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A Revised Maritime Physical Accommodation Guidance for the Royal Australian Navy

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ABSTRACT

In 2015 an Anthropometric Survey of the Royal Australian Navy (ASRAN) was conducted providing comprehensive female and male body size and shape data of the Royal Australian Navy operational workforce. That data was then developed into evidence based human factors engineering design guidance, presented in this document that can be used to tailor design solutions to optimise the fit between the RAN population and HMA Surface Ships and Submarines, and their systems, subsystems, and facilities. The main purpose of this guidance is to provide future and modified naval vessels with physical habitability requirements that reflect the physical and social needs of the personnel that use it. The end goal is to optimise performance, health and safety, quality of life, and satisfaction.

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Executive Summary

In 2015 an Anthropometric Survey of the Royal Australian Navy (ASRAN) was conducted providing comprehensive digital and manual anthropometric data (body size and shape) that can be used for the design of vessels, equipment, and clothing. This document has used that data to develop evidence based human factors engineering design guidance that can be used to tailor design solutions to optimise the fit between the Royal Australian Navy (RAN) population and Her Majesty's Australian (HMA) Surface Ships and Submarines, and their systems, subsystems, and facilities. The main purpose of this guidance is to provide future and modified naval vessel projects with physical habitability requirements that reflect the physical and social needs of the personnel that use it. The end goal is to optimise performance, health and safety, quality of life, and satisfaction. This document forms part of the ongoing Human Systems Integration advice provided to the Future Submarine Program (FSP), but also has widespread application to all RAN vessels/projects.

In preparing the requirements for this document a variety of stakeholder interviews and focus groups were conducted with the FSP, Future Frigate Program Office, Navy Technical Bureau (NTB), Landing Helicopter Dock (LHD) Program, Capability Acquisition and Sustainment Group (CASG) Engineers, and Defence Science and Technology (DST) Naval Architects. Key findings were, the requirement for information on what human factors engineering design guidance values are based on to have information on the trade space, and evidence-based quantitative information to argue for space claims. A second key requirement was for design guidance that may be more easily accommodated on conventional submarines, as human factors engineering requirements for ships can often not be accommodated within submarine space constraints.

A review of ergonomic literature, industry and defence human factors engineering standards was conducted to assist in identifying the appropriate anthropometric dimension(s) for a design object/arrangement, the required movement allowance, and additional suggested allowances such as enhancing comfort. In addition RAN secular trend (generational growth changes) data, and clothing and equipment data were incorporated into the guidance development.

The guidance developed is mainly in the areas of space claims for general postures, workstations, bunks, access and passage, mess design, ablution facilities, and showers. This guidance can be applied to the design, construction, modification, and evaluation of HMA Surface Ships and Submarines to more effectively integrate the human in the design of a vessel, system, subsystem or facility, and to inform the human engineering and physical accommodation requirements in the design trade space. Note this is a revised version of *A Maritime Physical Habitability Guidance for the Royal Australian Navy* [1]. The

main revision changes include improved data for design objects/arrangements that require multiple anthropometric dimensions, clarity of how the values are derived, information on secular trend, and additional information on the target population to accommodate.

Future work intends to expand on human engineering requirements for design objects/arrangements that involve more dynamic movement tasks/activities such as climbing ladders and manoeuvring through hatches.

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Kate is a Certified Professional Ergonomist working in the Defence Science and Technology Group on submarine human factors research. Broadly her work focuses on the application of human systems integration (HSI) to minimise human related risks in the future submarine program. Under the broad spectrum of HSI, her recent work involves research and application in the area of human factors engineering, as well as conducting research into the crew endurance and habitability related design drivers for long duration missions.

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Glossary

ASRAN	Anthropometric Survey of the Royal Australian Navy
CASG	Capability Acquisition and Sustainment Group
DST	Defence Science and Technology
HFE	Human Factors Engineering
HMA	Her Majesty's Australian
HSI	Human Systems Integration
LHD	Landing Helicopter Dock (Amphibious Assault Ship)
PECCF	Personal Equipment and Clothing Correction Factors
RAN	Royal Australian Navy
%ile	Percentile

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1. Introduction

1.1. Revision information

This is a revised version of *A Maritime Physical Habitability Guidance for the Royal Australian Navy* [1]. The main revision changes include improved data for design objects/arrangements that require multiple anthropometric dimensions, clarity on how the values are derived, information on secular trend, updated personal equipment and clothing correction factor data, and additional information on the target population to accommodate.

1.2. Background

The Royal Australian Navy (RAN) has a strategic focus to maintain and build a highly capable and versatile maritime force that is able to undertake a wide range of activities into the region and beyond. This includes having regionally superior submarines and surface vessels that protect our sovereignty, maintain presence and project force [2]. The Navy is dependent upon its shipboard personnel to accomplish this strategy. The human component is a key enabler of operational capability and as such a platform design must be able to ensure the delivery of an effective human component. In order for the human component to be effective, it must be able to operate at and sustain optimal levels of performance [2,3].

Navy shipboard life contains a number of elements that may have a considerable bearing on the physical and psychological well-being of the ship's crew. These include environmental, physiological and psychological stressors such as long work hours, fatigue, confined spaces, separation from family and friends, intermittent danger, boredom, forced contact with others, shift work, and the unpredictable nature of the sea. The RAN recognizes the positive impact that appropriate habitability criteria and design practices can have on mitigating these factors [3].

Broadly, habitability covers aspects of temperature, noise, lighting, vibration and space attributes of the living and working environment including the provision of facilities (e.g., berthing, sanitary, food service, exercise, training, laundry, medical, dental, administrative, ship stores, and community or lounge facilities) [4]. Habitability characteristics contribute directly to personnel effectiveness and overall system performance [5], and has been linked to high levels of crew morale, performance, readiness, motivation, quality of life, safety, health, and comfort [4,5,6]. Shipboard habitability has a known impact on recruitment and retention [5,6], and research demonstrates that a ship's crew which is happy with their living and working conditions will have higher levels of job satisfaction, are less likely to seek alternative employment, and are more motivated, productive, proactive and perform their duties to a higher standard for a longer period of time [3,7].

Safety is of paramount importance and should be considered at all times in the design and implementation of ship habitability. Habitability directly and indirectly influences the safety of the crew and the platform. A ship that is well designed from a habitability view point will minimize the crew's exposure to hazards such as poor ergonomic and work system design [3]. Habitability should be considered as part of a project's implementation of Human Systems Integration (HSI).

1.2.1. Human Systems Integration

The systematic application and management of ergonomics and human factors in a system or materiel acquisition which takes into account all the human related issues and concerns over a system/materiel lifecycle is referred to as Human Systems Integration (HSI, also referred to as Human Factors Integration). HSI is often embedded within a systems engineering effort and provides methods and processes for integrated and comprehensive analysis, design and assessment of requirements, and operational and maintenance concepts. Overall program management as well as individual analysis and activities are focused on the HSI domains. These domains are the primary drivers of effective, affordable, and safe design concepts and deployed systems. Up to nine domains are typically used to support HSI, including:

- Manpower
- Personnel
- Training
- System safety
- Survivability
- Health hazards
- Habitability
- Human factors engineering
- Social and organisational [4,5,8,9,10].

Maintainability is a potential tenth domain to consider depending on the system/materiel being acquired and the context in which it is to be operated. For example in the context of submarine operations, on-board in-house maintenance can be essential for the sustainment of an operation which can result in maintainability as another HSI domain to specifically address.

Provision of HSI work and services should include a plan of the HSI processes and activities that address the human factors and human integration with the ship, submarine, system, sub-system, equipment, or facility. The processes and activities are to be in accordance with appropriate HSI standards, ensuring proven methods and data are used [3]. The HSI analysis and activities conducted are used by the procuring organisation to perform cooperative trade-offs to achieve acceptable and informed system performance levels and life-cycle costs [4].

Ergonomically designed work systems enhance safety, performance, and efficiency. They should also support the tasks done by officers and crewmembers under all conditions [3].

1.3. Scope

As stated in section 1.2 the HSI domain of habitability refers to a broad range of design characteristics. This guidance document refers specifically to the spatial attributes of habitability that is accommodating the fit, clearance, reach, vision, and posture of users in the platform. This is referred to as physical accommodation; the guidance is based on the 2015 Anthropometric Survey of the RAN (ASRAN) [11,12].

The guidance and data in this document applies to the sizing of equipment, accesses, and clearances to provide physical compatibility of the human body (in terms of physical dimensions). It contains design guidance for certain critical design points and areas on maritime platforms, including general postures, workstations, bunks, access and passage, mess design, heads, and showers.

1.4. Purpose

1.4.1. Background

The ASRAN was conducted in 2015, providing comprehensive digital and manual anthropometric data that can be used for the design of vessels, equipment, and clothing. Following a review of a variety of Human Factors Engineering (HFE) guidelines on how to implement this data into a design process it became apparent that all guidance documents (with the exception of some guidance on certain workstation designs) did not provide a method to translate anthropometric data into design guidance. Virtually all HFE guidance provides a value for design with no supporting information on what that value is based on. For example, if a value of 2100 mm is given for a vessels clear deck height it is assumed this is based on stature, although the specific anthropometric dataset it was derived from can be unclear or difficult to access, the measurement protocol can be unclear, which together makes population comparisons difficult. Further it is unclear what, if any, clothing and equipment allowance has been incorporated into the value, as well as other allowances such as movement, comfort, and psychological (space beyond basic fit and accommodation for a feeling of openness). Without knowing how a HFE value has been derived there is no way to determine if that value will suit and accommodate a different population given required movement and clearance requirements. In addition, there is no way for project staff and HFE professionals to determine the available trade space. For example, while some projects may want to include a comfort and psychological allowance in a design arrangement to enhance standard of living, other projects designing more space-constrained platforms may be satisfied with a design arrangement that allows for basic fit, clothing, and movement only.

In preparing the requirements for this document a variety of stakeholder interviews and focus groups were conducted[1]. Key outcomes were the requirement for information on what HFE design guidance values are based on to have information on the trade space, and evidence based quantitative information to argue for space claims. A second key requirement was for design guidance that was more useful in diesel electric submarine design, as general HFE guidance for ship design often cannot be accommodated in conventional submarines, leaving designers and project staff with little information on basic requirements. Therefore this guidance document has been structured in a way to outline what space claim is needed for basic fit, clothing, and movement in accordance with accepted ergonomic practice (e.g., accommodating 5th – 95th percentiles as a minimum); followed with further information on additional allowances that could be included to increase the standard of living that may be expected on other Navy vessels.

1.4.2. Use of guidance

This document is intended for use by project staff, design engineers, systems engineers, maintainability engineers, operations analysts, human factors specialists, and others engaged in the definition, development, or evaluation of human factors requirements. This document can be used alongside the ASRAN data which has further information on anthropometric assessment and design evaluation [11, 12: version 1 currently under revision].

This guidance is based on the physical accommodation needs of a ship or boats complement and is intended to encourage design solutions to optimise the fit between the RAN population and HMA Surface Ships and Submarines, and their systems, subsystems, and facilities. The main purpose of this guidance is to provide future and modified naval vessels with physical habitability requirements that reflect the physical and social needs of the personnel that use it. The end goal is to optimise performance, health and safety, quality of life, and satisfaction [3,13].

This guidance can be used to more effectively integrate the human in the design of a vessel, system, subsystem or facility and to inform the human engineering and physical accommodation requirements of habitability in the design trade space [14].

1.5. Application

This physical accommodation guidance should be applied to the design, construction, modification and evaluation of RAN Surface Ships and Submarines their structures and for equipment, systems, subsystems, and facilities that human crew members come into contact with for any manner of operation, habitability, and maintenance purposes [3,13,14].

[1] Participants were from the: Future Submarine Program Office, Future Submarine Technical Office, Future Frigate Program Office, Navy Technical Bureau, LHD Program, CASG Engineers, and DST Naval Architects.

This guidance is presented based on the size and shape characteristics of the 2015 RAN population. For ongoing and widespread utility the information has been presented in such a way that the main anthropometric guidance can be replaced with alternate data.

1.6. Process for using anthropometric data

This guidance document provides a starting point for design and space claim requirements across a variety of arrangements for maritime platforms that is based on anthropometric data.

The recommended process for using anthropometric data is:

1. Identify the anthropometric dimension relevant to product design
2. Use anthropometric data representative of the intended users (see section 1.7)
3. Have clearly defined accommodation targets (see section 1.7.1)
4. Use statistically valid models of body size variation (see sections 1.7.1 and 1.7.2.2 on boundary manikins and reference to central population targets)
5. Apply the anthropometric data in a systematic and structured way (see sections 1.7 and 1.8)
6. Apply allowances for secular trend, personal equipment and clothing correction factors, movement, and comfort as required (see sections 1.7.2.1 and 1.8.6)
7. Establish early and ongoing design and sizing evaluations (adapted from [15]).

These processes are best completed in consultation with Human Factors professionals, particularly those with recent expertise in anthropometry to ensure steps 1-6 are applied robustly and accurately.

1.7. Anthropometric reference

Anthropometry is the branch of Human Factors that deals with measurements of body size, including lengths, breadths, depths, and circumferences relating to reach, clearance and fit; weight/mass is also typically measured [16,17].

The anthropometric reference in this design guidance document is the 2015 ASRAN data. This data includes female and male data of age's representative of the RAN operational workforce. The ASRAN data is available in the form of univariate dimensions outlining the range of percentiles for each dimension [11,12]. Requests for the raw data can be made to DST Group, Maritime Division, Human Systems and Information Integration. Digital 3D anthropometric data is also available from DST Group, Land Division, Human Systems Integration Team. See the RAN Preliminary Anthropometry Standard [11] for further details.

Application of anthropometric data is critical in matching and designing the physical form and dimensions of compartments, workspaces, systems or equipment to those of the users [16]. In order to maximise crew performance, anthropometric data should be incorporated into all areas designed for human work, to support human life at sea; and in development and procurement of virtually all equipment and clothing.

Defining crew anthropometric characteristics is recommended to occur in the conceptual design phase of a project to enable the habitable volume requirements and overall architectural layout designs to occur in the preliminary design phase [17].

Anthropometric data that most closely reflects the intended target population should be used with a particular focus given to the nationality, occupation, age of participant's vs population, and age of the data set. Anthropometric data is often used to define size limits in design based on the dimensions of the anticipated population of operating and maintenance personnel. By imposing size limits in design (e.g., designing so the shortest expected operator or maintainer can reach all controls), it follows that personnel who are beyond/within these extremes will also be accommodated [18].

1.7.1. Accommodation targets

The default position shall ensure the physical accommodation, compatibility, operability, and maintainability by both the 5th – 95th percentile females and 5th – 95th percentile males, or, central 90% of the population (using female and male limiting data separately)[2]. Accommodating the 3rd to 97th percentiles is preferred, and up to the 1st to 99th percentiles (or central 98%) and/or minimum and maximum values where possible, and where safety critical and life support functions require [13,14,19,20,21,22]. These guidelines reflect the widely accepted levels of accommodation used for design purposes [4,14,18,19].

Deviations from this approach are only to occur at the permission of the procuring organisation where the implications of excluding gender data, or, using combined data is made clear with specific detail on the population that is and is not accommodated. If the minimum 5th to 95th percentiles (or central 90% of the population) cannot be accommodated a risk shall be raised within the projects risk register to be addressed by a team involving human factors professionals to assess and inform the procuring organisation of the risk. Sufficient rationale and evidence should be provided where a design requirement has not been met, outlining the design and procurement attempts that have failed to meet the requirements. Approval to move forward with a design or option that does not meet the requirements shall be obtained by the procuring organisation [13].

[2] Often a target population guide is to accommodate at a minimum the 5th percentile female to 95th percentile male. The target population is often summarized as such, rather than referring to females and males separately as in most cases the 5th percentile female will capture the 5th percentile male, and the 95th percentile male will capture the 95th percentile female. However there are a few important dimensions for design where females are larger, and males are smaller. As such for precision and accuracy, female and male data should be examined and used separately unless evidence and rationale is presented for an alternative approach.

Consideration of anthropometric accommodation should also include other intended users outside of the normal population such as Army personnel and their equipment which may need to be accommodated on a Navy vessel.

1.7.2. Use of anthropometric data

In general, there are four principles of applied anthropometrics in design:

1. Design for the smallest: This principle applies primarily to the application of physical force and vertical and lateral reach distances. For example, the forces required to reach controls, and pull, push, or turn a handle. Usually, the maximum force that can be readily applied by the 5th percentile female for that movement is used as the criterion. Similarly, the reach of the 5th percentile female is often used as the criterion for the positioning of controls and handles etc.

2. Design for the largest: This principle applies primarily to clearances, such as escape hatches, maintenance accesses, lifeboats, walkways, workstations, bunk design, and overhead clearances. Clearances generally are such that at least the critical dimensions at the 95th percentile are accommodated as a minimum. Safety critical and life support functions such as escape hatches should consider the 99th percentile and/or maximum values as appropriate. In some cases, persons whose body size exceeds the designed clearances are precluded from selection for the system for safety reasons. It should be noted that although males usually reflect the limiting criteria, there are certain instances where females at the 95th percentile have larger dimensions, such as hip breadth, and chest depth. Therefore when designing for the target population and limiting criteria, always check both gender dimensions.

3. When it's acceptable to design for the average: The use of the 50th percentile data should only occur for certain objects in design where adjustability is not feasible, additional design considerations to cover the range of users is not feasible, the interaction is considered to be operationally and functionally insignificant, and there is a minimal impact on work performance and standard of living. For example, when determining the height of a wash basin the use of the 50th percentile elbow height standing may in this case be a suitable compromise as adjustability is not feasible, use is short term and relatively infrequent, and there would be a minimal impact on standard of living. There can be an erroneous tendency to consider the 50th percentile data as sufficient to accommodate the majority of users. This is an incorrect assumption as accommodating the 50th percentile person, depending on the design context, will only accommodate the 50th percentile person for the dimension in question, or, in design objects or arrangements concerning access, reach and posture for example, this approach will prevent 50% of the population from being accommodated. The 50th percentile dimensions will accommodate only a narrow portion of the population, not a majority of the users. The full size range of users must be considered for the majority of design objects and arrangements [23,24].

4. Design for the range: This principle is applied when determining the amount of adjustability that should be built into such things as variable height work surfaces and workstation seating to accommodate the target population [18]. Where appropriate, building in adjustability for the target population should be a primary design consideration.

1.7.2.1. Allowances, clearances, secular trends

Anthropometric data is typically collected on semi-nude participants, as is the case with the 2015 ASRAN data. As such it is necessary to consider additional allowances for good design, and in some cases subtractions to replicate posture or equipment changes. There are five main considerations:

a. Personal equipment and clothing correction factors (PECCF). This refers to the additional volume that clothing and equipment or other encumbrance normally worn adds to a dimension. For example work boots may add 43mm to a person's stature. Note, ranges of motion, reach envelopes, dexterity, mobility, strength, tactile sensitivity, and grasping capability can also be affected by worn equipment and clothing [18]. Some range of motion data is currently being collected with different RAN ensembles.

b. Secular trend. This refers to the generational changes in dimensions that can occur over time. For example height has been found to be increasing over the last 150 years [25,26,27]. It is important to consider secular trend where designs are formed many years before equipment/systems/platforms are operational and where they may be in service for many years or decades.

   A review of RAN secular trend has been conducted using the 1977 and 2015 RAN anthropometric surveys, matching for occupation and age. The main findings include:

   1. Body dimensions of male RAN personnel increased substantially over time
   2. Variability in body dimensions of male RAN typically increased and was more right-skewed over time (indicating the largest increases were observed in those with the largest body size) [27].

   A summary of this data is presented in Appendix A.

   The continuation of past secular trends cannot be confirmed without future anthropometric surveys. However given the past increases observed in RAN data it is recommended to consider applying secular trend allowances in design, where the design process or service life of the equipment/system/platform spans a decade or more.

