firstly, the shorter shelf-life cook chill process is commonly known as simple 'cook chill', but is also known as short term cook chill, conventional cook chill or short shelf life (SSL) cook chill. Apart from rapid chilling equipment used to quickly cool foods, a conventional kitchen will already have most of the equipment required to operate this type of cook chill. In SSL cook chill, the food is given a pasteurisation[7] process equivalent to at least two minutes at 70 °C. This is often simply achieved by cooking to an endpoint of 75 °C or above. Packaging of products might or might not be under vacuum or modified atmosphere. The product has a refrigerated shelf life not exceeding 10 days at storage temperature of 5 °C or below. Therefore food products which have been treated by SSL may be suitable for naval platforms which commonly deploy for periods of 10 days or less.

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[6] Statistically valid sensory evaluation of new food products, with the target audience, can help predict the acceptability of the new processing techniques before committing to the introduction of the new products to naval platforms. DSTO-Scottsdale has many years of experience in the evaluation of Defence foods and feeding systems.

[7] Pasteurisation is a process of heating food, to a specific temperature for a predefined length of time (for example two minutes at 70 °C) and then immediately cooling it after it is removed from the heat (for example to below 5 °C). This process slows spoilage caused by microbial growth in the food. Unlike sterilisation, pasteurisation is not intended to kill all micro-organisms in the food. Instead, it aims to reduce the number of viable pathogens so they are unlikely to cause disease assuming the pasteurized product is stored as indicated and is consumed before its expiration date.

Secondly, cook chill can also refer to extended shelf life cook chill process or heat treated refrigerated food (HTRF)[8] packaged for an extended shelf life. This is also known as long life cook chill or long-term cook chill. Extended shelf life means that a thermal process has been applied to the food, usually equivalent to at least 10 minutes at 90 °C, and it is then stored at 5 °C or below to give a refrigerated shelf life of greater than 10 days, typically several weeks but in some cases up to 2 months. Further investigation into HTRF could be considered for naval platforms which deploy for up to 2 months. Both individual meals and food packaged for group feeding can be provided using HTRF. HTRF foods packaged for feeding groups may best suit the RAN culture, as the food could be prepared, heated and plated for each meal, with the option of adding fresh elements to enhance eating experience. Assuming HTRF meals are prepared in an industrial kitchen and delivered to the vessel; advantages of using HTRF would be reduced food and labour costs, and minimal or no requirement for freezer space.

The systematic nature of the cook chill process allows the introduction of systematic safety and quality assurance programs [9]. The systematic documentation required for cook chill may eliminate issues associated with poor stock rotation which may occur on some naval vessels. Disadvantages of cook chill include high capital cost of production (for HTRF), high requirement for staff training if hazard analysis of critical control points (HACCP) is going to be effective, and a high risk of food spoilage/poisoning if the system controls are not maintained. Other disadvantages specific to the RAN may include a difficulty in re-supplying in foreign ports, and difficulties maintaining the cool-chain during hand-over from commercial supplier to Defence vessel, as time at port may change at short notice due to operational demands.

#### *2.2.1.2 High Pressure Processing (HPP) and High Pressure Thermal Processing (HPTP)*

High pressure processing (HPP) is an established non-thermal pasteurisation technique, with a technology readiness level (TRL) of 9. HPP consists of submitting food products, for some minutes, to high levels of hydrostatic pressure. The pressure vessel is filled with water and packaged foods, and pressure applied (up to 600 Mpa). The pressurisation of foods at cold or room temperature inactivates the vegetative micro-organisms, both pathogenic and spoilage, present in the food. The high pressure acts mainly to modify the cellular membrane of the micro-organisms and also inactivate certain vital enzymes. The uniform distribution of the pressure makes possible an homogenous treatment of the whole product, regardless of its shape and size. The result is the desired level of hygenisation, without deterioration in the organoleptic properties. The range of foods

[8] Sous vide, pronounced 'sue veed' is a type of HTRF. Sous vide products are produced by vacuum packing raw, fully cooked or par-cooked foods and then giving a controlled heat treatment to fully cook them. They are then stored at refrigerated temperatures. When required they are either reheated or the cooking is completed. Sous vide is claimed to produce foods of superior sensory and nutritional characteristics compared to conventionally cooked food. The method is intended to maintain integrity of the ingredients by cooking them for an optimal time, often many hours, at relatively low temperatures. Sous vide is widely used in industry and has a TRL of 9. [9] Cox, B. and M. Bauler, *Cook chill for foodservice and manufacturing: guidelines for safe production, storage and distribution*. 2008: The Australian Institue of Food Science and Technology Incorporated. p. 222.

suitable for HPP is very wide. In general, any product containing a high percentage of water can be processed by HPP, including meat products, fish and seafood, dairy, juice and most fruits and vegetables. Australian HPP products commercially available include fruit juice and avocado dip, with much research into economically viable fruit and vegetable products and investigation into fresh meat processing. HPP products must be stored chilled, as spore forming organisms are not deactivated during this non-thermal process.

The high quality of chilled HPP products, has led to research into HPP that includes an additional short thermal treatment. This is known as high pressure thermal processing (HPTP) or pressure-assisted thermal processing (PATS). High pressure sterilisation (HPS), is a sterilisation technique based on HPP. With the addition of a short thermal treatment to the high pressure treatment, a shelf-stable[9] product, or a chilled extended shelf-life product (shelf-life and storage conditions are dependent on the foodstuff) that retains high organoleptic quality can be produced. A shelf-stable HPTP mashed potato recently received US Food and Drug Administration (FDA) approval [8], its TRL is estimated at 6. CSIRO has a HPTP pilot plant at their Werribee site. DSTO-Scottsdale and CSIRO have worked on a collaborative project to produce shelf-stable pears [10]. HPTP for RAN victualling that is able to be stored (chilled) for 2-3 months has, however, not yet been investigated. Technically these foods would fall between the already obtainable (TRL 9) chilled HPP products of short shelf-life, and the emerging long-life shelf-stable products required for Army rationing (TRL 6). These 'midway' products present a fertile area of research, and may be considered as dual use in that they have a prospect of becoming supermarket-shelf products. The potential to meeting RAN victualling needs (food culture expects high quality) and those of the Australian food industry for fresh products for the export market makes this technology a prime candidate for collaborative Defence and Industry research. A five-year research program investigating the ability of HPTP to meet RAN victualling needs, if beginning in the next couple of years, could confirm or exclude this technology as being fit-for-purpose for future RAN platforms.

#### *2.2.1.3 Microwave Assisted Thermal Sterilisation*

A consortium led by Washington State University (WSU), and including US Defense feeding interests [11], has developed microwave assisted thermal sterilisation (MATS) to the point of technology transfer to industry [8, 12]. Although this technique is in the mid stages of readiness with an estimated technology readiness level (TRL) of 6, MATS shows promise in delivering shelf-stable products of high quality. Initially two MATS processed products have achieved Food and Drug Administration (FDA) approval in the US; mashed potato and salmon in a cream sauce.

During MATS processing [13], packaged food is passed through a microwave field (915 MHz) which induces dielectric heating. Processing with this technology is much quicker

[9] Shelf-stable is used to denote food products that can be stored for extended periods without spoiling. It is preferable to the term 'non-perishable' as it recognises that all food will have some defined shelf life. Of particular interest in a military context are food products that are shelf-stable for extended periods at ambient temperatures. Freeze-dried meals used in Combat Ration Packs are an example of a food that is shelf-stable for up to 3 years at ambient temperature.

than conventional thermal processing, as the heat is generated internally. Shorter processing time/temperature combinations enable the retention of food quality parameters such as colour, texture and sensitive nutritional components. In conventional thermal processing, the slow heat conduction from the heating medium to the cold-spot often results in treatment of the material at the periphery of the container that is far more severe than that required to achieve commercial sterility, resulting in loss of food quality.