   In addition to matching for age and occupation, secular trend evaluation requires the careful matching of measurement protocol and measurement tool (e.g., manual measure vs 3D scans and accompanying software) to ensure the change in a dimension being evaluated is not confounded by a different measurement approach. For example, abdominal extension may be taken whilst the subject is

breathing out, or breathing in, which will affect the values captured. As such there is currently only RAN secular trend information for 11 dimensions.

c. Dynamic movement. This refers to the additional space required for normal posture and movement when conducting a task. For example when determining the height of a space that people transit through, the motion of walking will require an additional 50-100mm for head clearance. Dynamic movement allowances are often an estimation that should be verified with kinematic investigations to check the geometry of motion, and movement trials with physical designs prior to finalising an appropriate allowance.

d. General allowances and clearances. The previous allowances are considered to be the basic minimum additions to the anthropometric data for space claims. For optimal habitability additional allowances and clearances will be necessary for many work spaces, environments, and industries. The reference data refers to the minimum factors to consider in a space claim for submarines. Other platforms may have the design freedom and imperative to include additional allowances. Additional factors to consider include, ingress/egress allowance, comfort allowance (being able to stretch and move more freely), and psychological allowance (feeling of more space and openness). Societal expectations such as proximity to others and personal space can also factor in to this consideration.

e. Subtractions. Certain subtractions to the values are presented where, for example, there are expected cushion or mattress compressions, or postural slump in individuals. Due to the varying nature of these potential reductions they are best tested in a physical mock-up with representative users in a realistic context. For example, some cushions or mattresses may soften over time but initially compress very little.

1.7.2.2. Summation of anthropometric dimensions

Summation of anthropometric percentile data will in most situations lead to error in the percent of the population that is intended to be accommodated resulting in unintended design failures. This occurs as individuals will not be at the same percentile across all dimensions. For example when adding 5th percentile female body segments the resulting manikin can be more than 15cm shorter than the actual 5th percentile stature [28]. A similar situation will occur for any percentile individual. Percentiles within a category of data to varying degrees are exclusive [20]. This also extends to the relationship between anthropometric dimensions and aspects such as joint movement and strength. There are many examples and case studies where design failures have occurred from adding multiple anthropometric percentiles together at once for a design object/arrangement. One such example is the design of an aircraft using 1st percentile female to 99th percentile male data. The design led to 90% of females, 80% of African-American males, and 30% of Caucasian males unable to fly the aircraft [29, for further information see 30,31,32].

Due to this known error that occurs when adding anthropometric percentile data, this process can only be accepted in two situations. Firstly, when it is known that there is a

strong correlation between all the dimensions required for a design object/arrangement. This can require detailed anthropometric data for the target population. Or secondly, in the case of conducting initial checks or suggesting preliminary space claims that is further followed by a more accurate approach which looks at the true body size and shape of individuals. This can often rely on access to raw anthropometric data (instead of just percentiles), which if available can be as quick and efficient as using percentile data.

In design contexts where multiple anthropometric dimensions are simultaneously important for fit, clearance, reach, vision, and posture, an appropriate multivariate approach to design, assessment, and evaluation should be followed. This can occur with the summation of the participant's raw anthropometric data [38] (to examine each individuals true body size/shape for a design component) which is the approach used in this document for the highest level of accuracy, or, using an approach such as principle component analysis to develop boundary manikins.

Finally, physical mock-ups provide an important last step in adapting, finalising and accepting designs. These procedures should follow any preliminary checks and designs prior to finalising and acceptance of designs or assessments/evaluations as no other method can verify and validate designs as accurately as a physical test. An important component of physical mock-ups is examining the difference in real world posture adaptations that can differ from the measurement protocol in the anthropometry survey.

See the Preliminary Anthropometric Standard for the RAN [12: version 1 currently under revision] for further detail.

1.8. Using this document

The majority of guidance in this document presents values based on addressing the target population identified in 1.7.1. Also refer to 1.7.2.1 for important additional information.

1.8.1. Submarine vs Ship application

Within the design guidance tables there is reference data and a formula outlining how the reference data was used to develop the design guidance value. The reference data is considered the minimum space claim requirement for fit and accommodation of body size, required clothing and equipment, and basic movement. This is intended as the current minimum design requirements for submarines, especially diesel electric submarines, where space is extremely limited and the main concern and desire is to at least accommodate the basic fit and movement of people. This design intention is to allow for basic standards of living, and to ensure work can be conducted without discomfort and injuries. Beneath the reference data are suggested possible additions.

Within the possible addition data, the secular trend and alternate clothing suggestions are also pertinent for submarine design. They are listed as possible additions to allow for individual projects to apply as necessary. With secular trend, each project should forecast their requirement to future proof the fit of the population which will vary given project

design timelines and platform life. Alternate clothing allowance needs to be considered based on the platforms standard operating procedures. For example, a project may want to ensure that under every circumstance all personnel can pass each other wearing firefighting clothing and equipment, or, a project may decide that only one of two people passing in a passageway needs to be accommodated in a firefighting ensemble.

As many other surface ship platforms do not have the extreme space constraints as submarines, additional space may be afforded, and required to meet the standard of living expectations of the workforce. For surface ship design, consideration should be given not only to secular trend and alternate clothing allowances, but also to suggestions on additional movement, comfort and psychological allowance.

Care must be taken to adapt the minimum values presented for submarines so as to not remove current standard of living conditions in other platforms.

1.8.2. Values for unobstructed space claim

The values presented in this guidance document refer to the unobstructed space claim required for fit, accommodation and basic movement. Any platform fixtures, fittings, piping etc. should be placed outside of this space claim. For example, if a suggested clear deck height is 2100mm, this refers to the unobstructed height for the users. Space required for any piping, air filters, lights etc. should be added to the physical accommodation values, or, a human systems integration risk needs to be raised within the project and addressed as per outlined in 1.7.1.

1.8.3. Allowances

1.8.3.1. Clothing

For some design objects and arrangements an alternate clothing allowance is included in the possible additions section of the tables. An alternate clothing allowance is presented where project staff may determine a need to accommodate a bulkier clothing and equipment ensemble for the certain design object/arrangement in their context. For example in some workstation designs a general clothing allowance of 10mm has been suggested. However project staff may determine that they will need to cater for persons wearing firefighting clothing and equipment whilst at a workstation. If this is the case an alternate or worst case clothing allowance can replace the general clothing allowance.

There are also instances where a clothing allowance from an alternate source is suggested as a suitable substitute where particular data may be lacking. For example, Hip Breadth, Sitting clothing correction values are not available for the submarine firefighting ensemble. If a bulky clothing allowance is considered to be required to add to the Hip Breadth, Sitting dimension, the clothing (PECCF) value for the ‘Boarding Party’ (applicable to surface ships) ensemble could be used.

1.8.3.2. Secular Trend

There are certain design objects/arrangements in this document where secular trend was deemed an important addition to consider, however specific data was lacking. For example, Abdominal Extension Depth, Sitting is considered to be a dimension that will likely have increased over time, as Waist Circumference and Weight both substantially increased. As specific data is not available however for Abdominal Extension, a nominal secular trend allowance is sometimes suggested. Similarly RAN secular trend information is available for Bideltoid Breadth and is often a suggested addition where Forearm-Forearm Breadth is used instead of Bideltoid Breadth for a width dimension. This is suggested to help future proof width dimensions in the absence of specific data.

See Appendix A for RAN secular trend data.

1.8.3.3. Movement and general allowance

Any possible addition termed 'alternate' is intended to be used instead of a smaller allowance already incorporated in the design guidance values presented. An alternate allowance will provide more freedom and options in movement. The choice of which additional allowance to include is at the discretion of human factors engineers, project and safety staff who can evaluate the trade-offs with other platform requirements and current standard of living expectations. As mentioned in 1.7.2.1 movement allowances should be verified with kinematics and physical trials.

1.8.3.4. Applying allowances

There is no priority to these 'Possible additions', they need to be considered within the unique design context for each project/platform/equipment/system.

1.8.4. Adjustable design features

Both adjustable and fixed design guidance are sometimes presented. Adjustable designs are always preferred as a wide proportion of the population can often be accommodated with sufficient adjustability. Where fixed designs are proposed, rationale for this approach should be presented with the resulting impact on the target population regarding their, fit, clearance, reach, vision and posture.

1.8.5. Threshold and Objective criteria

Occasionally ergonomic design features have been presented where they complement the design area, but are not based on anthropometrics. For example, back rest recline information complements all other anthropometrically based chair design information but this criteria itself is based on reducing spinal disc pressure and promoting good posture. Where examples such as this occur two values are presented for design. A 'threshold' value, which is a target minimum design criteria, and an 'objective' value, which is the preferred, design criteria. Where the threshold criterion is not met, a risk shall be raised within the projects risk register to be addressed by a team involving human factors

professionals; and approval to move forward with a design or option shall be obtained by the procuring organisation, as outlined in section 1.7.1 [13].

1.8.6. Allowance information

See Appendix B for data on allowances that can be applied.

1.8.7. Use of raw data

As mentioned in 1.7.2.2 adding anthropometric percentile data can lead to errors in the percent of the population that will be accommodated. For this reason, alternative multivariate methods are needed when a design object/arrangement requires the simultaneous addition or subtraction of anthropometric dimensions. Throughout this guidance document this has occurred where in the reference data percentile values have been replaced with a statement 'Consult raw data for relationship between multiple dimensions'. In these instances a new variable has essentially been computed with the addition or subtraction of each ASRAN participant's individual data, and new percentiles have then been computed. For example, for guidance point 1) Standing, Depth, there are three dimensions that are simultaneously important in the design, they are M23 Abdominal Extension Depth, Sitting; M61 Radiale-Stylion Length; and M66 Hand Length. The raw data for these three dimensions have been added together, and new percentile data is then calculated to examine the true proportions of these dimensions. Computing a new variable that accommodates (with fire-fighting clothing) 95% of Males requires a depth of 755mm; using percentile data, the same calculation would result in a space requirement of 776mm. In this example combining percentile data has overestimated the space claim required, but in other examples an under-estimation is found.

1.8.8. Adapting, accepting and finalising designs

The design guidance presented outlines initial space claim requirements. Physical mock-ups using representative personnel meeting the required extreme percentiles prior to design acceptance is strongly recommended and necessary where the activities and tasks required involve dynamic movement and multiple relevant anthropometric dimensions. Digital human modelling can be a very useful step in between static designs and physical mock-ups to refine designs, but physical mock-ups are best to validate and de-risk designs that require consideration of movement and postural requirements [22, 33].

2. Design Guidance

Table 1 Content list of physical accommodation guidance

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47. Water closets depth and width
48. Distance between centre lines of adjacent wash basins
49. Distance between centre lines of wash basin and adjacent bulkhead
50. Walking clearance between wash basin and facing bulkhead
51. Clearance between facing wash basins
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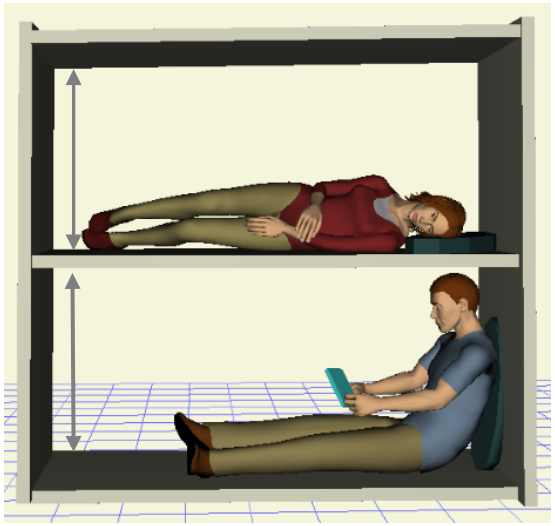
53. Shower width and depth – Objective guidance
54. Shower height

2.1. Example of use

1. Bunk vertical separation – for sitting

	Percentile Accommodated			
	95th %ile Male	97th %ile Male	99th %ile Male	Example
Vertical separation - for sitting	**1048**	**1053**	**1068**	**1111.4**
Reference data (mm):				
Sitting Height (M39)	998	1003	1018	1003
Dynamic allowance, movement	50	50	50	-
M39 + dynamic allowance				
Possible additions:				
Secular trend (M39) p/a	0.71	0.71	0.71	28.4
Alternate dynamic movement allowance	100	100	100	100
Psychological allowance	50	50	50	-
Clothing, general	10	10	10	-
Postural slump	-45	-45	-45	-
Mattress compression	-TBA	-TBA	-TBA	-20



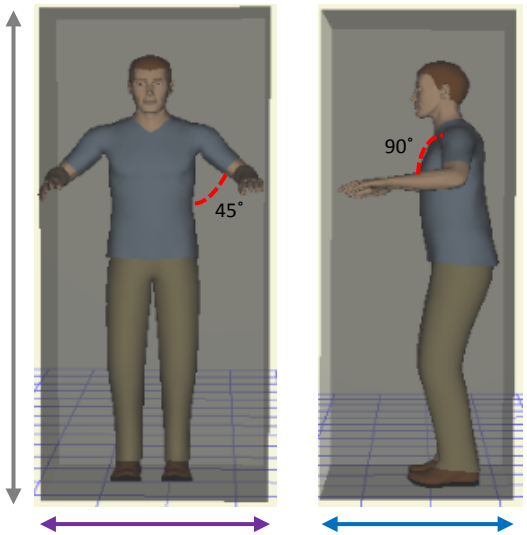
Rationale: The values reflect the vertical separation between the top of a mattress and the next bunk/deck height for the majority of the population to be able to sit upright in their bunks. If space permits, an alternate movement allowance can be used, as well as a psychological allowance for a greater feeling of space and openness. A clothing allowance may be appropriate to add depending on the operational temperatures and air conditioning systems. A subtraction to the value to account for postural slump is reasonable, and expected mattress compression can be subtracted too. Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

Working example: The project in question has a strong focus on optimal habitability and meeting quality of life expectations, and as space permits the project want to list a bunk design requirement that exceeds the minimum bunk vertical separation requirement of 1048mm. The project wants to accommodate the 97th percentile as a minimum. The use of the Alternate dynamic movement allowance of 100mm over the default minimum 50mm is desired to ensure crew can change posture in their bunks easily, and to also ensure those above the 97th percentile have their basic fit accommodated when sitting. This project wishes to accommodate current known growth trends and therefore will include a secular trend allowance. This project will have a 10 year design and build phase and a 30 year operational life; therefore secular trend for 40 years has been calculated and included (0.71 * 40 = 28.4mm). The mattress supplier has a tested mattress compression average of 20mm (when new), therefore this value has been subtracted. The requirement is therefore made up of 97th%ile male sitting height + 28.4mm secular trend + 100mm dynamic movement allowance – 20mm mattress compression.

2.2. General body space requirements

1. Standing

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Height	**2100**	**2119**	**2152**
Reference Data (mm):			
Stature (M38)	1906	1925	1958
Clothing allowance (Fire Fighting M38)	94	94	94
Dynamic allowance, walking	100	100	100
M38 + clothing + dynamic allowance			
Possible additions:			
Stature secular trend p/a	1.24	1.24	1.24
Psychological allowance	50	50	50
Width	**1227**	**1238**	**1260**
Reference data (mm):			
Forearm-Forearm Breadth (M22)	Consult raw data for relationship between multiple dimensions		
Acromion-Radiale Length (M60)			
Upper arm 45˚ from torso, sin(45)	0.707	0.707	0.707
Clothing allowance (Fire Fighting M22)	84	84	84
*M22+(M60*1.414)+clothing*			
Possible additions:			
Secular trend (M18) p/a	0.82	0.82	0.82



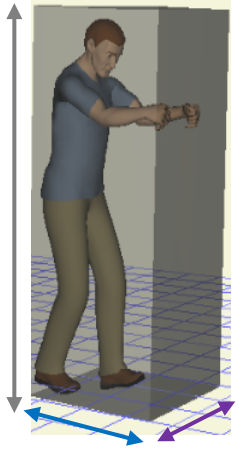
Rationale: The values reflect the space requirement for an individual to stand upright and perform simple tasks involving little effort and force requirements, e.g., reviewing paper documents and overseeing seated operators. The width and depth dimensions were calculated with the upper arms at 45˚ from the torso, and the elbows flexed at 90˚. Fire-fighting clothing allowance for stature has been included (boots and helmet).

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more. Psychological allowance, if space permits, will provide a greater

Depth	755	761	770	sense of openness and spaciousness, which can affect standard of living. [29]
Reference data (mm): Abdominal Extension Depth, Sitting (M23) Radiale-Stylion Length (M61) Hand Length (M66)	Consult raw data for relationship between multiple dimensions			
Clothing allowance (Fire Fighting M23) *(M23/2) + M61 + M66 + (clothing/2)*	211	211	211	

2. Standing and pulling

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Height	**2100**	**2119**	**2152**
Reference Data (mm):			
Stature (M38)	1906	1925	1958
Clothing allowance (Fire Fighting M38)	94	94	94
Dynamic allowance, walking *M38 + clothing + DA*	100	100	100
Possible additions:			
Secular trend (M38) p/a	1.24	1.24	1.24
Psychological allowance	50	50	50
Width	**825**	**837**	**858**
Reference data (mm):			
Forearm to forearm breadth (M22)	641	653	674
Dynamic allowance, pulling	100	100	100
Clothing allowance (Fire Fighting M22) *M22 + DA + clothing*	84	84	84
Possible additions:			
Secular trend (M18) p/a	0.82	0.82	0.82
Depth	**1091**	**1110**	**1139**
Reference data (mm):			
Thumbtip Reach (M37)	900	919	948
Dynamic allowance, pulling	100	100	100
Clothing allowance (Fire Fighting M20) *M37 + DA + (clothing/2)*	182	182	182

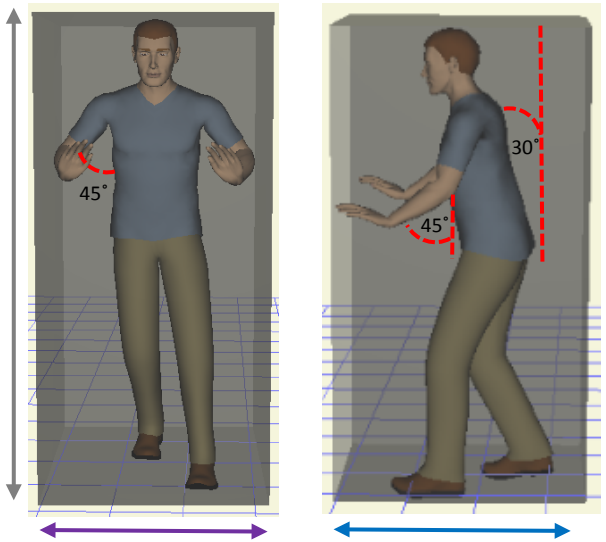


Rationale: The values reflect an initial space claim value for an individual wearing a fire-fighting ensemble to pull an object with arms stretched out for reach and without shoulder abduction. The values presented are an initial suggested starting point to determine the space claim required for a static posture. The overall space claim for dynamic exertions will be influenced by push/pull height, individual strength, torso position and feet position. The more complex cases of dynamic exertions should be solved by trial and error [22]. Additional references can be consulted for information on push/pull frequency, load size and characteristics, lift limits/frequency, coefficient of friction impacts, compression forces, posture and risk levels [14,22,35,36,37].

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

3. Standing and pushing

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Height	**2100**	**2119**	**2152**
Reference Data (mm):			
Stature (M38)	1906	1925	1958
Clothing allowance (Fire Fighting M38)	94	94	94
Dynamic allowance, walking	100	100	100
M38 + Footwear + DA			
Possible additions:			
Stature secular trend p/a	1.24	1.24	1.24
Psychological allowance	50	50	50
Width	**1227**	**1238**	**1260**
Reference data (mm):			
Forearm-Forearm Breadth (M22)	Consult raw data for relationship between multiple dimensions		
Acromion-Radiale Length (M60)			
Upper arm 45˚ from torso, sin(45)	0.707	0.707	0.707
Clothing allowance (Fire Fighting M22)	84	84	84
*M22+(M60*1.414)+clothing*			
Possible additions:			
Secular trend (M18) p/a	0.82	0.82	0.82
Dynamic allowance, movement	100	100	100
Depth	**1413**	**1430**	**1462**
Reference data (mm):			
Stature (M38)	Consult raw data for relationship between multiple dimensions		

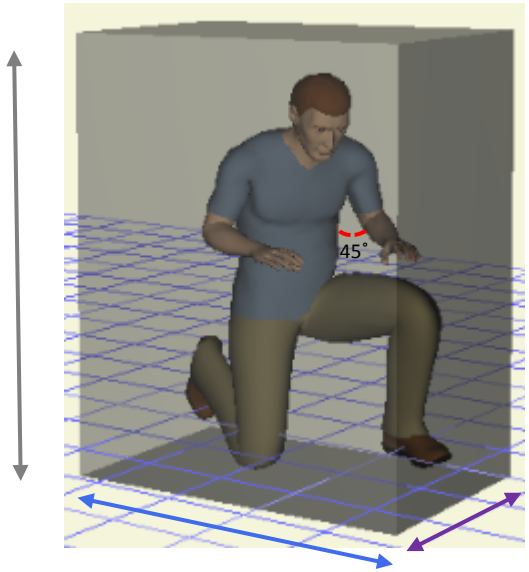


Rationale: The values reflect an initial space claim value for an individual wearing a fire-fighting ensemble to push an object with their upper arms at 45˚ from the torso, 45˚ elbow flexion, and a 30˚ stature lean. The height value is based on the need to stand upright before the push task. The depth value assumes that the position of the torso and arms will accommodate the depth of the fire-fighting ensemble and therefore this hasn't been added. The values presented are an initial suggested starting point to determine the space claim required for a static posture. The overall space claim for dynamic exertions will be influenced by push/pull height, individual strength, torso position and feet position. The more complex cases of dynamic exertions should be solved by trial and error [22]. Additional references can be consulted for information on push/pull frequency, load size and characteristics, lift

Acromion-Radiale Length (M60)				limits/frequency, coefficient of friction impacts, compression forces, posture and risk levels [14,22,35,36,37]. Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.
Radiale-Stylion Length (M61)				
Dynamic allowance, pulling	100	100	100	
Stature at 30° lean, sin(30)	0.5	0.5	0.5	
Upper and forearm at 45˚, sin(45)	0.707	0.707	0.707	
*M38 * 0.5 + M60 * 0.707 + M61 * 0.707 + DA*				
Possible additions:				
Secular trend (M38) p/a	1.24	1.24	1.24	

4. Kneeling (1 knee)

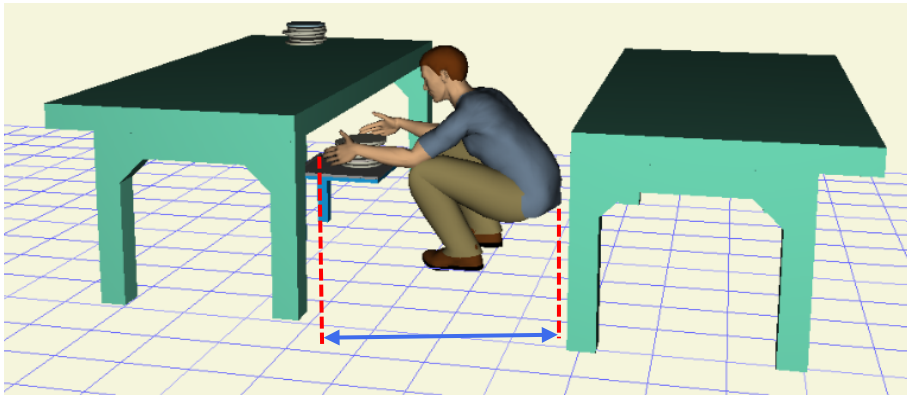
	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Height	**1451**	**1465**	**1487**
Reference data (mm):			
Stature (M38)	Consult raw data for relationship between multiple dimensions		
Knee Height, Sitting (M13)			
Footwear height	43	43	43
Dynamic allowance, movement	100	100	100
M38 - M13 + Footwear + DA			
Possible additions:			
Secular trend (M38) p/a	1.24	1.24	1.24
Alternate clothing allowance (Fire Fighting M38)	94	94	94
Width	**1277**	**1288**	**1310**
Reference data (mm):			
Forearm-Forearm Breadth (M22)	Consult raw data for relationship between multiple dimensions		
Acromion-Radiale Length (M60)			
Upper arm 45˚ from torso, sin(45)	0.707	0.707	0.707
Clothing allowance (Fire Fighting M22)	84	84	84
Dynamic allowance, movement	50	50	50
*M22 + (M60*1.414) + clothing + DA*			
Possible additions:			
Secular trend (M18) p/a	0.82	0.82	0.82
Alternate dynamic allowance, movement	100	100	100
Depth	**1413**	**1425**	**1458**
Reference data (mm):			



Rationale: The values reflect an initial space claim requirement for an individual wearing a fire-fighting ensemble kneeling on one knee and conducting light activities. The height values reflect the requirement once a person is kneeling and wearing shoes (no helmet), refer to design point (1) for standing height requirement. The width values assume the upper arm is at 45˚ from the torso. The depth values assume the posture will in itself accommodate the depth of a fire-fighting ensemble and therefore this hasn't been added; this posture also assumes reach does not extend beyond the knee. The values presented are an initial suggested starting point to determine the space

Knee Height, Sitting (M13) Buttock-Knee Length (M25)	Consult raw data for relationship between multiple dimensions			claim required for a static posture. The overall space claim for dynamic exertions will be influenced by task requirements, individual strength, and required force. The more complex cases of dynamic exertions should be solved by trial and error [22]. Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.
Footwear height	43	43	43	
Footwear length	41	41	41	
Dynamic allowance, movement *M13 + Footwear height + M25 + Footwear length + DA*	50	50	50	
Possible additions:				
Secular trend (M25) p/a	0.55	0.55	0.55	
Alternate dynamic allowance, movement	100	100	100	

5. Squat and reach



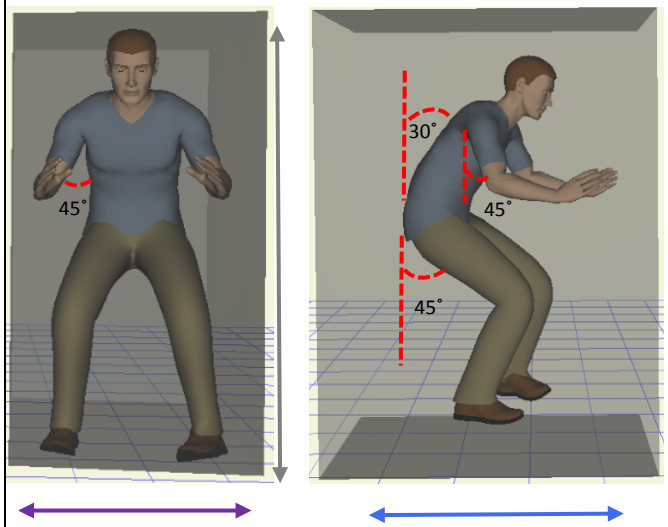
	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Length	**1275**	**1287**	**1315**
Reference data (mm):			
Buttock-Knee Length (M25)			
Radiale-Stylion Length (M61)	Consult raw data for relationship between multiple dimensions		
Hand Length (M66)			
Dynamic allowance, movement	100	100	100
Clothing allowance, general	10	10	10
M25 + M61 + M66 + dynamic allowance + clothing			
Possible additions: Alternate clothing allowance - Boarding party Buttock-Knee Length (M25)	152	152	152
Secular trend (M25) p/a	0.55	0.55	0.55

Rationale: The values reflect an initial space claim requirement for an individual squatting and reaching with their forearms beyond their knees to perform light tasks. A general clothing allowance has been included that could be substituted for a bulkier clothing ensemble if required. The values presented are an initial suggested starting point to determine the space claim required for a static posture. The overall space claim for dynamic exertions will be influenced by task requirements, individual strength, and required force. The more complex cases of dynamic exertions should be solved by trial and error [22].

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

6. Bending at waist height

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Height	**1859**	**1874**	**1908**
Reference data (mm):			
Knee Level (M83)			
Hip Level (M82)	Consult raw data for relationship between multiple dimensions		
Thigh Level (M82-M83)			
Upper leg at 45˚, sin(45)	0.707	0.707	0.707
Stature (M38)	Consult raw data for relationship between multiple dimensions		
Torso and Head (M38 - M82)			
Torso and Head at 30˚ lean, cos(30)	0.866	0.866	0.866
Clothing allowance (Fire Fighting M38)	94	94	94
Dynamic allowance, movement	100	100	100
*M83 + (Thigh Level * 0.707) + (Torso and Head * 0.866) + Clothing + DA*			
Possible additions:			
Secular trend (M38) p/a	1.24	1.24	1.24
Secular trend (M25) p/a	0.55	0.55	0.55
Width	**1327**	**1338**	**1360**
Reference data (mm):			
Foreare-Forearm breadth (M22)	Consult raw data for relationship between multiple dimensions		
Acromion-Radiale Length (M60)			
Upper arm 45˚ from torso, sin(45)	0.707	0.707	0.707
Clothing allowance (Fire Fighting M22)	84	84	84
Dynamic allowance, movement	100	100	100
*M22 + (M60*1.414) + clothing + DA*			



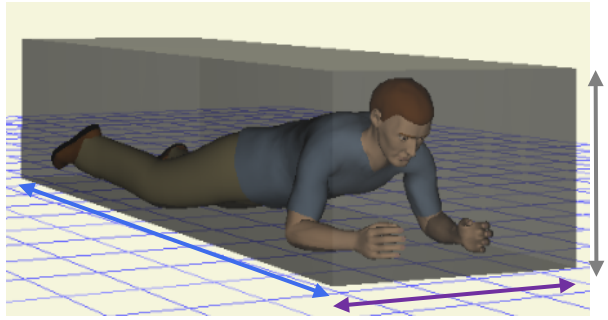
Rationale: The values reflect an initial space claim requirement for an individual wearing a fire-fighting ensemble bending at waist height to perform light tasks. The height values reflect the requirement once a person has bent forward wearing the full fire-fighting clothing and equipment, with a thigh angle of 45˚ and torso angle of 30˚. The width value assumes the upper arm is at 45˚ from the torso (shoulder abduction). The depth values assume the posture itself will accommodate the depth of a fire-fighting ensemble. The values presented are an initial suggested starting point to determine the space claim required for a static posture. The overall space claim for dynamic exertions will be influenced by task requirements, individual strength, and required force. The more complex cases of dynamic exertions should be solved by trial and error [22].

Projects should consider secular trend where the design

Possible additions:				process and/or platform lifecycle spans a decade or more.
Secular trend (M18) p/a	0.82	0.82	0.82	
Depth	**1342**	**1356**	**1383**	
Reference data (mm):				
Stature (M38)				
Hip Level (M82)	Consult raw data for relationship between multiple dimensions			
Torso and Head (M38 - M82)				
Torso and Head at 30˚, sin(30)	0.5	0.5	0.5	
Acromion-Radiale Length (M60)	Consult raw data for relationship between multiple dimensions			
Upper arm 45˚ from torso, sin(45)	0.707	0.707	0.707	
Radiale-Stylion Length (M61)	Consult raw data for relationship between multiple dimensions			
Hand Length (M66)				
Dynamic allowance, movement	100	100	100	
*(Torso and Head * 0.5) + (M60 * 0.707) + M61 + M66 + DA*				
Possible additions:				
Secular trend (M38) p/a	1.24	1.24	1.24	

7. Prone

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Height	**1029**	**1035**	**1056**
Reference data (mm):			
Acromion-Radiale Length (M60)			
Stature (M38)	Consult raw data for relationship between multiple dimensions		
Acromion Height (M03)			
Head and Neck Height (M38-M03)			
Clothing allowance (Fire Fighting M23)	211	211	211
Dynamic allowance, movement	100	100	100
M60 + Head and neck + clothing + DA			
Possible additions:			
Secular trend (M38) p/a	1.24	1.24	1.24
Fire Fighting Helmet	51	51	51
Width	**825**	**837**	**858**
Reference data (mm):			
Forearm-Forearm Breadth (M22)	641	653	674
Clothing allowance (Fire Fighting M22)	84	84	84
Dynamic allowance, movement	100	100	100
M22 + clothing + DA			
Possible additions:			
Secular trend (M18) p/a	0.82	0.82	0.82
Depth	**2255**	**2273**	**2317**
Reference data (mm):			
Stature (M38)	Consult raw data for relationship between multiple dimensions		



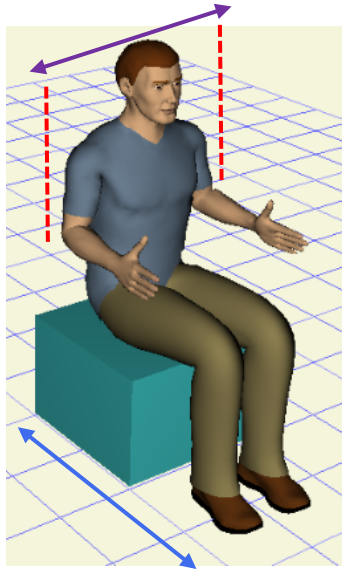
Rationale: The values reflect an initial space claim requirement for an individual wearing a fire-fighting ensemble (no helmet) in a prone position supported on both elbows with the hands reaching in front of the head. Height and width values include the fire-fighting ensemble. The values presented are an initial suggested starting point to determine the space claim required for a static posture. The overall space claim for dynamic exertions will be influenced by task requirements, individual strength, and required force. The more complex cases of dynamic exertions should be solved by trial and error [22].

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

Hand Length (M66)				
Footwear height	43	43	43	
Dynamic allowance (movement)	100	100	100	
M38 + M66 + footwear + DA				
Possible additions:				
Secular trend (M38) p/a	1.24	1.24	1.24	

8. Sitting

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Width	**726**	**738**	**759**
Reference data (mm):			
Forearm-Forearm breadth (M22)	641	653	674
Clothing allowance	10	10	10
Dynamic allowance, movement	75	75	75
M22 + clothing + dynamic allowance			
Possible additions:			
Secular trend (M18) p/a	0.82	0.82	0.82
Alternate clothing allowance (Fire Fighting M22)	84	84	84
Ingress/egress requirements	TBA	TBA	TBA
Depth	**971**	**985**	**1013**
Reference data (mm):			
Buttock-Popliteal Length (M26)	Consult raw data for relationship between multiple dimensions		
Foot Length (M71)			
Footwear length allowance	41	41	41
Dynamic allowance, movement *M26 + M71 + footwear allowance + dynamic allowance*	100	100	100
Possible additions:			
Clothing allowance (Boarding Party M25)	152	152	152
Secular trend (M25) p/a	0.55	0.55	0.55



Rationale: The values reflect an initial space claim requirement for a seated individual in general clothing. Bulkier clothing ensembles can be substituted for the general clothing allowance. These values only represent an initial space claim once an individual is seated; additional space requirements may be needed for ingress/egress. Height values have not been included as they are dependent on task and provided equipment.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

2.3. Workstations

9. Work surface underside (thigh) clearance

- Threshold	Percentile Accommodated 95th %ile Male	97th %ile Male	99th %ile Male
Fixed Height	**762**	**770**	**786**
Reference data (mm):			
Popliteal Height (M14)	Consult raw data for relationship between multiple dimensions		
Thigh Clearance (M12)			
Footwear height	43	43	43
Dynamic allowance, movement *M14 + M12 + footwear + dynamic allowance*	50	50	50
Possible additions:			
Secular trend (M12) p/a	0.26	0.26	0.26
Secular trend (M25) p/a	0.55	0.55	0.55
Clothing allowance, general	10	10	10
Alternate dynamic movement allowance	100	100	100

- Objective	Percentile Accommodated 1st %ile Female	3rd %ile Female	5th %ile Female
Adjustable Minimum Height	**565**	**608**	**611**
Reference data (mm):			
Popliteal Height (M14)	Consult raw data for relationship between multiple dimensions		
Thigh Clearance (M12)			
Footwear height	43	43	43
Dynamic allowance, movement *M14 + M12 + footwear + dynamic allowance*	50	50	50
Possible additions:			

Rationale: The values reflect the underside clearance requirements at a seated workstation. Threshold values have been provided where a work surface will have a fixed height. Objective values have been provided for an adjustable work surface height. If a work surface is adjustable the alternative movement allowance of 100mm is suggested if a seat pan height adjustment range can accommodate the range of users (elbow rest height for keyboard use). A nominal clothing allowance is subsumed within the dynamic movement allowance, although an additional clothing allowance can be added. Projects should also consider whether individuals wearing a bulkier clothing ensemble would need to sit at workstations. Encumbrance

Secular trend (M12) p/a	0.26	0.26	0.26
Secular trend (M25) p/a	0.55	0.55	0.55
Clothing allowance, general	10	10	10
Alternate dynamic movement allowance	100	100	100

	Percentile Accommodated		
- Objective	95th %ile Male	97th %ile Male	99th %ile Male
Adjustable Maximum Height	**762**	**770**	**786**
Reference data (mm):			
Popliteal Height (M14)	Consult raw data for relationship between multiple dimensions		
Thigh Clearance (M12)			
Footwear height	43	43	43
Dynamic allowance, movement *M14 + M12 + footwear + dynamic allowance*	50	50	50
Possible additions:			
Secular trend (M12) p/a	0.26	0.26	0.26
Secular trend (M25) p/a	0.55	0.55	0.55
Clothing allowance, general	10	10	10
Alternate dynamic movement allowance	100	100	100

values for thigh clearance were not captured in ASRAN therefore an estimation should be made for a bulky clothing ensemble depending on the nature of the ensemble required for operational reasons.

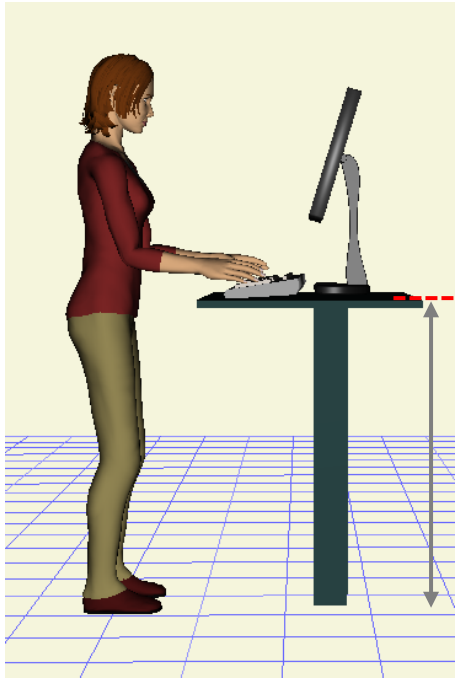
Underside clearance that is too low will impinge on users thigh clearance leading to discomfort, reduced blood flow, difficult posture adjustment, increase the likelihood of postural fixity, and inhibit ingress/egress.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

Note: these values do not reflect the actual work surface height, only the clearance needed underneath. Actual work surface height will need to add the thickness of the work surface. For ships and submarines a nominal amount of 30mm can be used as a starting value. It is desirable to have a work surface as thin as possible to avoid impacting on thigh clearance and elbow rest height.