Research is underway to better understand the dielectric properties of foods, model the thermal profiles of different foods and food products [14, 15] and develop packaging optimised for this processing technique. DSTO, through the Centre for Food Innovation (CFI), and in collaboration with University of Tasmania (UTAS), CSIRO and the Australian industry, is currently developing a business case to establish a MATS pilot plant in Australia. A MATS pilot plant in Australia would enable further R&D of this emerging technique. Furthermore, such research and development could mitigate the risk of achieving a suitable TRL of 9 by key decision dates for future naval platforms (5-10 years).

Advantages of MATS products for naval victualling are similar to those outlined for cook chill, above. MATS products packaged in bulk rather than as individual meals may best suit the RAN culture, as the food could then be prepared, heated and plated for each meal, with the option of adding fresh elements to enhance eating experience. MATS meals would be prepared in an industrial kitchen and delivered to the vessel, adding the advantages of reduced food and labour costs, and no requirement for freezer or chilled space as MATS meals are shelf-stable[10] at ambient temperatures.

#### *2.2.1.4 Other emerging and future food processing technologies of interest*

The usefulness, or otherwise, of emerging technologies is difficult to predict. In addition to HPP/HPTP and MATS/MAPs, other food processing technologies are being investigated [8]. Many of the techniques appear, however, to be suited to liquid or 'pumpable' foods such as milk, juices, sauces and soups. Many are used in the treatment of waste water in the food industry, and have also found application as a pre-treatment to enhance extraction or dehydration processes. Currently, they do not appear to be readily applicable to naval victualling. A summary of some of these emerging technologies is given below[8]:

- Pulsed Electric Field – a non-thermal technology using high-energy pulsed electric field (PEF) to breakdown harmful microorganisms and enzymes in liquids and slurries. Liquids are pumped through treatment chambers, where a rapidly pulsed electric field is applied. The field ruptures the cell walls and membranes of the microorganisms in the liquid, killing the cells and rendering them harmless.
- Supercritical Fluids [8] – carbon dioxide is often used as a supercritical fluid. The fluid is brought to its critical point by increasing pressure and temperature, so the

[10] A pasteurised version of MATS or MAPs – microwave assisted pasteurisation – would produce pasteurised meals which require chilling. MAPs may be of more interest to the commercial food industry than MATS, and so available to RAN at lower price, in greater variety and sooner than MATS. This is based on the assumption that MAPs would be technically less difficult to achieve than MATS due to the lower temperature processing requirements for pasteurisation. MATS, or a sterilised product would only be required when no chilled storage is available, for example Army rationing in the field.

fluid has the high solvency properties of a liquid and the high diffusivity of a gas. Supercritical fluid extraction (SFE) has been used for the extraction of essential oils, lipids and other expensive components. Supercritical $CO_2$ has also been found to inactivate enzymes and microorganisms. This is a non-thermal treatment, so organoleptic properties are retained, but currently only small batches can be processed.

- 3D-Printing – 3D printing or additive manufacturing has been in development for many years, and is currently used in manufacturing application such as the rapid development of prototypes in house, and 'printing' tools, jigs and various replacement components. There are a number of different 3D printing techniques; two of the more developed methods are fused deposition modelling (FDM) [16] and selective laser sintering (SLS) [17]. For FDM the material is melted and extruded in layers, one upon the other to build up the object in 3D. For SLS a bed of powdered material, such as nylon or titanium, is sintered or hardened, layer upon thin layer within it, until a model is pulled out of the remaining powder. The range of materials used in 3D printing is increasing rapidly, and today includes thermoplastics, polystyrene, graphene, ceramics, glass, nylon and metals including titanium, aluminium and silver [18] and [19]. Biomedical applications are under development, and in the future customised replacement organs and joints may be produced by 3D printing. Food processing has seen the demonstration of basic proof of concept applications, such as a 3D printed pizza, cookies and confectionery with sugar and chocolate [20]. These concepts extend to foods that don't require heating before consumption, or that are cooked after printing. However, its imaginable that in the near future, a food bar customised to an individual's nutritional requirements - perhaps with the results of a quick cheek swab or finger prick suppling the specific print file could be printed and consumed in a few minutes to allow an individual to recover fitness, energy and/or cognition.