10. Standing workstation - fixed height

- Threshold for computer use	Non-adjustable
Fixed Height	**1072**
Reference data (mm):	
Elbow rest height, standing*, Female 50th%ile	1020
Elbow rest height, standing*, Male 50th%ile	1087
Footwear height	43
Keyboard/input control height	-25 Or as advised
**New variable computed, Stature (M38) - (Sitting Height (M39) - Elbow Rest Height, Sitting (M11))*	
(Female elbow rest height standing + Male elbow rest height standing) / 2 + footwear height - keyboard/input control height	
Possible additions:	
Secular trend (M38) p/a	1.24
Secular trend (M39) p/a	0.71



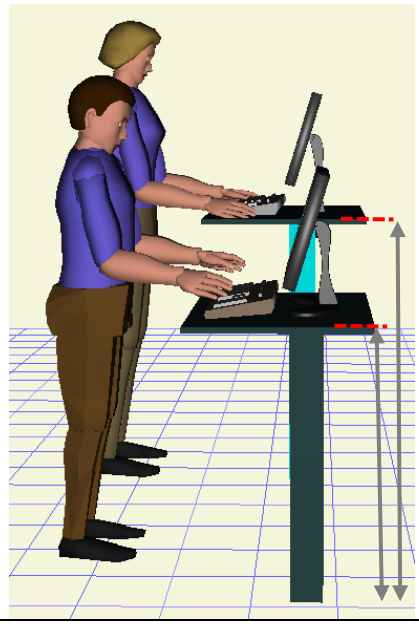
Rationale: The values reflect the threshold (non-adjustable) height recommendation for a fixed height standing workstation. For a fixed height workstation the 50th percentile dimension is used as a compromise, and will reduce the optimal working posture for the majority of users. This trade-off for fixed designs will likely result in shorter users having to raise their arms up to reach the keyboard/input devices leading to static loading of the muscles; and taller users may end up stooping when using an input device resulting in a poor working posture. For irregular or short term use this may be acceptable. An adjustable height workstation is recommended for regular workstation use. The values are based on providing an optimal height for keyboard/mouse/trackpad use. Placement of displays should refer to guidance points 26, 27, 28 and 29.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

11. Standing workstation – adjustable height

- Objective for computer use	Percentile Accommodated 1st %ile Female	3rd %ile Female	5th %ile Female
Adjustable Minimum Height	**922**	**950**	**967**
Reference data (mm):			
Elbow rest height, standing*	904	932	949
Footwear height	43	43	43
Keyboard/input control height	-25 Or as advised	-25 Or as advised	-25 Or as advised
**New variable computed, Stature (M38) - (Sitting Height (M39) - Elbow Rest Height, Sitting (M11))*			
Elbow rest height, standing + footwear height - keyboard/input control height*			
Possible additions:			
Secular trend (M38) p/a	1.24	1.24	1.24
Secular trend (M39) p/a	0.71	0.71	0.71

- Objective for computer use	95th %ile Male	97th %ile Male	99th %ile Male
Adjustable Maximum Height	**1188**	**1196**	**1227**
Reference data (mm):			
Elbow rest height, standing*	1170	1178	1209
Footwear height	43	43	43
Keyboard/input control height	-25 Or as advised	-25 Or as advised	-25 Or as advised
**New variable computed, Stature (M38) - (Sitting Height (M39) - Elbow Rest Height, Sitting (M11))*			
Elbow rest height, standing + footwear height - keyboard/input control height*			
Possible additions:			
Secular trend (M38) p/a	1.24	1.24	1.24
Secular trend (M39) p/a	0.71	0.71	0.71

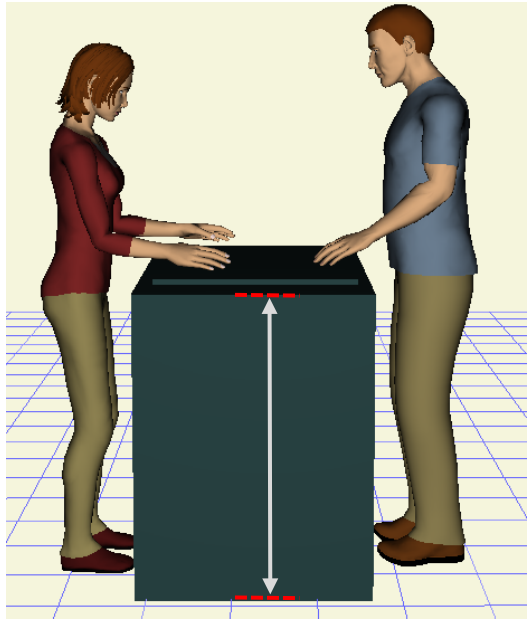


Rationale: The values reflect the objective adjustable height recommendations for a standing workstation. The values are based on providing an optimal height for keyboard/mouse/trackpad use. Placement of displays should refer to guidance points 26, 27, 28 and 29.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

12. Navigation/chart table - fixed height

- Threshold	Non-adjustable
Fixed Height	**997**
Reference data (mm):	
Elbow rest height, standing*, Female 50th%ile	1020
Elbow rest height, standing*, Male 50th%ile	1087
Footwear height	43
Work height allowance	-100
**New variable computed, Stature (M38) - (Sitting Height (M39) - Elbow Rest Height, Sitting (M11))*	
(Female elbow rest height standing + Male elbow rest height standing) / 2 + footwear height - working height allowance	
Possible additions:	
Secular trend (M38) p/a	1.24
Secular trend (M39) p/a	0.71



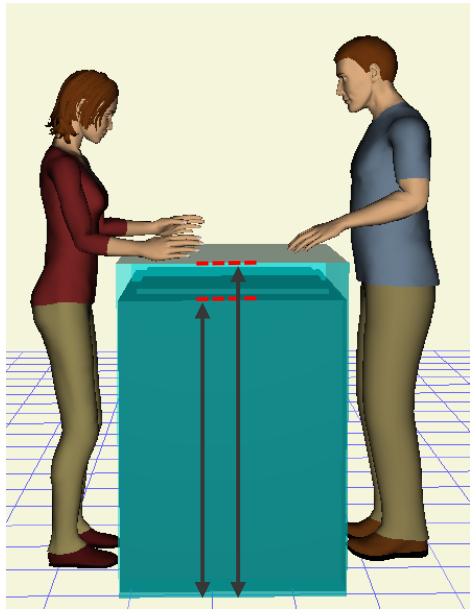
Rationale: The values reflect the threshold (non-adjustable) height recommendation for a fixed height navigation/chart table. The value is based on the 50th percentile dimension as a compromise, and will reduce the optimal working posture for the majority of users. This trade-off for fixed designs will likely result in shorter users having to raise their arms up to reach the chart table leading to static loading of the muscles; and taller users may end up stooping resulting in a poor working posture. For irregular or short term use this may be acceptable. An adjustable height table is recommended for regular use. A working height allowance is subtracted in this case to allow for a suitable work posture given the tasks undertaken.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

13. Navigation/chart table – adjustable height

- Objective	Percentile Accommodated 1st %ile Female	3rd %ile Female	5th %ile Female
Adjustable Minimum Height	**847**	**875**	**892**
Reference data (mm):			
Elbow rest height, standing*	904	932	949
Footwear height	43	43	43
Work height allowance **New variable computed, Stature (M38) - (Sitting Height (M39) - Elbow Rest Height, Sitting (M11))* *Elbow rest height, standing* + footwear height - working height allowance*	-100	-100	-100
Possible additions:			
Secular trend (M38) p/a	1.24	1.24	1.24
Secular trend (M39) p/a	0.71	0.71	0.71

- Objective	Percentile Accommodated 95th %ile Male	97th %ile Male	99th %ile Male
Adjustable Maximum Height	**1113**	**1121**	**1152**
Reference data (mm):			
Elbow rest height, standing*	1170	1178	1209
Footwear height	43	43	43
Work height allowance **New variable computed, Stature (M38) - (Sitting Height (M39) - Elbow Rest Height, Sitting (M11))* *Elbow rest height, standing* + footwear height - working height allowance*	-100	-100	-100
Possible additions:			
Secular trend (M38) p/a	1.24	1.24	1.24
Secular trend (M39) p/a	0.71	0.71	0.71



Rationale: The values reflect the objective adjustable height recommendation for a navigation/chart table. A working height allowance is subtracted in this case to allow for a suitable work posture given the tasks undertaken.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

14. Seat pan height

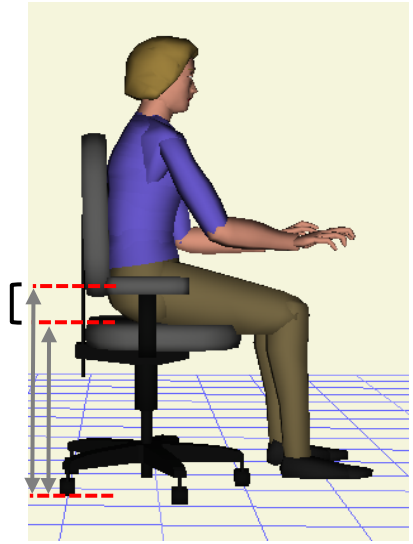
-**Threshold** - computer workstation only

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Adjustable Minimum	**Work surface - M11**	**Work surface - M11**	**Work surface - M11**
Reference data (mm):			
Work surface height	TBA	TBA	TBA
Elbow Rest Height, Sitting (M11)	275	280	288
Work surface height - M11			

	Percentile Accommodated		
	1st %ile Female	3rd %ile Female	5th %ile Female
Adjustable Maximum	**Work surface - M11**	**Work surface - M11**	**Work surface - M11**
Reference data (mm):			
Work surface height	TBA	TBA	TBA
Elbow Rest Height, Sitting (M11)	165	186	193
Work surface height - M11			

-**Objective** - workstation and general use

	Percentile Accommodated		
	1st %ile Female	3rd %ile Female	5th %ile Female
Adjustable Minimum	**387**	**396**	**402**
Reference data (mm):			
Popliteal Height (M14)	344	353	359
Footwear height	43	43	43
M14 + footwear			



Rationale: The values reflect the seat pan height adjustment range requirements for threshold (fixed) and objective (adjustable) work surface heights. The threshold values are only to be applied where there is a fixed height workstation as outlined in guidance point (9, (threshold)) and the task is a computer based one requiring predominant keyboard/mouse use, or, with the forearms positioned in a similar manner for a neutral posture. The threshold values will require a footrest for the majority of the population as a fixed work surface height accommodates the largest users resulting in a relatively high chair position for optimal keyboard use/posture.

Objective values are only of use where there is either an adjustable height work surface, or, as currently occurs on Collins class submarines, the control room chairs are

	Percentile Accommodated		
	5th %ile Female	3rd %ile Female	1st %ile Female
Adjustable Maximum	**Work surface - M11**	**Work surface - M12**	**Work surface - M13**
Reference data (mm):			
Work surface height	TBA	TBA	TBA
Elbow Rest Height, Sitting (M11)	193	186	165
Work surface height - M11			

Note:

- A footrest shall be provided when the range of adjustment of the chair, work surface, or both, does not permit the persons feet to be supported by the floor [32].
- The seat pan shall support the body weight of the 95th percentile male as a minimum (112.4kg), and should support the body weight of the 99th percentile male (123.3kg).
- A chair cushion can vary in thickness, for example, they may curve up at the sides, and curve down at the front. The section of the chair pan close to the back rest can be used to measure seat pan height as this will reflect where the ASRAN thigh clearance and elbow rest height measures were taken from.

rotated facing inwards to the control room and they are used for a non-computer based activity as well.

Seats which are too low concentrates pressure on a small portion of the buttocks overlying the ischial tuberosities, increase awkward postures such as arm flexion, shoulder abduction, and reduced thigh-torso angles (hip flexion) which can degrade comfort and performance. Users will tend to flex their spine, require greater leg room and experience greater problems standing up and sitting down. For shorter users, low seats will require them to work with their elbows below desk height which can increase static loading of the upper body [20,34,38].

Seats which are too high commonly results in a concentration of pressure on the popliteal area at the back of the knee and underside of the thighs reducing circulation to the lower extremities. This can lead to the feeling of 'pins and needles', swollen feet, general blood flow restriction and discomfort [20,28,34,38].

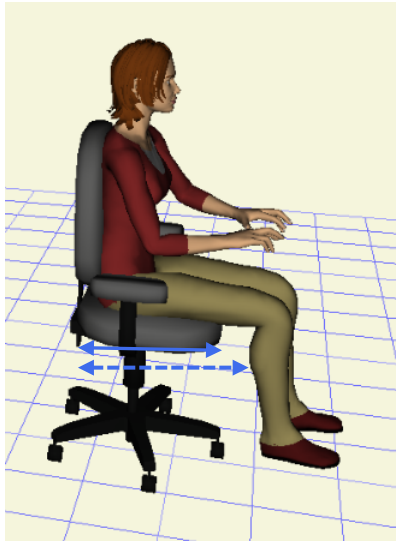
Actual work surface height will need to include how thick the work surface is, therefore the workstation underside clearance values presented in this document are not the same as work surface height. If using underside clearance as a starting point for work surface height, a nominal amount of 30mm can be used as a starting value for the thickness of the work surface for ships and submarines

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

15. Seat pan depth

	Percentile Accommodated		
	1st %ile Female	3rd %ile Female	5th %ile Female
Minimum/Default	**402**	**417**	**427**
Reference data (mm):			
Buttock-Popliteal Length (M26)	412	427	437
Clothing, general	10	10	10
M26 - clothing			
Possible additions:			
Secular trend (M25) p/a	0.55	0.55	0.55

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Maximum if adjustable	**534**	**542**	**562**
Reference data (mm):			
Buttock-Popliteal Length (M26)	544	552	572
Clothing, general	10	10	10
M26 - clothing			
Possible additions:			
Secular trend (M25) p/a	0.55	0.55	0.55



Rationale: The values reflect the seat pan depth default and adjustment range (if possible). A general clothing allowance has been included in the value, however projects should consider if a bulkier clothing ensemble will be routinely worn, and subtract a larger clothing allowance from the anthropometric dimension if required.

Seat pan depths that are too long (exceed the buttock-popliteal length) will prevent proper engagement with the backrest without placing unacceptable pressure on the backs of the knees.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

16. Seat pan width

	Percentile Accommodated		
	95th %ile Female	97th %ile Female	99th %ile Female
Width	**530**	**540**	**566**
Reference data (mm):			
Hip Breadth, Sitting (M24)	460	470	496
Clothing & leg rotation allowance	70	70	70
M24 + allowance			
Possible additions:			
Secular trend (M24) p/a	0.68	0.68	0.68

Note:

- Females have a larger hip breadth sitting compared to males, therefore female data is the limiting criteria.

Rationale: These values reflect the seat pan width requirements for the majority population that includes an allowance for clothing and leg rotation [38].

Seat pan widths that are too narrow will impinge on the size and shape of the users leading to discomfort, reduced blood flow, difficult posture adjustment, increase the likelihood of postural fixity, and inhibit ingress/egress.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

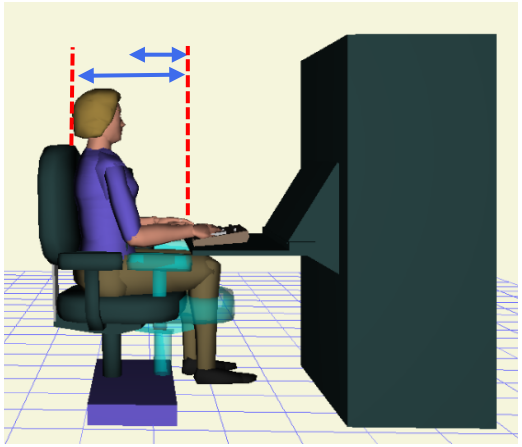
17. Seat pan forwards/backwards adjustment

	Percentile Accommodated		
	1st %ile Female	3rd %ile Female	5th %ile Female
Required minimum distance between seat back and front edge of workstation for keyboard reach	**217**	**223**	**226**
Reference data (mm):			
Radiale-Stylion Length (M61)	217	223	226
M61			

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Required space accommodation between seat back and front edge of workstation	**399**	**406**	**427**
Reference data (mm):			
Abdominal Extension Depth, Sitting (M23)	339	346	367
Clothing, general	10	10	10
Dynamic allowance, movement	50	50	50
M23 + clothing + dynamic allowance			
Possible additions:			
Secular trend, general, p/a	10	10	10

Note:

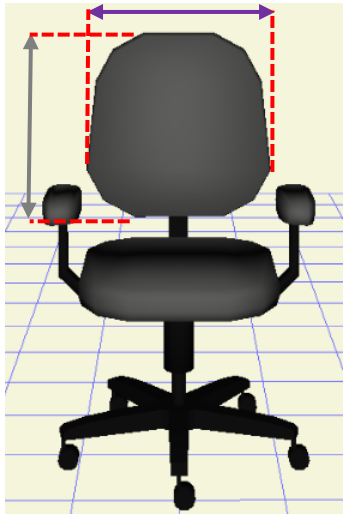
- This guidance is provided for ships and submarines where the chairs can be fixed to the deck or a rail on the deck.
- At the larger percentiles, male abdominal extension depth (in ASRAN data) exceeds male radiale-stylion length, making it the limiting criteria for maximum values.



Rationale: The values reflect the seat pan forwards/backwards adjustment range required to meet the range of reach and fit requirements.
An adjustment range that does not accommodate the minimum value will result in smaller users having to reach forwards to use controls and/or sit forwards in the chair being unable to use the backrest. This can lead to static loading of the upper body and an inability to relieve/reduce spinal pressure. An adjustment range that does not accommodate the maximum value will restrict the fit and accommodation of the larger users leading to discomfort, difficult posture adjustment, increase the likelihood of postural fixity, and inhibit ingress/egress. Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

18. Seat back rest

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Height	**654**	**660**	**674**
Reference data (mm):			
Acromion Height, Sitting (M10)	654	660	674
M10			
Possible additions:			
Alternate reference dimension: Sitting Height (M39)	998	1003	1018
Secular trend (M39) p/a	0.71	0.71	0.71
Width	**463**	**469**	**481**
Reference data (mm):			
Back Width (M50)	413	419	431
Dynamic allowance (movement)	50	50	50
M50 + dynamic allowance			



Rationale: The values reflect the backrest height and width requirements for optimal support. If supporting the neck and head is also required, the alternate reference dimension of Sitting Height (M39) can be used instead of Acromion Height, Sitting (M10). Backrests that are too low and narrow will provide insufficient support to the thoracic spine, and less balance particularly when using a backrest recline. A high backrest allows the users to lean back in the chair and reduce the compressive loading on the spine [38]. A backrest that is too high and too wide can possibly interfere with mobility of the shoulders and elbows – this is task dependant and to be assessed on a case-by-case basis [20].

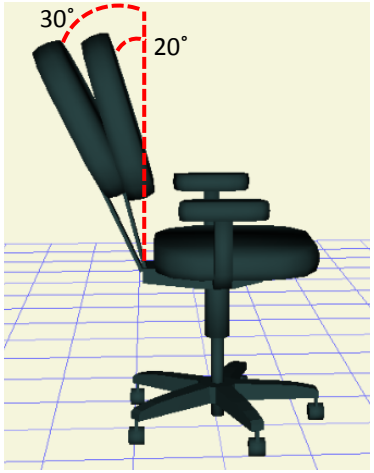
Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

19. Seat back rest recline

	Recline	
	Threshold	Objective
Recline from 90°	**20°**	**30°**
Reference data (mm):		
[19,20,32]	20°	30°

Note:

- These values are not based on anthropometric data, they are from accepted ergonomic guidelines.



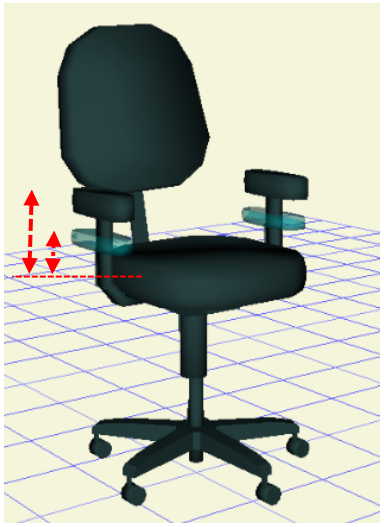
Rationale: The values reflect the minimum (threshold) and preferred angles of backrest recline from upright 90˚ position.
Recline of the backrest is required as increasing the angle of recline from 90˚ transfers the body weight to the backrest and reduces spinal disc pressure. As the backrest angle increases, a greater proportion of the weight of the trunk is supported, reducing the compressive force on the spinal discs. In addition increasing the angle between the trunk and the thigh improves spine lordosis, promoting the natural curve of the spine.

20. Seat arm rest height

	Percentile Accommodated		
	1st %ile Female	3rd %ile Female	5th %ile Female
Adjustable Minimum	**165**	**186**	**193**
Reference data (mm):			
Elbow Rest Height, Sitting (M11)	165	186	193
M11			

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Adjustable Maximum	**275**	**280**	**288**
Reference data (mm):			
Elbow Rest Height, Sitting (M11)	275	280	288
M11			

	Non-adjustable
Non-adjustable default	**234**
Reference data (mm):	
Elbow Rest Height, Sitting (M11), Female 50th%ile	236
Elbow Rest Height, Sitting (M11), Male 50th%ile	232
(Female M11 + Male M11) / 2	



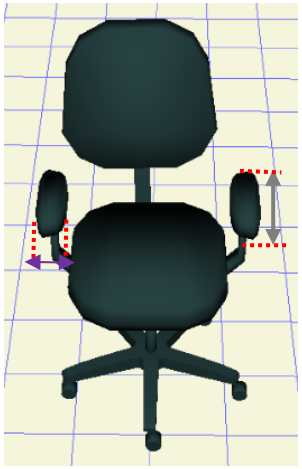
Rationale: The values reflect the height adjustment range or non-adjustable height of arm rests from the seat pan.
Arm rests should be high enough to support the forearm when the user is sitting upright. Supporting the arms can lead to less load being placed on the lumbar spine and increase comfort [20,21,34,38]. Arm rests that are too high or too low commonly lead to awkward postures, which is why height adjustability is preferred [38].

21. Seat arm rest width and length

	Percentile Accommodated		
	1st %ile Female	3rd %ile Female	5th %ile Female
Length	**186**	**191**	**195**
Reference data (mm):			
Abdominal Extension Depth, Sitting (M23)	186	191	195
M23			

	Threshold	Objective
Width	**50**	**75**
Reference data (mm):		
[MIL-STD1472G; ASTM F1166]	50	75

Note:
The width values are not based on anthropometric data, they are from accepted ergonomic guidelines.



Rationale: The values reflect the length and width of arm rests to support the users. The length is based on anthropometric data, the width is based on ergonomic guidelines.
The width of the arm rests should be designed to distribute the forces evenly over the contact area [38]. The lengths of arm rests should ensure they do not interfere with the front edge of the work surface and prevent the user from moving the chair under the work surface to the extent required for their task to reach controls and input devices. For this reason abdominal extension depth, sitting, has been used rather than forearm length as allowing clearance for the abdomen should prevent interference with the front edge of the work surface.

22. Seat arm rest separation

	Percentile Accommodated		
	95th %ile Female	97th %ile Female	99th %ile Female
Width	**530**	**540**	**566**
Reference data (mm):			
Hip Breadth, Sitting (M24)	460	470	496
Clothing & leg rotation allowance	70	70	70
M26 - clothing			
Possible additions:			
Secular trend (M24) p/a	0.68	0.68	0.68

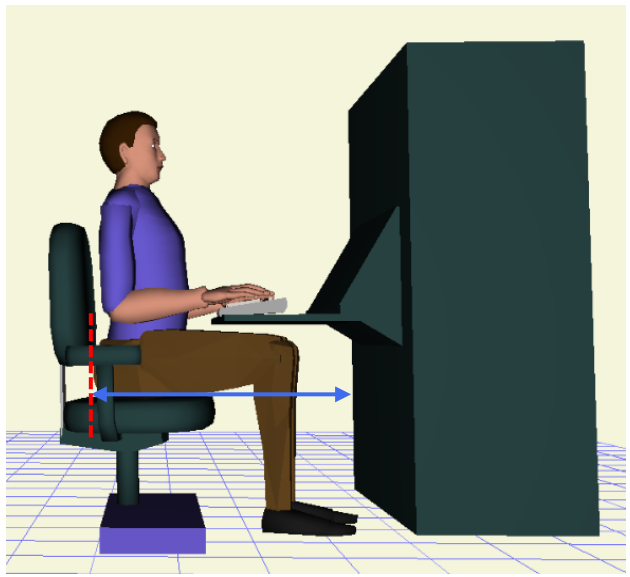
Note:
Females have a larger hip breadth sitting compared to males, therefore female data is the limiting criteria.

Rationale: The values reflect the armrest separation width requirement that is based on hip breadth and seat pan width requirements. This is to ensure ingress/egress from the chair is not inhibited by an armrest separation distance that is too narrow.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

23. Knee allowance

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Depth	**732**	**742**	**753**
Reference data (mm):			
Buttock-Knee Length (M25)	672	682	693
Clothing allowance, general	10	10	10
Dynamic allowance, movement	50	50	50
M25 + clothing + dynamic allowance			
Possible additions:			
Secular trend (M25) p/a	0.55	0.55	0.55
Alternate dynamic movement allowance	100	100	100
Alternate clothing allowance (Boarding Party M25)	152	152	152



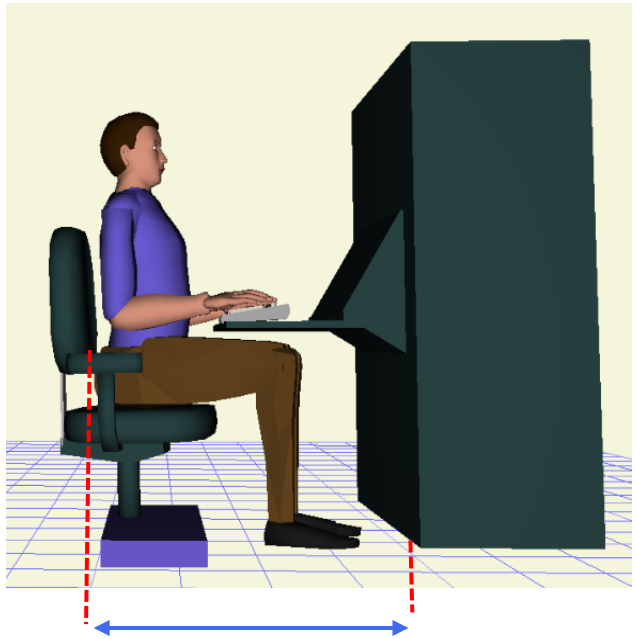
Rationale: The values reflect the space needed to accommodate the knees from the front of the seat back rest going forward, with the chair in the forward most position. A project may determine based on their operational requirements that they need to accommodate a more bulkier clothing ensemble than the general clothing allowance that has been included. An alternate movement allowance is also suggested where it can be accommodated.

A knee allowance which does not meet the values provided can lead to knees that are touching and pressing against equipment which can lead to inadvertent manipulation of switches under the consoles, user discomfort, difficult or limited posture adjustment, increase the likelihood of postural fixity, and require users to position their chair further back from controls which can increase static loading of the upper body.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

24. Feet allowance

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Depth	**931**	**945**	**973**
Reference data (mm):			
Buttock-Popliteal Length (M26)	Consult raw data for relationship between multiple dimensions		
Clothing allowance, general	10	10	10
Foot Length (M71)	Consult raw data for relationship between multiple dimensions		
Footwear length	41	41	41
Dynamic allowance, movement *M26 + clothing + M71 + footwear allowance + dynamic allowance*	50	50	50
Possible additions:			
Alternate clothing allowance (Boarding Party M25)	152	152	152
Secular trend (M25) p/a	0.55	0.55	0.55
Alternate dynamic movement allowance	100	100	100



Rationale: The values reflect the space needed to accommodate the legs and feet from the front of the seat back rest going forward, with the chair in the forward most position. A project may determine based on their operational requirements that they need to accommodate a more bulkier clothing ensemble than the general clothing allowance that has been included. An alternate movement allowance is also suggested where it can be accommodated.

A feet allowance which does not meet the values provided can lead to the feet touching and pressing against equipment which can lead to inadvertent manipulation of switches, user discomfort, difficult or limited posture adjustment, increase the likelihood of postural fixity, and require users to position their chair further back from controls which can increase static loading of the upper body.

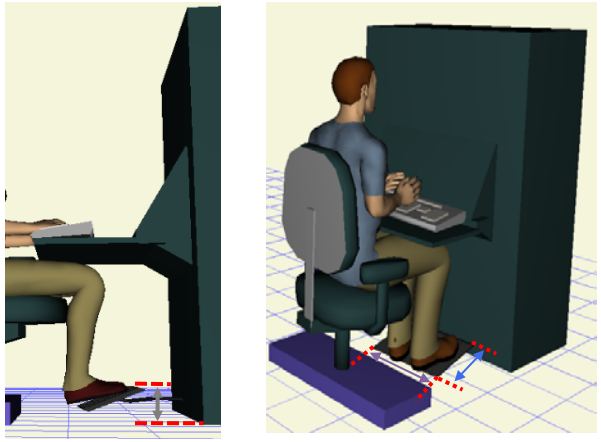
Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

25. Footrest

	Percentile Accommodated		
	1st %ile Female	3rd %ile Female	5th %ile Female
Height - maximum	**Max seat pan height - 387**	**Max seat pan height - 396**	**Max seat pan height - 402**
Reference data (mm):			
Maximum seat pan height	TBA	TBA	TBA
Popliteal Height (M14)	344	353	359
Footwear height *Max seat pan height - (M14 + Footwear height)*	43	43	43

	95th %ile Male	97th %ile Male	99th %ile Male
Depth	**335**	**338**	**344**
Reference data (mm):			
Foot Length (M71)	294	297	303
Footwear length	41	41	41
M71 + Footwear length			

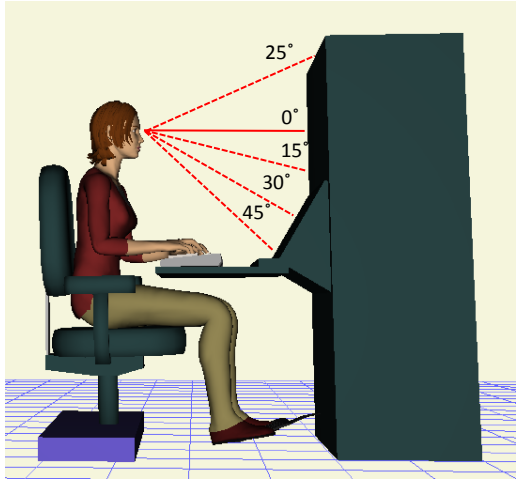
	95th %ile Male	97th %ile Male	99th %ile Male
Width	**490**	**500**	**526**
Reference data (mm):			
Foot Breadth, Horizontal (M27)	111	113	116
Footwear Breadth	15	15	15
Hip Breadth, Sitting (Female M24)	460	470	496
Feet separation *(M24 - (M27 * 2) (M27 * 2) + (footwear allowance * 2) + feet separation*	238	244	264



Rationale: The values reflect the suitable dimensions for a footrest. The footrest height should be adjustable from the values presented (maximum height required), downward. A footrest is necessary in cases where the height of the seat pan required to adopt an ergonomic posture for the task, does not allow the users feet to rest flat on the floor. As well as checking popliteal and footwear height to determine footrest height, the need for a footrest must also involve checking the work surface height, chair adjustment height, and elbow rest height of the users. A user which cannot rest their feet flat on the floor can experience increased pressure on the thighs and behind the knees which can restrict blood flow [38,39]. The design of the footrest and workstation should also ensure that the footrest can be positioned out of the way to not interfere with space required for the legs and feet of the larger users.

26. Display location: vertical field of view

	Optimal: Normal line of sight	Objective: Minimum display height (eye movement)	Threshold: Minimum display height (eye and head movement)	Threshold: Maximum display height	Example: Line of sight placement 5th %ile Female
Fixed Height	**Sitting eye height - (0.267 * distance to display)**	**Sitting eye height - (0.577 * distance to display)**	**Sitting eye height - (1 * distance to display)**	**Sitting eye height + (0.466 * distance to display)**	**1243.1**
Reference data (mm): Degree from eye level (0°)	15˚ below	30˚ below	45˚ below	25˚ above	15˚ below
Eye Height, Sitting (M09)					868
Optimal chair height consider: - Task being conducted - Work surface height - Elbow Rest Height (M11) - Popliteal Height (M14) - Footwear height					587 Task: Computer based Work surface height: 780 - Elbow Rest Height: 193
Distance to the display (Chest Depth (M20) can be used to approximate eye position)					700
15° below horizontal: tan(15) = 0.267 *30° below horizontal: tan(30) = 0.577* *45° below horizontal: tan(45) = 1*					
25° above horizontal: tan(25) = 0.466					*1455 - (0.267 * 700) - Chair compression*
Other considerations:					
Postural slump	-45	-45	-45	-45	-45



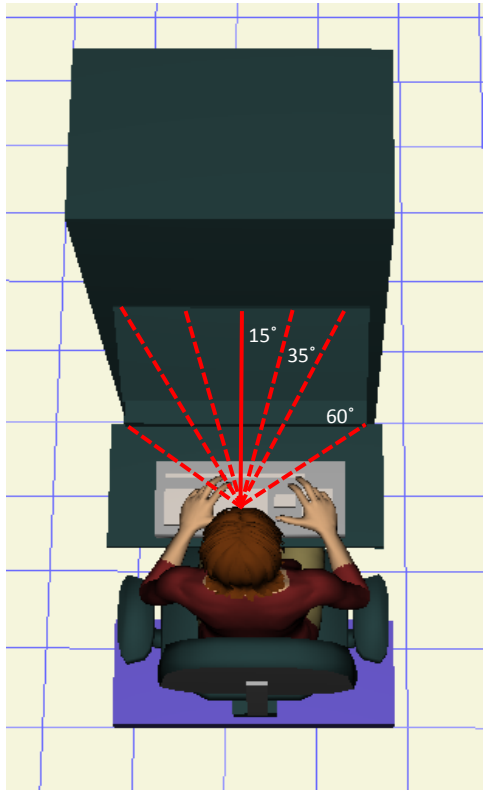
Rationale: Set values cannot be provided for vertical display location due to the number of influencing variables that cannot be controlled. Wherever possible a display should be located directly in front of the user at 15˚ below horizontal from their sitting eye height. Where there is more than 1 vertically stacked display, or for large displays, guidance for their location is presented in terms of appropriate viewing angles. Once the range of sitting eye heights for the users is known, as well as the distance to the display, the forumla's presented can be used to determine threshold and objective display vertical locations. [13,20,21,38].

The vertical height of a display represents a compromise between minimising visual discomfort and musculoskeletal discomfort of

Chair compression	-25 Or as indicated by supplier	-25 Or as indicated by supplier	-25 Or as indicated by supplier	-25 Or as indicated by supplier	-25 Or as indicated by supplier	the neck and shoulders. In general lowering a screen or increasing the viewing distance will reduce visual discomfort. However greater neck flexion is undesirable for comfort and strain, and over a period of time neck flexion beyond 30˚ can lead to severe muscle fatigue. Display screen height above eye level has been associated with static loading of the upper body and musculoskeletal discomfort [20,38].

27. Display location: horizontal field of view

Horizontal location	Objective (eye movement) **0.53 * distance to display**	Threshold (eye movement) **1.4 * distance to display**	Threshold (eye and head movement) **2.46 * distance to display**	Example: Threshold (eye movement) **980**
Reference data (mm):				
Degree ± from centre	15	35	60	35
Distance to the display (Chest Depth (M20) can be used to approximate eye position)	TBA	TBA	TBA	700
*15° from centre: tan15 = .26; * 2 = 0.53*				
*35° from centre: tan35 = 0.7; * 2 = 1.4*				*1.4 * 700*
*60° from centre: tan60 = 1.73; * 2 = 2.46*				



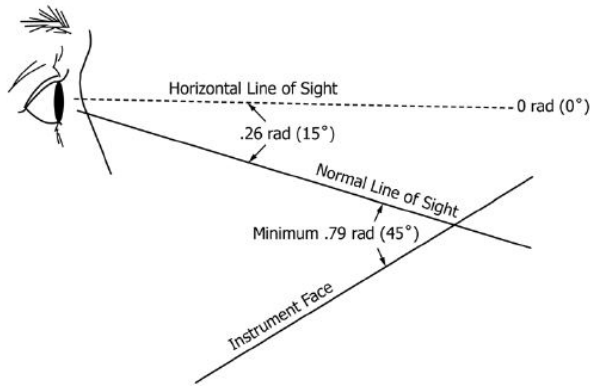
Rationale: Set values cannot be provided for vertical display location due to the number of influencing variables that cannot be controlled. Wherever possible a display should be located directly in front of the user. Where there is more than 1 horizontally positioned display, or for large displays, guidance for their location is presented in terms of appropriate viewing angles [13,14,34]. The guidance presented outlines two threshold approaches, one with just eye movement (preferred) and one with eye and head movement (a secondary threshold criteria). A display(s) position that requires head movement will increase the likelihood of static postures and musculoskeletal discomfort and strain.

28. Display angle/orientation

	Optimal	Objective	Threshold
Angle to line of sight	**Perpendicular**	**Between line of sight and normal to the display less than 30°**	**Between line of sight and normal to the display less than 45°**
Reference data (mm): Line of sight	15° below horizontal	15° below horizontal	15° below horizontal

Note:
These values are not based on anthropometric data, they are from accepted ergonomic guidelines.

Figure representing the Threshold requirement:



(MIL-STD 1472G, 5.2.1.2.3)

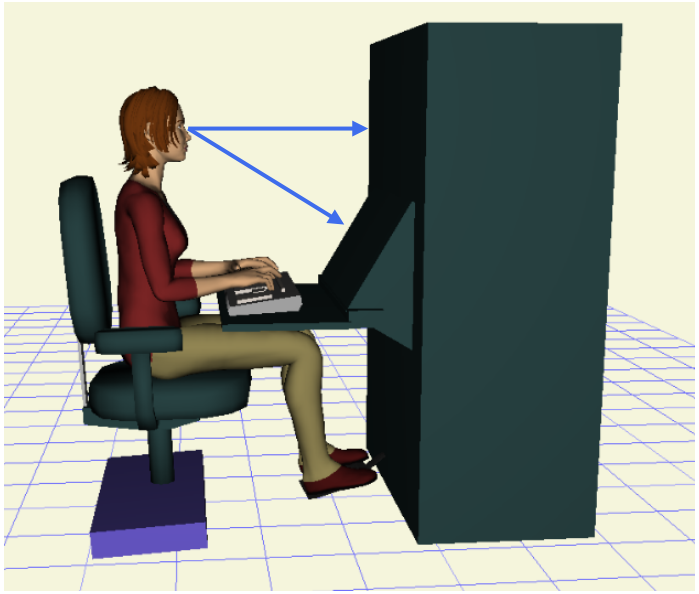
Rationale: The values reflect the minimum (threshold) and preferred angles of displays to the normal line of sight (15˚ below horizontal) [14,23].

Angling the display can assist with viewing over the top of consoles, and where more than one display is vertically stacked, it assists in bringing more display area into the acceptable fields of view.

These angles of orientation are a general guide. Reference **must** be made to the display operating information and qualities to determine if these viewing angles align with each individual displays capabilities.

Consideration should also be given to positioning the displays and light sources to minimise glare.

29. Distance from eye to display



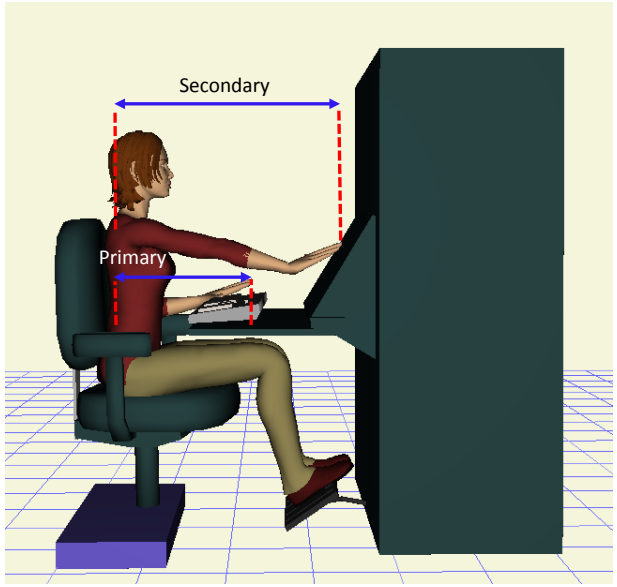
	Minimum	Maximum
Distance from eye to display	**600**	**1000**
Reference data (mm):		
Various human factors sources	600	1000

Note:
These values are not based on anthropometric data, they are from accepted ergonomic guidelines.

Rationale: It is recommended to position displays within the minimum and maximum range presented. Suitable distance depends on character size, image quality, lighting, age, and individual vision. Visual fatigue and strain increases when displays are placed closer than the minimum value and further than the maximum. This can lead to a burning sensation in the eyes, dry eyes, redness, ocular pain, headache, blurred vision, and double vision. For very narrow distances (less than 500mm) some research has suggested that near sightedness may occur. Whilst some standards can state acceptable distances at 500mm or less, other research has found increased visual fatigue with this distance [20,40,41,42].

30. Reach

	Percentile Accommodated		
	1st %ile Female	3rd %ile Female	5th %ile Female
Length - Primary reach	**377**	**381**	**386**
Reference data (mm): Radiale-Stylion Length (M61) Hand Length (M66) *M61+M66*	Consult raw data for relationship between multiple dimensions		
Possible additions: Forward movement of the upper arm (M60) by 20˚ if unrestricted sin(20) = (M60 * .342) + M61 + M66	Consult raw data for relationship between multiple dimensions		
Length - Secondary reach	**635**	**655**	**660**
Reference data (mm): Thumbtip Reach (M37) *M37*	635	655	660
Possible additions: Forward lean of the torso if unrestricted			



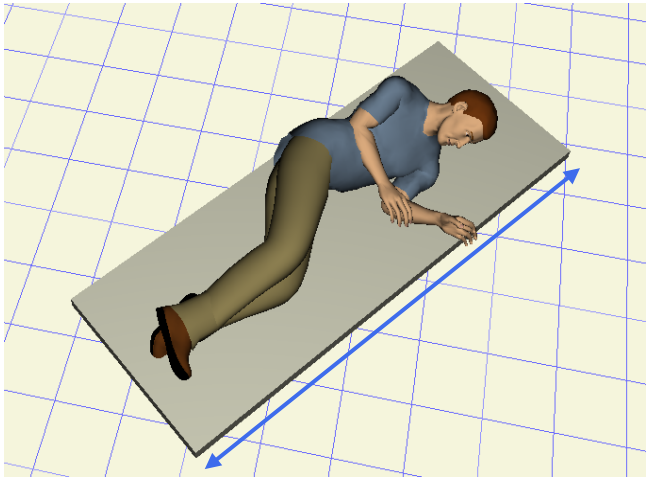
Rationale: The values reflect the distance where controls should be placed (from the front of the backrest) to be easily reached. If a user will not be restrained and can easily move, forward movement of the arm and torso can be added. An acceptable frequent forward movement of the upper arm is considered to be at 20˚ [37].