### 2.2.2 Reducing Waste

Managing victualling waste must be carefully considered and implemented as part of a holistic integrated solution. All waste generated by the food system of a naval vessel must be processed, then either stored on board until the platform returns to port, or ejected over board in accordance with the current MARPOL regulations. There may also be operational constraints placed on the naval platform which do not allow any waste to be pumped over board during certain missions.

Waste products consist of: food scraps discarded during preparation, uncooked portions of foods, leftover cooked foods and spoiled foods that have passed the best before date. In addition, grey water from cooking and cleaning and food packaging also contribute to victualling waste. Waste generated from the outer packaging of food can be reduced by unpacking the food before it is brought on board. However, this activity does take time and space. This activity could be undertaken by the crew as they store the food or by the logistics company as they deliver the food to the quayside.

Using pre-prepared fresh foods such as peeled and cut fruit and vegetables could reduce food scraps and save preparation time and space. The shelf-life and storage requirements of the pre-prepared fresh products depends on the food item, but generally most items will have a longer shelf-life if stored chilled (temperature < $4^{0}C$). These foods could be sourced in the appropriate package size to help reduce the waste generated from uncooked portions of food not used in the meal. However, pre-prepared products and smaller sized portions of foods will contribute more to the packaging waste burden. Peeled and cut fruit and vegetables may be contained in specialised packaging, such as modified atmosphere packaging (MAP), to help retain freshness. Packaging which is soiled by food must be treated/cleaned and managed, perhaps by crushing and storing in a chilled area to prevent the microbial growth and the development of off-odours.

Wastage generated from cooked left-over food could be reduced by systematic menu planning and ordering. Commercially available software packages, such as *Nutmeg* and *Saffron,* assist inventory control, purchasing, receiving and recipe management [21], and could likely be adapted to naval victualling with minimal cost and effort. These electronic meal planning systems can also help provide the optimal nutrition and energy requirements for the deployment. Potentially, the menu planning software could be interfaced to an app which allows the crew members to pre-order their desired meal daily, from a range offered by the chef – further reducing waste from cooked leftover food, and increasing meal satisfaction.

## 2.3 Platform design: galley and food storage areas

The size, location and equipment of the galley and the food storage areas will be decided in the context of the overall design of the platform, but should be given adequate consideration alongside other platform systems, such as navigation, weapons and propulsion systems. Clever design of the victualling system as a whole can increase platform endurance and hence the Defence capability.

The design and location of the galley and the food storage areas can make a significant difference to the smooth running of the vessel. Size, weight and power requirements (SWAP) are key issues in naval platform design, but the decisions become critical in the highly constrained environment such as those of a submarine. Ideally, a submarine galley will comply with the following design philosophy:

- Be close to the centre of longitudinal rotation (close to midships) to reduce motions.
- Be adjacent to the dry store, the cool store and the cold store to reduce the distance the cooks have to carry food.
- Be adjacent to the mess compartments where the food will be served and consumed.
- Be large enough to allow meals to be prepared and cooked for the standard crew, including any extra personnel which may be on board (extended crew).
- Contain enough equipment to cater for the extended crew with sufficient redundancy to cope with equipment failure.
- Allow for safe cooking of meals when the submarine is on the surface in a seaway and is rolling significantly each side for prolonged periods of time.

On board naval platforms, food is traditionally stored in three types of store rooms; the dry store (ambient temperature), the cool store (under 5 °C) and the cold store (under -20 °C). Each store may or may not be adjacent to each other in the general arrangement layout, however if the distance between each store and the galley can be minimised this will greatly affect the ability of the chefs to retrieve food when it is required. The storage route should also be considered early in the design cycle, to avoid having to carry large quantities of bulky victualling items through the submarine or surface ship when storing, this is a known WH&S issue.