Controls requiring frequent use such as mouse and keyboards should be positioned within the primary reach zone, where there is also appropriate support for the hands, wrists, and forearms to reduce static loading of the upper limbs. All controls which are to be used infrequently, but still need access, can be placed within the secondary reach zone. Placing controls outside of this distance (from the front of the backrest) will prevent the majority of the population from being able to reach, access and operate controls. Care should also be taken to assess the height of controls and adjust the values accordingly. The values may also need adjusting to accommodate force required for control operation.

2.4. Bunk requirements

31. Mattress length

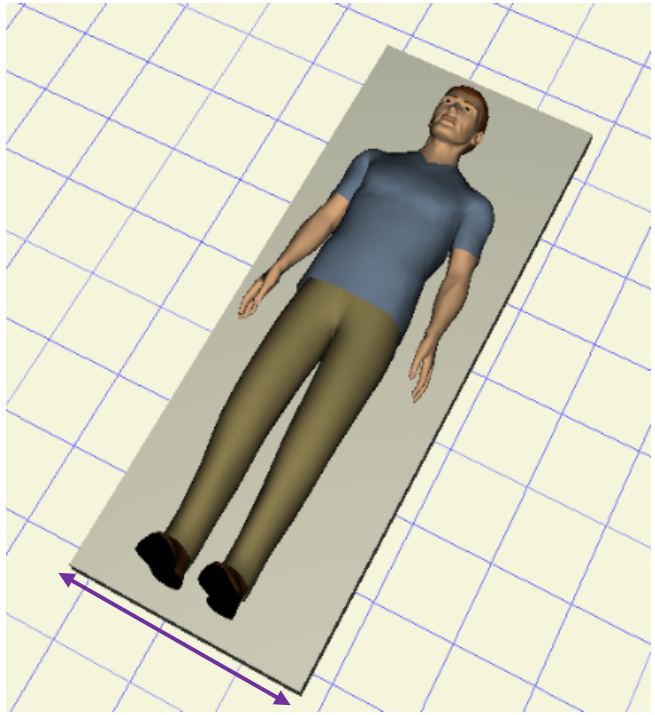
	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Mattress Length	**1956**	**1975**	**2008**
Reference data (mm):			
Stature (M38)	1906	1925	1958
Dynamic allowance, movement	50	50	50
M38 + dynamic allowance			
Possible additions:			
Secular trend (M38) p/a	1.24	1.24	1.24
Alternate dynamic allowance: hands above head	128	128	128
Comfort factor	200	200	200



Rationale: The values reflect the length of a mattress required for the majority of the population to lie fully extended in their bunk. A small amount of movement allowance has been included to enable slight position change without contacting the vessels structure. Lying fully extended is an important requirement to meet where the vertical separation of bunks does not allow personnel to roll over and comfortably sleep on their sides and change sleeping positions; and where the bunk space is also used for recreational purposes such as reading and screen use. If space permits an alternate movement allowance can be used and/or and additional comfort factor applied. Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

32. Mattress width

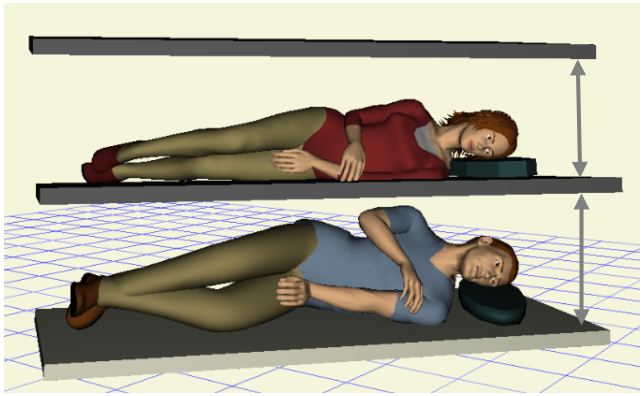
	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Mattress Width	**741**	**753**	**774**
Reference data (mm):			
Forearm-Forearm Breadth (M22)	641	653	674
Dynamic allowance, movement	100	100	100
M22 + dynamic allowance			
Possible additions:			
Secular trend (M18) p/a	0.82	0.82	0.82
Clothing, general	10	10	10
Clothing, cold weather	152	152	152
Alternate dynamic allowance, arms and curling comfort factor	304	304	304



Rationale: The values reflect the width of a mattress required for the majority of the population to lie on their backs with their arms by their side, including a small amount of movement allowance. If space permits an alternate movement allowance can be used, and a clothing allowance may be appropriate to add depending on the operational temperatures and air conditioning systems. Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

33. Vertical separation – for sleep position change

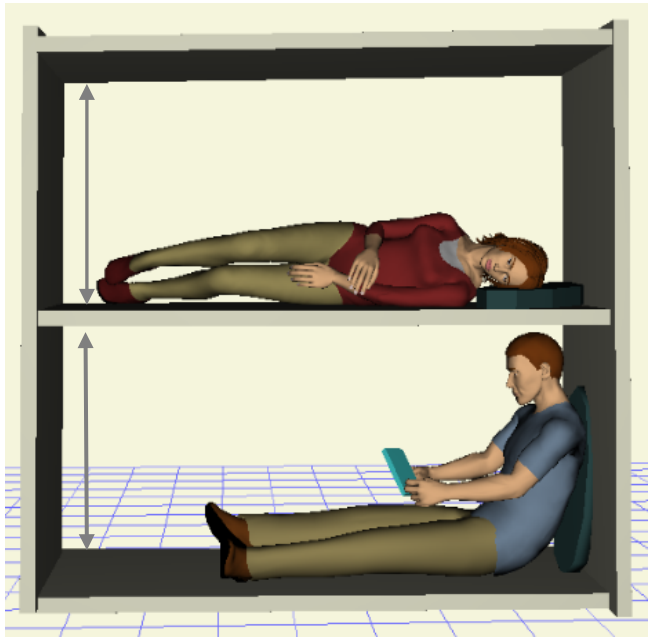
	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Vertical separation - for sleep position change	**600**	**607**	**624**
Reference data (mm):			
Bideltoid Breadth (M18)	550	557	574
Dynamic allowance, movement	50	50	50
M18 + dynamic allowance			
Possible additions/considerations:			
Secular trend (M18) p/a	0.82	0.82	0.82
Alternate dynamic movement allowance	100	100	100
Psychological allowance	50	50	50
Clothing, general	10	10	10
Mattress compression	-TBA	-TBA	-TBA



Rationale: The values reflect the vertical separation between the top of a mattress and the next bunk/deck height for the majority of the population to be able to adjust their posture and turn over. These are initial space claim values for a static posture and given the dynamic nature of turning over in a bunk further examination of required space with physical mock-ups will be useful to determine accurate space requirements. If space permits an alternate movement allowance can be used, and a clothing allowance may be appropriate to add depending on the operational temperatures and air conditioning systems. A psychological allowance may be added where space permits to increase the feeling of openness and spaciousness. Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

34. Vertical separation – for sitting

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Vertical separation - for sitting	**1048**	**1053**	**1068**
Reference data (mm):			
Sitting Height (M39)	998	1003	1018
Dynamic allowance, movement	50	50	50
M39 + dynamic allowance			
Possible additions:			
Secular trend (M39) p/a	0.71	0.71	0.71
Alternate dynamic movement allowance	100	100	100
Psychological allowance	50	50	50
Clothing, general	10	10	10
Postural slump	-45	-45	-45
Mattress compression	-TBA	-TBA	-TBA

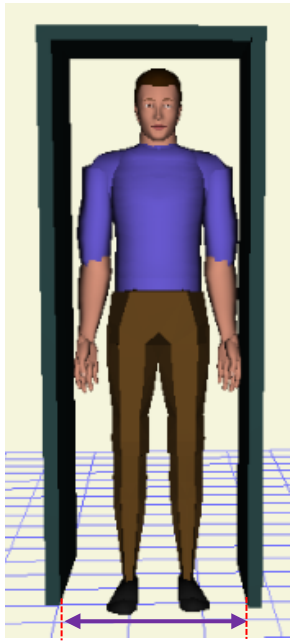


Rationale: The values reflect the vertical separation between the top of a mattress and the next bunk/deck height for the majority of the population to be able to sit upright in their bunks. If space permits, an alternate movement allowance can be used, as well as a psychological allowance for a greater feeling of space and openness. A clothing allowance may be appropriate to add depending on the operational temperatures and air conditioning systems. A subtraction to the value to account for postural slump is reasonable, and expected mattress compression can be subtracted too. Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

2.5. Passage requirements

35. Passageway width – one individual walking forwards

	Percentile Accommodated			
	95th %ile Male	97th %ile Male	99th %ile Male	Maximum
Width	**640**	**647**	**664**	**701**
Reference data (mm):				
Bideltoid Breadth (M18)	550	557	574	611
Clothing allowance (Fire Fighting M18)	40	40	40	40
Dynamic allowance, movement *M18 + clothing allowance + dynamic movement*	50	50	50	50
Possible additions:				
Secular trend (M18) p/a	0.82	0.82	0.82	0.82
Alternate dynamic allowance	100	100	100	100



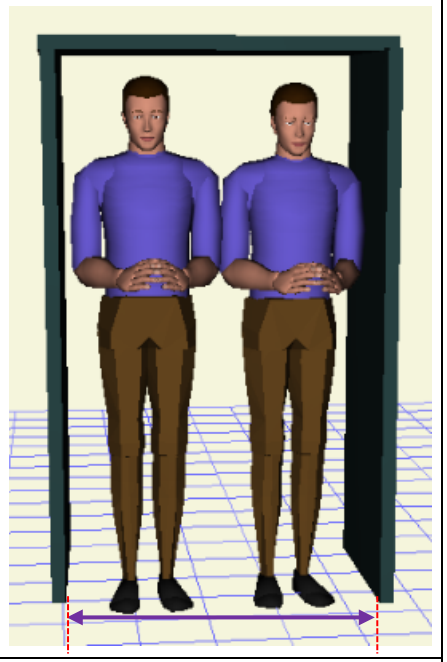
Rationale: The values reflect the space requirement for an individual wearing fire-fighting clothing and equipment to walk forwards through a passageway unobstructed with their arms by their torso. A small amount of movement allowance has been included to aid unobstructed walking; this value could be increased for more relaxed movement. Failure to meet the value for the 95th percentile male may result in the majority population not being able to pass forwards through a passageway wearing required encumbrance for damage control in an efficient manner. Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

For passageway height requirements see guidance point 1.

Note the current RES-Q-Mate stretcher primarily used in the RAN (and for helicopter transfers) has dimensions when assembled of 1820mm * 254mm [43].

36. Passageway width – two individuals walking abreast

	Percentile Accommodated			
	95th %ile Male	97th %ile Male	99th %ile Male	Maximum
Width	**1280**	**1294**	**1328**	**1402**
Reference data (mm):				
Bideltoid Breadth (M18)	550	557	574	611
Clothing allowance (Fire Fighting M18)	40	40	40	40
Dynamic allowance, movement	50	50	50	50
*(M18 * 2) + (clothing allowance * 2) + dynamic allowance * 2*				
Possible additions:				
Secular trend (M18) p/a	0.82	0.82	0.82	0.82
Alternate clothing allowance, general	10	10	10	10
Alternate dynamic allowance	100	100	100	100



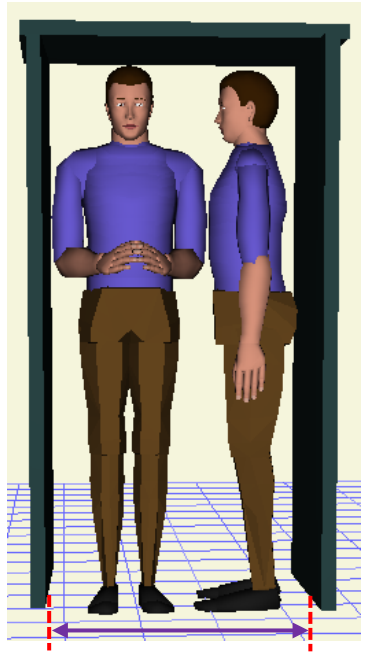
Rationale: The values reflect the space requirement for two individuals both wearing fire-fighting clothing and equipment to walk forwards through a passageway unobstructed with their arms by their torso. A small amount of movement allowance has been included to aid unobstructed walking; this value could be increased for more relaxed movement. Failure to meet the value for the 95th percentile male may result in the majority population not being able to walk abreast wearing required encumbrance for damage control in an efficient manner. Each project should consider their operational response to damage control and the need for two individuals to be able to walk abreast in fire-fighting clothing and equipment. If this is not required an alternate general clothing allowance can replace one of the fire-fighting clothing allowances. Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

For passageway height requirements see guidance point 1.

Note the current RES-Q-Mate stretcher primarily used in the RAN (and for helicopter transfers) has dimensions when assembled of 1820mm * 254mm [43].

37. Passageway width – two individuals passing, one sideways

	Percentile Accommodated			
	95th %ile Male	97th %ile Male	99th %ile Male	Maximum
Width	**1039**	**1053**	**1091**	**1172**
Reference data (mm):				
Bideltoid Breadth (M18)	550	557	574	611
Clothing allowance (Fire Fighting M18)	40	40	40	40
Abdominal Extension Depth, Sitting (M23)	339	346	367	411
Clothing allowance, general	10	10	10	10
Dynamic allowance, movement *M18 + clothing allowance + M23 + clothing allowance + dynamic allowance * 2*	50	50	50	50
Possible additions:				
Secular trend (M18) p/a	0.82	0.82	0.82	0.82
Alternate clothing allowance for 'general', Fire fighting Abdominal Extension Depth (M23)	211	211	211	211
Alternate dynamic allowance	100	100	100	100



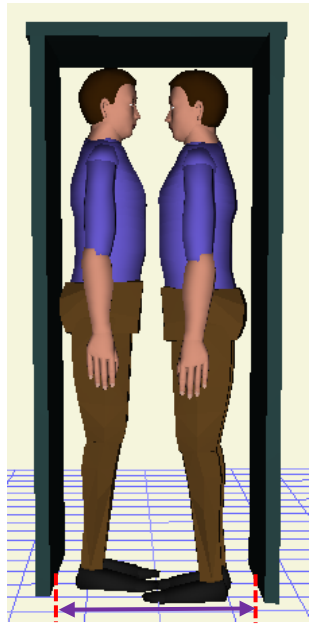
Rationale: The values reflect the space requirement for two individuals passing, one in a forward motion wearing fire-fighting clothing and equipment, and one turned sideward wearing general clothing, to pass through a passageway unobstructed with their arms by their torso. A small amount of movement allowance has been included to aid unobstructed walking; this value could be increased for more relaxed movement. Failure to meet the value for the 95th percentile male may result in the majority population not being able to pass with one individual moving forwards wearing required encumbrance for damage control in an efficient manner. Each project should consider their operational response to damage control and the need for two individuals to pass each other in fire-fighting clothing and equipment. If this is required the alternate clothing allowance can replace the general clothing allowance for the sidewards individual. Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

For passageway height requirements see guidance point 1.

Note the current RES-Q-Mate stretcher primarily used in the RAN (and for helicopter transfers) has dimensions when assembled of 1820mm * 254mm [43].

38. Passageway width – two individuals passing, face-to-face

	Percentile Accommodated			
	95th %ile Male	97th %ile Male	99th %ile Male	Maximum
Width	**999**	**1013**	**1055**	**1143**
Reference data (mm): Abdominal Extension Depth, Sitting (M23)	339	346	367	411
Clothing allowance (Fire Fighting M23)	211	211	211	211
Clothing allowance, general	10	10	10	10
Dynamic allowance, movement *(M23 * 2) + clothing fire fighting + clothing general + (dynamic allowance *2)*	50	50	50	50
Possible additions: Alternate clothing allowance for 'general', Fire fighting Abdominal Extension Depth (M23)	211	211	211	211
Alternate dynamic allowance	100	100	100	100



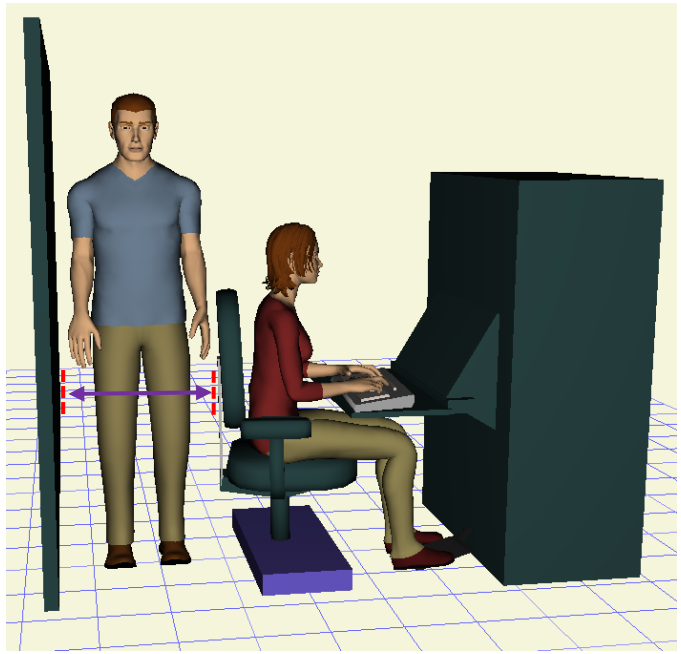
Rationale: The values reflect the space requirement for two individuals passing face-to-face through a passageway unobstructed with their arms by their torso, with one individual wearing fire-fighting clothing and equipment. A small amount of movement allowance has been included to aid unobstructed walking; this value could be increased for more relaxed movement. Failure to meet the value for the 95th percentile male may result in the majority population not being able to pass each other in a passageway in an efficient manner if one individual is wearing required encumbrance for damage control. Each project should consider their operational response to damage control and the need for two individuals to pass each other in fire-fighting clothing and equipment. If this is required the alternate clothing allowance can replace the general clothing allowance for the second individual. Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

For passageway height requirements see guidance point 1.

Note the current RES-Q-Mate stretcher primarily used in the RAN (and for helicopter transfers) has dimensions when assembled of 1820mm * 254mm [43].