If the food processing technologies discussed (Section 2.2.1), become available before key decision dates are reached, the need for either cold or chilled storage areas could be reduced or eliminated. The cook chill HTRF, HPP and MAPs require chilled storage, and HTPT and MATS are expected to produce shelf-stable products. Although the rate of development of emerging technologies is difficult to predict, both HPTP and MATS TRL are estimated at 6. It is highly likely that in 5-10 years timeframe, Australian industry will have taken up one or both of these technologies, and be in a position to provide the RAN with high quality products. Risk mitigation strategies could include RAN co-investment in developing these technologies and products, or tasking DSTO-Scottsdale to conduct R&D in this area.

As mentioned earlier (Section 2.1), food and feeding are highly specific to different cultures. The galley design and food storage philosophy of foreign naval platforms may be fundamentally different to that of an Australian designed naval platform in food preparation, cooking/heating techniques and the storage areas required. Although the differences may be subtle, further analysis of victualling systems of Military off the Shelf (MOTS) options for future naval platforms is warranted in the early stages of Defence projects. Submarines are very sensitive to weight and the distribution of weight in all three dimensions and galley requirements and options should be well known by 2$^{nd}$ pass of the project.

## 2.4 Logistics

The logistics chain to support a naval victualling system are represented below, Fig. 2

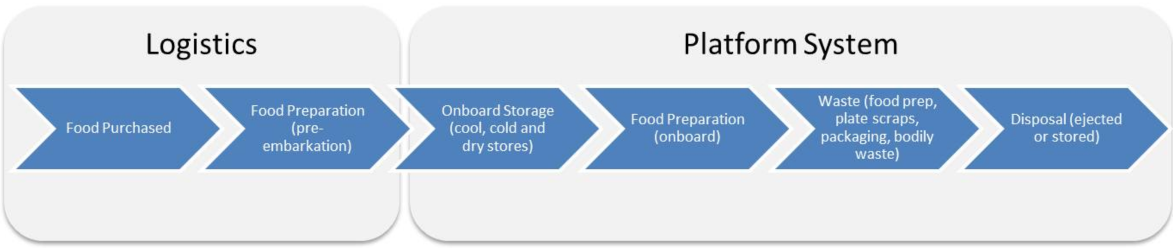


*Figure 2     Naval victualling logistics chain*

If the victualling system of a naval platform is changed the impact on the logistics chain needs to be considered as part of an overall design philosophy.

If sourcing specialised products, such as cook chill HTRF, HPP and/or MAPs which require refrigeration, the cold chain will need to be controlled throughout the handover from supplier to vessel. If the cold chain is compromised, shelf-life may be reduced, and food safety could become an issue. Robust analysis of the availability of these products at foreign ports should also be completed, to assist RAN planning of re-supply.

## 2.5 Opportunities, risks and mitigation activities

The use of new technologies provides many opportunities for the RAN, but may also introduce some risks, as benefits to the one component of the system may lead to detriments to another component of the system. Any changes to the victualling system should be considered as an integrated whole.

Opportunities:

1. Extend the endurance, and hence capability of RAN platforms through introduction of long shelf-life foods
2. Reduce waste, labour and preparation time by using pre-prepared foods
3. Increase nutrition and health outcomes by using electronic menu planning
4. Increase uptake of new victualling systems through new education and promotion techniques such as social marketing
5. Increase fit of new victualling system with RAN platform through understanding RAN food culture
6. Develop functional foods specific for RAN crews, for example Vitamin D enhancement for submariners
7. Increase safety and reduce WH&S issues by clever galley and food storage area design

Risks and mitigation strategies:

1. Beneficial changes (for example: use of pre-prepared fresh products) in one component produce detrimental change in another (for example: increase in packaging waste)
   a. Mitigation Strategy – consider victualling system holistically by conducting a systems study
2. TRL of emerging food processing technologies not ready by key decision dates
   a. Mitigation Strategy - conduct/task R&D into food processing technologies with relevance to RAN (for example cook chill HTRF, MAPs and HPP)
   b. Mitigation Strategy - RAN co-investment with Australian industry to produce RAN specific products (for example RAN investment in MATS pilot plant)

   c. Mitigation Strategy - conduct/task a watching brief on emerging technologies

3. Limited availability of specialised food in foreign ports
   a. Mitigation Strategy - detailed analysis and mapping of availability and consider international collaboration in food supply to fill identified gaps

4. Crew have low acceptability and uptake of new victualling system
   a. Mitigation Strategy – (see opportunities 4 and 5' above) use of social marketing and understanding RAN food culture

5. RAN chefs loose skills and morale declines
   a. Mitigation Strategy - use victualling systems which require preparation and use of some fresh products at each meal

6. Optimisation of the RAN victualling system reduces redundancy and may lead to reduced flexibility to adapt to unforseen events. For example, if an optimised victualling system is designed to include only dry and cool stores and no frozen foods are required, if there is a failure in the one of the two remaining stores (i.e. cool store) the vessel has only the dry store to meet the victualling needs.
   a. Mitigation Strategy – retain a small amount of redundancy in the stores to provide options to meet unforeseen circumstances

# 3. Conclusions

The victualling system of RAN vessels can affect endurance, and hence capability. As major Defence naval projects move towards key decision dates, it is important to identify emerging technologies, understand the technology readiness levels (TRLs) of candidate food processing technologies, and analyse the impact, opportunities and risks these technologies present to RAN victualling. Naval victualling may be considered as a system, where changes in one component can affect other components either beneficially or detrimentally. In thinking of victualling as a system it is important to understand the context in which the system sits. Understanding RAN food culture also has a bearing on the choice and introduction of systems and in making decisions as to which options are a good fit in terms of both utility and acceptance, and are most likely to be successfully introduced into service.

Food processing technologies which may be a good fit for the RAN are considered to be cook chill HTFR, HPP and MAPs. As both HPP and MAPs are emerging technologies, it is recommended that a watching brief be maintained that would monitor the developing maturity (TRLs) and industry up-take (affecting availability and cost) of these technologies. This brief should be maintained up to the key decision dates of the major projects.

In addition to improving the current naval victualling system, new technologies offer the scope to also improve nutrition (and hence health) of the RAN crew, and reduce waste. In particular the introduction of electronic menu-managements systems should be considered. Functional foods can also offer targeted solutions for specific nutritional challenges such as vitamin D deficiency, which can be experienced by submariners subjected to frequent and extended periods without sunlight. The introduction of new systems and technologies can be a challenge for personnel, here the use of social marketing techniques could help with gaining a widespread understanding and acceptance of new food processing techniques and victualling systems for the RAN.

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victualling, food processing technologies, shelf-stable foods, future naval platforms

19. ABSTRACT

Rapid Prototyping, Development and Evaluation (RPDE) are investigating alternative victualling methods for submarines and surface ships of the Royal Australian Navy (RAN). Emerging food processing technologies were identified and considered in the context of the RAN victualling system and naval food culture. Technologies such as cook chill - heat treated refrigerated food (HTRF) - have a shelf-life up to 2 months and are currently available. Other technologies, such as high pressure processing (HPP) and microwave assisted pasteurisation (MAPs) promise 'fresh-like' foods with extended shelf-life under chilled storage. While other developing technologies such as microwave assisted thermal sterilisation (MATS) and high pressure thermal processing (HPTP) aim to produce extended shelf-life foods which are fresh-like and shelf-stable. Although the technology readiness levels (TRLs) of the emerging technologies estimated to be ~ 6, key decision dates of some future naval platforms are still about 5-10 years away. These technologies might then reach maturity within this timeframe. Opportunities, risks and mitigation strategies are also discussed.

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