39. Space required to pass behind a seated console travelling forwards

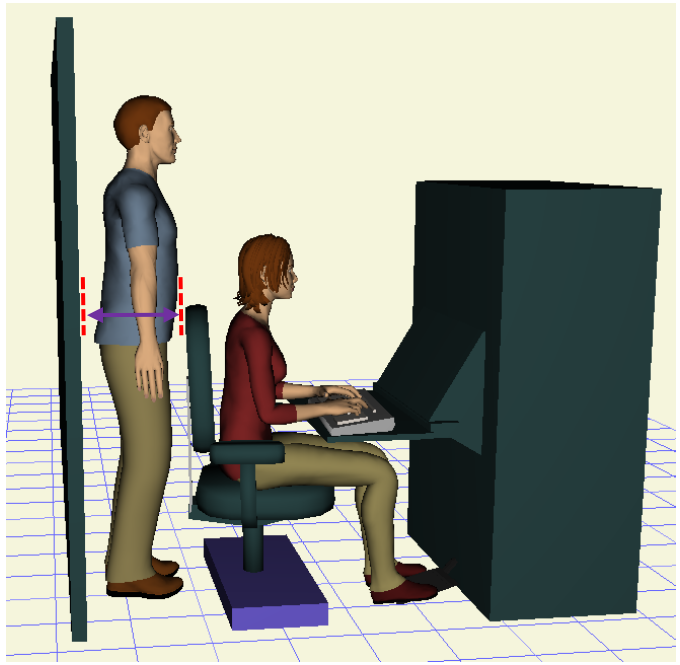
	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Width	**701**	**713**	**734**
Reference data (mm):			
Forearm-Forearm Breadth (M22)	641	653	674
Dynamic allowance, movement	50	50	50
Clothing, general *M22 + dynamic allowance + clothing*	10	10	10
Possible additions:			
Secular trend (M18) p/a	0.82	0.82	0.82
Alternate clothing allowance (Fire Fighting M22)	84	84	84
Additional movement allowance	50	50	50



Rationale: The values reflect the space requirement for an individual to pass behind a seated console travelling in a forwards motion with their arms by their torso wearing general light clothing (e.g., standard Navy DPNU's). A small amount of movement allowance has been included to aid unobstructed walking; this value could be increased for more relaxed movement. Failure to meet the value for the 95th percentile male may result in the majority population not being able to pass in an efficient manner and without obstruction behind seated operators when moving through a vessel. Each project should consider their operational response to damage control and the need for an individual to pass behind seated operators in fire-fighting clothing and equipment. If this is required the alternate clothing allowance can replace the general clothing allowance. Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

40. Space required to pass behind a seated console passing sideward

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Width	**399**	**406**	**427**
Reference data (mm): Abdominal Extension Depth, Sitting (M23)	339	346	367
Dynamic allowance, movement	50	50	50
Clothing, general *M23 + dynamic allowance + clothing*	10	10	10
Possible additions: Alternate clothing allowance for 'general', Fire fighting Abdominal Extension Depth (M23)	211	211	211
Additional movement allowance	50	50	50
Secular trend, general, p/a	10	10	10



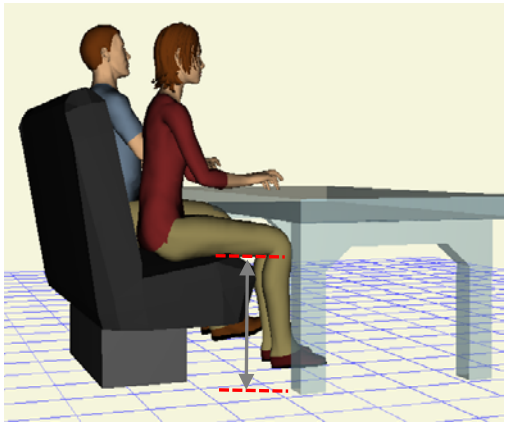
Rationale: The values reflect the space requirement for an individual to pass behind a seated console in a sidewards motion wearing general light clothing (e.g., standard Navy DPNU's). A small amount of movement allowance has been included to aid unobstructed walking; this value could be increased for more relaxed movement. Failure to meet the value for the 95th percentile male may result in the majority population not being able to pass in an efficient manner and without obstruction behind seated operators when moving through a vessel. Each project should consider their operational response to damage control and the need for an individual to pass behind seated operators in fire-fighting clothing and equipment. If this is required the alternate clothing allowance can replace the general clothing allowance. Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

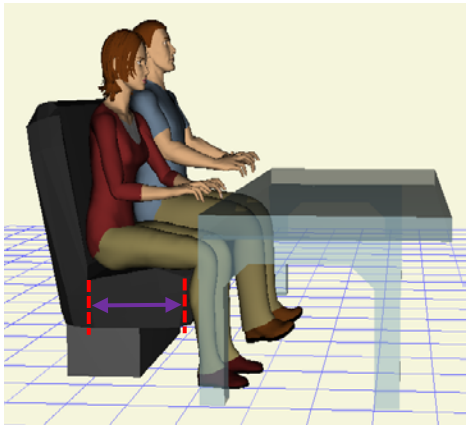
2.6. Mess seating requirements

41. Mess seat height and depth

	Non-adjustable
Fixed Height	**459**
Reference data (mm):	
Popliteal height (M14), Female 50th%ile	397
Popliteal height (M14), Male 50th%ile	435
Footwear height	43
(Female M14 + Male M14) / 2 + footwear	

	Non-adjustable
Depth	**427**
Reference data (mm):	
Buttock-Popliteal Length (M26) Female 5th%ile	437
Clothing allowance, general	10
M26 - clothing	
Possible additions:	
Secular trend (M25) p/a	0.55





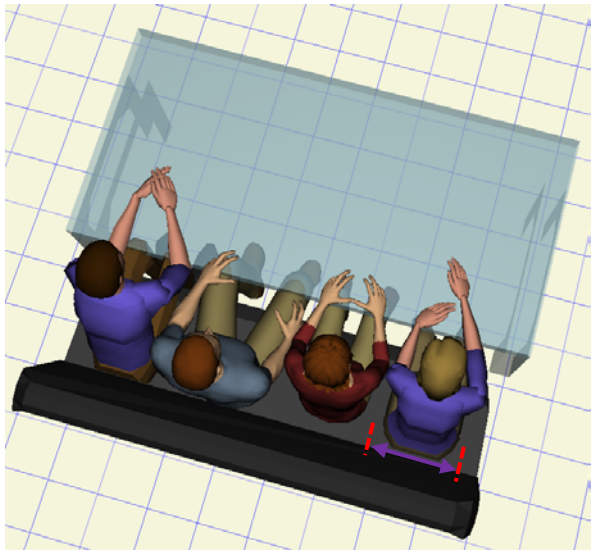
Rationale: The values are recommended for a fixed (non-adjustable) mess seat/booth. Fixed height seating is considered acceptable where adjustability is not feasible and there is minimal operational and functional impact on performance and standard of living. Fixed height seating is common for short term, non-work-related seating. The guidance is based on an average of the female and male 50th percentile popliteal height plus footwear; use of the 5th percentile data for this design object/ arrangement could also be considered.

The values for depth are based on 5th percentile female dimensions to prevent placing unacceptable pressure on the backs of the knees. A general clothing allowance has been included in the value, however projects should consider if a bulkier clothing ensemble will be routinely worn, and subtract a larger clothing allowance from the anthropometric dimension if required.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

42. Mess seat width, booth allocation per individual

	Percentile Accommodated		
	95th %ile Female	97th %ile Female	99th %ile Female
Width	**580**	**590**	**616**
Reference data (mm):			
Hip Breadth, Sitting (M24)	460	470	496
Clothing & leg rotation	70	70	70
Interpersonal space allowance	50	50	50
M24 + clothing + space allowance			
Possible additions:			
Secular trend (M24) p/a	0.68	0.68	0.68

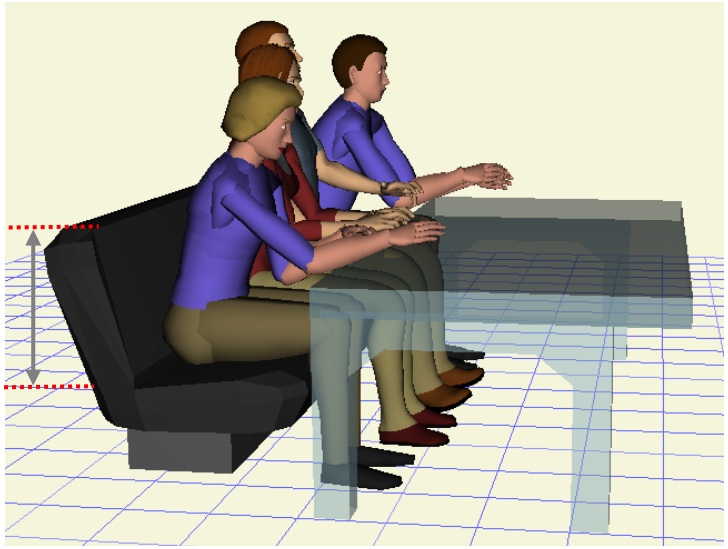


Rationale: The values reflect the space requirements for the majority population to sit comfortably given general clothing and normal posture requirements. A small amount of interpersonal space has been included to allow individuals to sit without pressing against others. As it could be unlikely to have all 95th percentile females seated at once, an alternative approach would be the calculation of the likely distribution of people's size to accommodate at any one time (plus clothing & leg rotation and interpersonal space allowance).

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

43. Mess back rest height

	Non-adjustable
Non-adjustable height	**400**
Reference data (mm):	
HFE Guidance	400
HFE Guidance for short term support	
Alternate reference data:	
Back Length (M51) Male 95th %ile	524
Back Length (M51) Male 97th %ile	532
Back Length (M51) Male 99th %ile	545
Sitting Height (M39), Male 95th%ile	998
Sitting Height (M39), Male 97th%ile	1003
Sitting Height (M39), Male 99th%ile	1018
Secular trend (M39) p/a	0.71

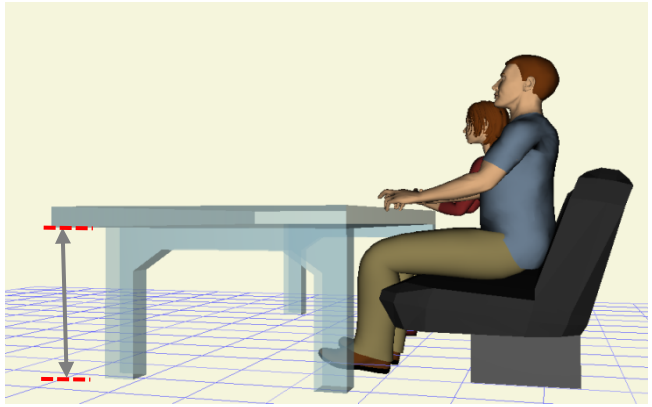


Rationale: The value reflects the general human factors engineering guidance for a backrest height for short-term seating. This is the minimum acceptable height. The alternate reference data of Back Length (M51) provides values that would provide better support to the whole back; these values can be considered as an alternate threshold criteria should the seating be used for regular work purposes. The other alternate reference data of Sitting Height (M39) provides values for a backrest height that would support the whole back, neck, and head, which can be considered as objective criteria.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more, and can be applied in this case where a project chooses to use Back Length or Sitting Height dimension data.

44. Mess table height, non-adjustable

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Fixed Height	**762**	**770**	**786**
Reference data (mm):			
Popliteal Height (M14)	Consult raw data for relationship between multiple dimensions		
Thigh Clearance (M12)			
Footwear height	43	43	43
Dynamic allowance, movement *M14 + M12 + footwear + dynamic allowance*	50	50	50
Possible additions:			
Secular trend (M12) p/a	0.26	0.26	0.26
Secular trend (M25) p/a	0.55	0.55	0.55
Clothing allowance, general	10	10	10

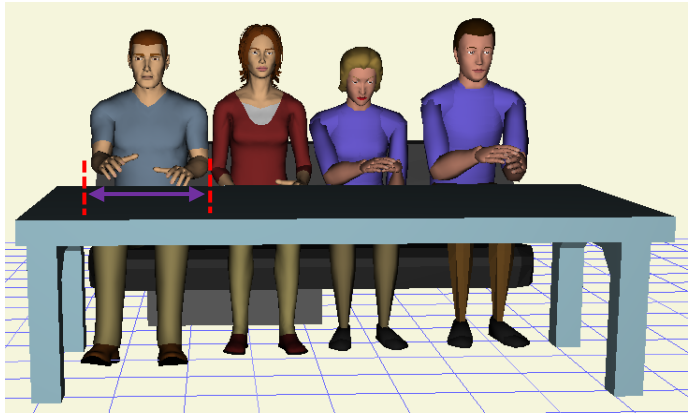


Rationale: The value reflects the underside clearance requirement for the majority population to fit under a fixed height table. A nominal clothing allowance is subsumed within the dynamic movement allowance and has been specifically done so in this case due to the difficulty in defining fixed height tables and chairs that are suitable for the majority population. An additional clothing allowance can be added, noting that any further increases to table height will widen the gap between the fixed height chair/booth and the table which would require more users to raise their arms to use the table.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

45. Table width per individual

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Width	**651**	**663**	**684**
Reference data (mm):			
Forearm-Forearm Breadth (M22)	641	653	674
Clothing allowance (general)	10	10	10
M22 + clothing			
Possible additions:			
Secular trend (M18) p/a	0.82	0.82	0.82



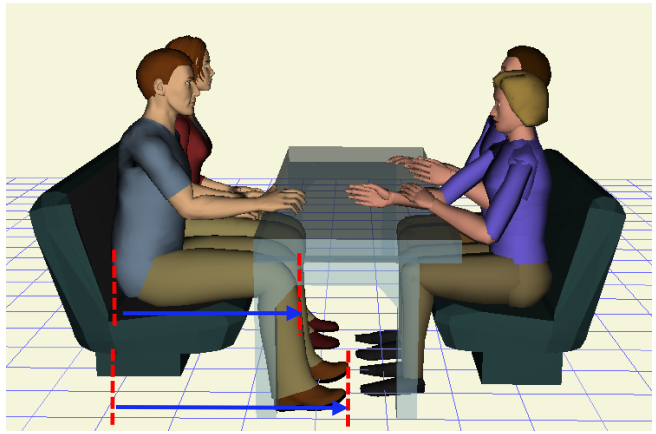
Rationale: The values reflect the space requirement for the majority population to use a table in a normal relaxed posture for a variety of functions. A movement allowance has not been allocated for this design object/arrangement as in a booth style mess arrangement it is unlikely to have all 95th percentile male seated at the table at once. Alternatively, a likely distribution of people's size to accommodate at any one time could be calculated and a movement allowance be added to that (along with clothing). Forearm-Forearm Breadth is the dimension used as opposed to Bideltoid Breadth as that would require users to bring their forearms inwards to fit, which may not accommodate the work functions often completed in the mess.

A greater width for table usage has been allocated over chair/booth width. This is to accommodate eating and working at the table, which requires more space than fitting the hips for sitting. It is expected that table width per individual will exceed chair width.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

46. Knee and feet allowance

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Knee Depth	**732**	**742**	**753**
Reference data (mm):			
Buttock-Knee Length (M25)	672	682	693
Clothing allowance, general	10	10	10
Dynamic allowance, movement	50	50	50
M25 + clothing + dynamic allowance			
Possible additions:			
Secular trend (M25) p/a	0.55	0.55	0.55
Alternate dynamic movement allowance	100	100	100
Alternate clothing allowance (Boarding Party M25)	152	152	152
Feet Depth	**931**	**945**	**973**
Reference data (mm):			
Buttock-Popliteal Length (M26)	Consult raw data for relationship between multiple dimensions		
Clothing allowance, general	10	10	10
Foot Length (M71)	Consult raw data for relationship between multiple dimensions		
Footwear length	41	41	41
Dynamic allowance, movement	50	50	50
M26 + clothing + M71 + footwear allowance + dynamic allowance			
Possible additions:			
Alternate clothing allowance (Boarding Party M25)	152	152	152
Secular trend (M25) p/a	0.55	0.55	0.55
Alternate dynamic movement allowance	100	100	100



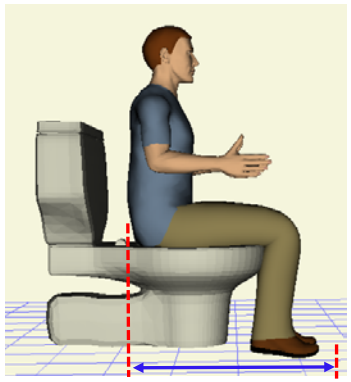
Rationale: The values for knee and feet depth reflect the space needed to accommodate the knees, legs, and feet for the majority population from the front of the seat back going forward. A small amount of movement allowance, general clothing and footwear length allowance has been included. A project may determine based on their operational requirements that they need to accommodate a more bulkier clothing ensemble than the general clothing allowance that has been included and in these situations projects can use the alternate clothing allowance instead of the general clothing allowance. If space permits an alternate dynamic movement allowance can replace the default allowance.

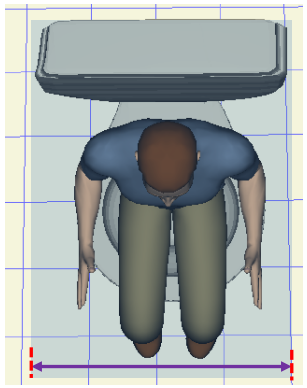
Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

2.7. Water closets and showers

47. Water closets depth and width

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Depth	**921 + fixtures and fittings**	**935 + fixtures and fittings**	**963 + fixtures and fittings**
Reference data (mm):			
Buttock-Popliteal Length (M26)	Consult raw data for relationship between multiple dimensions		
Foot Length (M71)			
Footwear length	41	41	41
Dynamic allowance, movement	50	50	50
Fixtures and fittings *M26 + M71 + footwear + DA + fixtures and fittings*	TBA	TBA	TBA
Possible additions:			
Door opening/closing	TBA	TBA	TBA
Alternate dynamic allowance	100	100	100
Secular trend (M25) p/a	0.55	0.55	0.55
Width	**751 + fixtures and fittings**	**763 + fixtures and fittings**	**784 + fixtures and fittings**
Reference data (mm): Forearm-Forearm Breadth (M22)	641	653	674
Clothing allowance, general	10	10	10
Dynamic allowance, movement	100	100	100
Fixtures and fittings *M22 + clothing + DA + fixtures and fittings*	TBA	TBA	TBA
Possible additions:			
Door opening/closing	TBA	TBA	TBA
Secular trend (M18) p/a	0.82	0.82	0.82



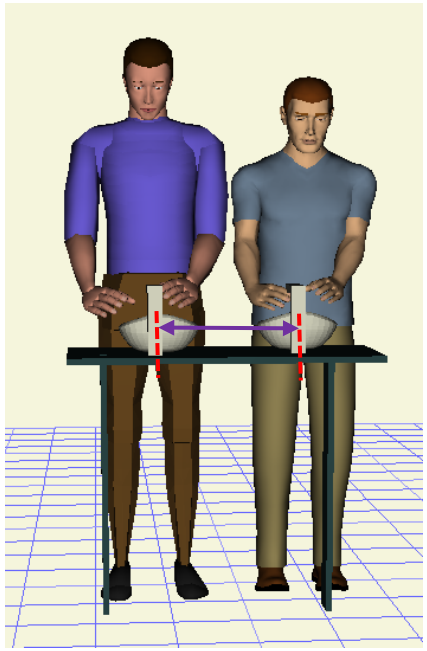


Rationale: The values reflect the space needed to accommodate the majority population once seated whilst using a water closest/toilet facility. Additional space will need to be added for fixtures and fittings once they are known for items such as toilet paper holders, the cistern and any piping that extends beyond the seated person, and provision of bins or wash basins within the allocated space. Opening and closing of the door also shall be considered in the allocated space, but has been listed as a possible addition as further space will only need to be allocated should there not be enough space to stand whilst opening/closing the door. Reference to Abdominal Extensions Depth, Sitting (M23) should be made when determining if there is enough space for standing.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

48. Distance between centre lines of adjacent wash basins

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Width	**651**	**663**	**684**
Reference data (mm):			
Forearm-Forearm Breadth (M22)	641	653	674
Clothing allowance, general	10	10	10
M22 + clothing			
Possible additions:			
Secular trend (M18) p/a	0.82	0.82	0.82

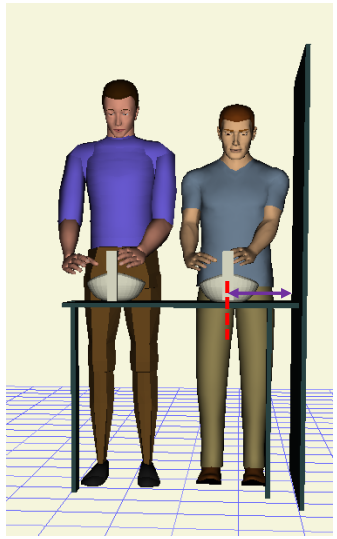


Rationale: The values reflect the space needed to accommodate the majority population using adjacent wash basins in general clothing. A movement allowance has not been allocated for this design object/arrangement as it is unlikely to have all 95th percentile male using adjacent washbasins at once, and also taking into account the short-term nature of use and impact on standard of living. An alternative design approach could include the calculation of the likely distribution of people's size to accommodate at any one time (adding clothing allowance).

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

49. Distance between centre lines of wash basin and adjacent bulkhead

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Width	**381**	**387**	**397**
Reference data (mm):			
Forearm-Forearm breadth (M22)	641	653	674
Clothing allowance, general	10	10	10
Dynamic allowance, movement *(M22 /2)+ clothing + dynamic allowance*	50	50	50
Possible additions:			
Secular trend (M18) p/a	0.82	0.82	0.82

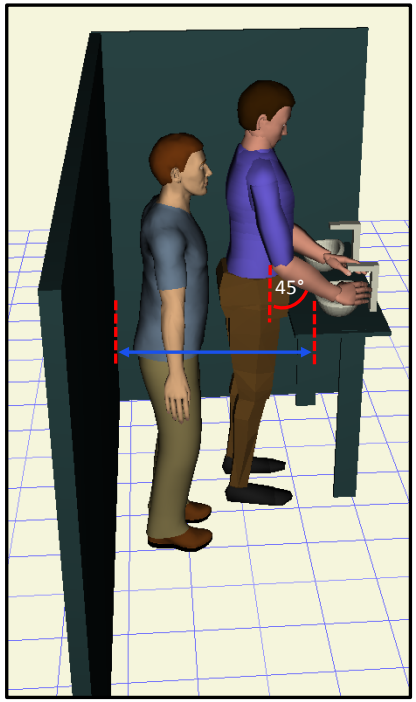


Rationale: The values reflect the space requirement from the centreline of a wash basin to the adjacent bulkhead to accommodate the majority population in general clothing using the washbasin. A small movement allowance has been included to avoid contact with the bulkhead.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

50. Walking clearance between wash basin and facing bulkhead

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Depth	**942**	**952**	**976**
Reference data (mm): Abdominal Extension Depth, Sitting (M23) Radiale-Stylion Length (M61)	Consult raw data for relationship between multiple dimensions		
Forearms raised to 45˚, sin(45)	0.707	0.707	0.707
Dynamic allowance, movement	50	50	50
Clothing allowance, general	10	10	10
*(M23) + (M61 * .707)) + 339 + dynamic allowance + (clothing * 2)* Note: 339mm is 95th%ile Male Abdominal Extension Depth Sitting			
Possible additions:			
Secular trend, general, p/a	10	10	10



Rationale: The values reflect the space requirement between the front edge of a wash basin and a rear bulkhead for the majority population in general clothing to pass behind an individual using a wash basin with their forearms raised at 45°. A small movement allowance has been included to allow unobstructed movement and to prevent contact between the individuals.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

51. Clearance between facing wash basins

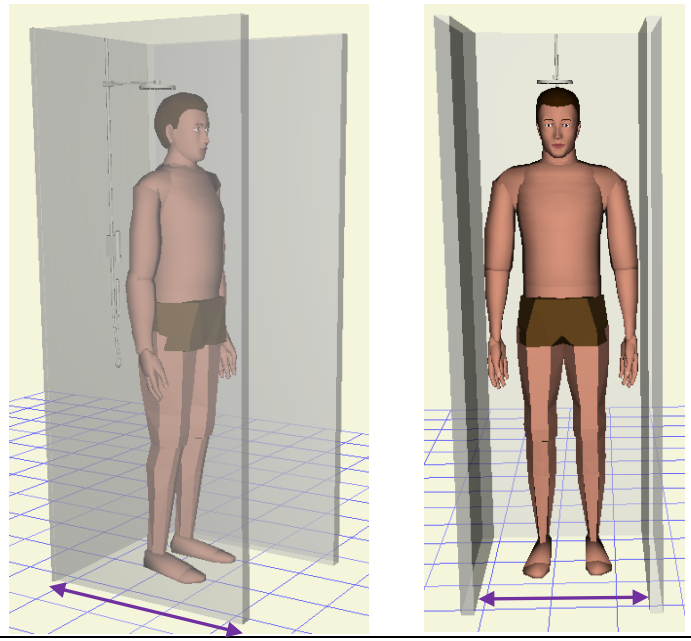
	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Depth	**1136**	**1157**	**1203**
Reference data (mm): Abdominal Extension Depth, Sitting (M23)	Consult raw data for relationship between multiple dimensions		
Radiale-Stylion Length (M61)			
Forearms raised to 45˚, sin(45)	0.707	0.707	0.707
Dynamic allowance, movement	50	50	50
Clothing allowance, general	10	10	10
2 (M23 + (M61 * 0.707)) + dynamic allowance + (clothing * 2)*			
Possible additions:			
Secular trend, general, p/a	10	10	10

Rationale: The values reflect the space requirement between the front edges of facing wash basins for the majority population in general clothing to use the basins with their forearms raised at 45°. A small movement allowance has been included to allow unobstructed movement and to prevent contact between the individuals.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

52. Shower width and depth – Threshold guidance

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Threshold Width & Depth	**741 + fixtures and fittings**	**753 + fixtures and fittings**	**774 + fixtures and fittings**
Reference data (mm):			
Forearm-Forearm Breadth (M22)	641	653	674
Dynamic allowance, movement	100	100	100
Fixtures and fittings *M22 + dynamic allowance + fixtures and fittings*	TBA	TBA	TBA
Possible additions:			
Secular trend (M18) p/a	0.82	0.82	0.82
Door opening/closing	TBA	TBA	TBA
Room for dressing/undressing/storage of dry clothes	TBA	TBA	TBA

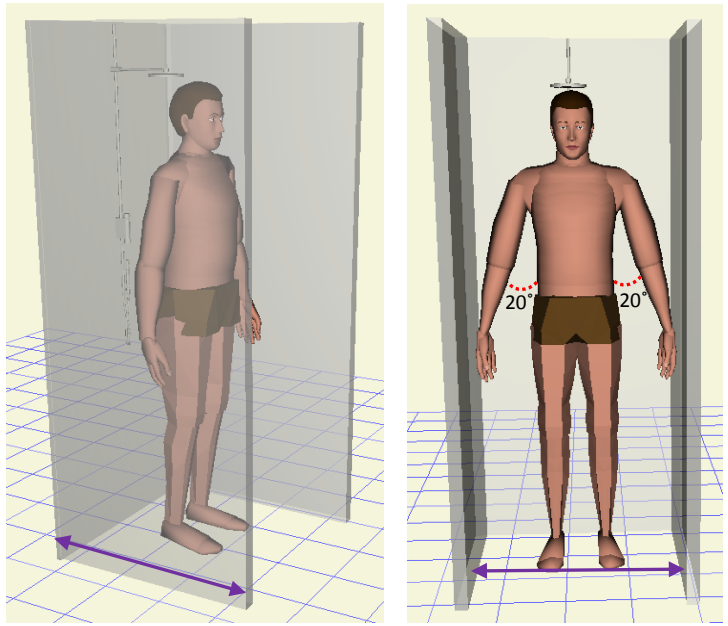


Rationale: The values reflect the width and depth threshold space requirement of a shower recess to accommodate the majority population with their arms by their torso, allowing sidewards movement. A movement allowance has been included to enable some posture change to aid washing. Additional space will need to be added for fixtures and fittings once they are known for items such as shower heads and taps. Opening and closing of the door also shall be considered in the allocated space, but has been listed as a possible addition as further space will only need to be allocated should there not be enough space to stand whilst opening/closing the door. Reference to Abdominal Extensions Depth, Sitting (M23) should be made when determining if there is enough space for standing when opening/closing the door. Additional space will also need to be considered should the intention be for the same space to accommodate dressing/undressing and the storage of dry clothes.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

53. Shower width and depth – Objective guidance

	Percentile Accommodated		
	95th %ile Male	97th %ile Male	99th %ile Male
Objective Width & Depth	**893 + fixtures and fittings**	**903 + fixtures and fittings**	**922 + fixtures and fittings**
Reference data (mm):			
Bideltoid Breadth (M18) Acromion-Radiale Length (M60)	Consult raw data for relationship between multiple dimensions		
Upper arm 20˚ from torso, sin(20)	0.342	0.342	0.342
Dynamic allowance (movement)	100	100	100
Fixtures and fittings *M18 + (M60 * 0.684) + dynamic allowance + fixtures and fittings*	TBA	TBA	TBA
Possible additions:			
Secular trend (M18) p/a	0.82	0.82	0.82
Door opening/closing	TBA	TBA	TBA
Room for dressing/undressing	TBA	TBA	TBA

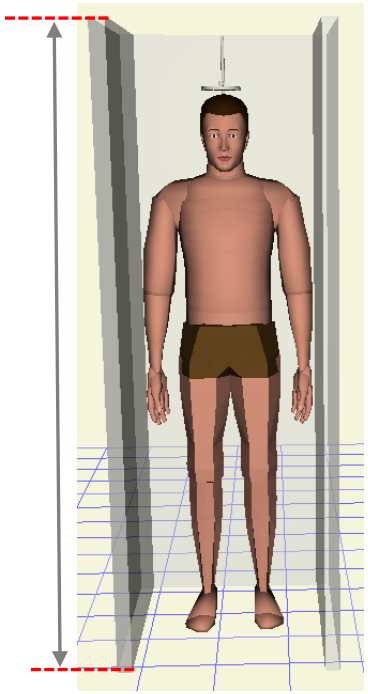


Rationale: The values reflect the width and depth objective space requirement of a shower recess to accommodate the majority population with their upper arms 20° from their torso for additional posture change. The movement allowance allows further posture change to aid washing and prevents contact with the shower walls. Additional space will need to be added for fixtures and fittings once they are known for items such as shower heads and taps. Opening and closing of the door also shall be considered in the allocated space, but has been listed as a possible addition as further space will only need to be allocated should there not be enough space to stand whilst opening/closing the door. Reference to Abdominal Extensions Depth, Sitting (M23) should be made when determining if there is enough space for standing when opening/closing the door. Additional space will also need to be considered should the intention be for the same space to accommodate dressing/undressing and the storage of dry clothes.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

54. Shower height

Height	Percentile Accommodated 95th %ile Male **2006 + fixtures and fittings**	 97th %ile Male **2025 + fixtures and fittings**	 99th %ile Male **2058 + fixtures and fittings**
Reference data (mm):			
Stature (M38)	1906	1925	1958
Dynamic allowance (walking)	100	100	100
Fixtures and fittings	TBA	TBA	TBA
M38 + dynamic allowance + fixtures and fittings			
Possible additions:			
Secular trend (M38) p/a	1.24	1.24	1.24



Rationale: The values reflect the space requirement for the majority population to walk into and stand unobstructed in a shower recess Additional space will need to be added for fixtures and fittings once they are known for items such as shower heads and any overhead piping.

Projects should consider secular trend where the design process and/or platform lifecycle spans a decade or more.

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Appendix A Secular Trend

Secular trends in absolute body dimensions of male RAN personnel matched by age and occupation between 1977 and 2015 (Adapted from [27])[3]

Measurement	1977		2015		Absolute change in means ± 95% CI	Change p.a. (mm, or, kg)	Change per decade (mm, or, kg)
	n	x±s	n	x±s			
Bideltoid Breadth (mm)	593	469 ± 24	593	500 ± 29	31 ± 3	0.82	8.16
Buttock Circumference (mm)	593	972 ± 59	593	1024 ± 77	52 ± 8	1.37	13.68
Buttock-Knee Length (mm)	593	600 ± 26	593	622 ± 32	21 ± 3	0.55	5.53
Foot Breadth (mm)	593	100 ± 5	593	101 ± 6	2 ± 1	0.05	0.53
Head Circumference (mm)	593	574 ± 16	593	577 ± 15	3 ± 2	0.08	0.79
Hip Breadth Sitting (mm)	593	356 ± 21	593	381 ± 31	26 ± 3	0.68	6.84
Sitting Height (mm)	593	913 ± 34	593	941 ± 35	27 ± 4	0.71	7.11
Stature (mm)	593	1749 ± 66	593	1796 ± 70	47 ± 8	1.24	12.37
Thigh Clearance (mm)	593	172 ± 12	593	182 ± 15	10 ± 2	0.26	2.63
Waist Circumference Omphalion (mm)	593	867 ± 86	593	943 ± 112	76 ± 11	2.00	20.00
Weight (kg)	593	74.8 ± 10.4	593	87.2 ± 14.0	12.4 ± 1.4	0.33	3.26

[3] n = number of participants in sample; x = mean; s = standard deviation; CI = Confidence Interval; mm = millimeters; kg = kilograms

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Appendix B Allowances to add to anthropometric data

Design criteria	Allowance (mm)	Reference
Bunk length - comfort factor	200	[24]
Bunk length - hands above head	128	[39]
Bunk width - arms and curling comfort factor	304	[39]
Clearance at sides of workstations	500	[29 p.103, 45]
Clearance at the back of desks for seating space	750	[29]
Clearance at the front of desks for passage	550	[29]
Clearance behind a seated operator to nearest obstacle - min (from front edge of worksurface)	1219	[13, 10.8.1]
Clearance behind a seated operator to nearest obstacle - preferred (from front edge of worksurace)	1372	[13, 10.8.1]
Clearance at the back of desks if there are cabinets behind	1000	[29]
Clearance behind a seated workstation for passage, minimum	1219	[14, 5.10.3.4.12]
Clearance behind a seated workstation for passage, preferred	1372	[14, 5.10.3.4.12]
Clearances behind a seated operator for passage- min	610	[13, 10.8.1]
Clearances behind a seated operator for passage - preferred	762	[13, 10.8.1]
Depth allowance - for movements at knee height add at least	50	[46,47]
Depth allowance - for movements for the feet add at least	100	[46,47]
Dynamic allowance - sitting height	100	[24]
Dynamic movement - walking	100	[29]
Dynamic movement - walking	100	[46]
Dynamic movement - walking	50	[13, 9.2.2.1(6)]
Dynamic movement - walking	50	[18]
Dynamic movement - knee height (when sitting depth allowance)	50 minimum	[42]
Dynamic movement - feet (when sitting depth allowance)	100 minimum	[42]
Dynamic movement - legs when sitting (width allowance)	350 minimum	[42]
Egress - space from front edge of worksurface to back of chair, minimum	720	[46]
Egress - space from front edge of worksurface to back of chair, preferred	1000	[46]

Footwear height allowance (work boots)	43	[19, p.106]
Footwear height, typical mens and womens flat shoes	25	[20]
Footwear length allowance (work boots)	41	[11, p.212]
Head clearance	100	[39]
Postural slump - shoulder height	-40	[34]
Postural slump - sitting eye height	-40	[34]
Postural slump - sitting eye height	-45	[21, p.257]
Postural slump - sitting height	-45	[13, 9.1.1.2, Table 11]
Postural slump - standing eye height	-20	[21, p.257]
Postural slump - standing height	-20	[13, 9.1.1.2, Table 11]
Psychological allowance - headroom	50	[29]
Safety allowance - headroom	50	[13, 9.2.2.1(7)]
Safety allowance - headroom	75	[18]
Seat compression (relevant to sitting height)	-25	[34]
Seat pan width, clothing and movement	70	[33]
Seat pan width: Clothing, movement and outward rotation of legs in normal sitting	70	[33]
Secular trend - bideltoid breadth	.15/pa	[39]
Secular trend - bideltoid breadth		[27]
Secular trend - sitting height	0.5/pa	[39]
Secular trend - sitting height	.71/pa	[27]
Secular Trend - stature	1/pa	[39]
Secular Trend - stature	1.24/pa	[27]
Sitting height - psychological allowance	50	[24, p.110]
Width - between hips light clothing	10	[34]
Width - between hips medium clothing	25	[34]
Width, light clothing allowance	25	[24, p.110]
Width, workstations for normal work activity	75	[33, p. 21]
Work surface thickness, as thin as possible, preferred maximum at front edge	30	[46,47]

Appendix C Personal Equipment and Clothing Correction Factors

PECCFs for the 22 measurements and 3 clothing ensembles measured as part of the ASRAN. [11,12][4].

Dimension (ASRAN code)	Escape Suit			Firefighting Ensemble			Boarding Party		
	Mean	SD	%	Mean	SD	%	Mean	SD	%
Acromion Height, Sitting (M10)	NA	NA	NA	NA	NA	NA	99	±8	16.6
Bideltoid Breadth (M18)	23	±18	4.6	40	±14	8.1	NA	NA	NA
Chest Breadth (M19)	16	±15	5.5	22	±13	7.1	227	±37	73.5
Chest Depth (M20)	54	±29	23.4	182	±10	76.4	129	±17	51.9
Forearm-Forearm Breadth (M22)	78	±31	15	84	±25	15.9	158	±37	31.1
Abdominal Extension Depth, Sitting (M23)	NA	NA	NA	211	±30	87.5	223	±15	89.9
Hip Breadth, Sitting (M24)	NA	NA	NA	NA	NA	NA	106	±31	28.2
Buttock-Knee Length (M25)	NA	NA	NA	NA	NA	NA	152	±19	24.9
Foot Breadth, Horizontal (M27)	6	±5	6.2	15	±4	14.6	16	±6	16.1
Head Circumference (M28)	192	±48	33.3	382	±13	66	316	±19	55
Chest Circumference (M33)	95	±36	9.8	377	±40	38.5	389	±35	39.5
Waist Circumference (Omphalion) (M35)	NA	NA	NA	NA	NA	NA	629	±83	70.3
Buttock Circumference (M36)	254	±15	26.3	146	±33	15.2	70	±23	7
Stature (M38)	20	±7	1.1	94	±11	5.2	76	±12	4.3
Weight (kg) (M40)	NA	NA	NA	NA	NA	NA	20.2	±0.6	24.7
Head Breadth (M41)	6	±4	3.9	89	±7	56.8	68	±4	42
Head Length (M42)	45	±18	22.7	106	±6	53.3	83	±9	41.3
Hand Breadth (M65)	1	±1	1.2	3	±2	3.2	NA	NA	NA
Hand Length (M66)	7	±8	3.5	8	±6	3.9	NA	NA	NA
Foot Length (M71)	38	±8	14	41	±8	15	33	±4	12.3
Hand Depth (M86)	2	±3	3.4	0	±2	0.8	NA	NA	NA
Overhead Fingertip Reach (M90)	NA	NA	NA	NA	NA	NA	-59	±40	-3.4

[4] SD = standard deviation, % = percent of the mean difference to semi-nude measurements

C.1. Applying PECCF values

What is typically applied to an anthropometric dimension is the mean PECCF value. Therefore a clothing correction factor for the fire-fighting ensemble for Bideltoid Breadth would be +40mm.

C.2. Future range of motion data

These measures were taken with the participants in the same postures as the basic anthropometric dimensions that is static postures. Research is currently underway at the University of South Australia to examine the impact that certain clothing combinations have on range of motion and movement.

C.3. Escape suit ensemble

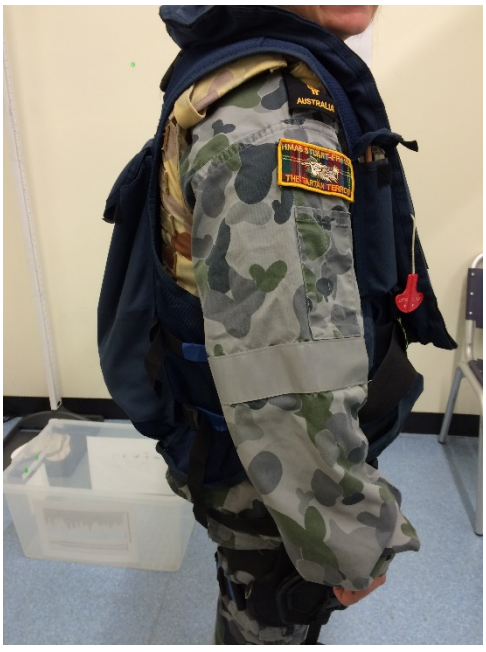
The escape suit PECCF data was collected with participants wearing the Submarine Escape Immersion Equipment MK10 Escape Suit. This is a one-size fits all suit, which was fitted over the participants standard Disruptive Pattern Navy Uniform (DPNU), without issued boots [11].

C.4. Firefighting ensemble

The firefighting PECCF data was collected with participants wearing the "full firefighting rig" [48], defined as: the standard Disruptive Pattern Navy Uniform (DPNU) (including issued boots), BA hood, firefighting gloves, two piece firefighting ensemble, structural firefighting helmet, helmet torch and OCCABA [11].

C.5. Boarding party ensemble

The boarding party ensemble was collected with participants wearing their standard Disruptive Pattern Navy Uniform (DPNU) including issued boots, along with MCBAS (no plates, both stab and spike and low velocity inserts), SOS marine lifejacket with integrated pockets, marine safety helmet PAS028 and SOS marine duty belt with thigh pistol holster [11].



Appendix D Dimensions measured in ASRAN

Physical measurements	Digital measurements
M01 Cervicale Height (mm)	M41 Head Breadth (mm)
M03 Acromion Height (mm)	M43 Menton-Sellion Length (mm)
M04 Suprasternale Height (mm)	M44 Bitragion Submandibular Arc (mm)
M07 Iliocristale Height (mm)	M45 Neck Circumference (mm)
M08 Crotch Height (mm)	M46 Nape-Bustpoint/Thelion Length (mm)
M09 Eye Height, Sitting (mm)	M47 Nape-Waist over Bust (mm)
M10 Acromion Height, Sitting (mm)	M48 Biacromial Breadth (mm)
M11 Elbow Rest Height (mm)	M49 Scye Depth (mm)
M12 Thigh Clearance (mm)	M50 Back Width (mm)
M13 Knee Height, Sitting (mm)	M51 Back Length (mm)
M14 Popliteal Height (mm)	M52 Nape-Waist Centre Back (mm)
M15 Interpupillary Breadth (mm)	M53 Vertical Trunk Circumference (Wide) (mm)
M16 Bizygomatic Breadth (mm)	M54 Crotch Length (Omphalion) (mm)
M18 Bideltoid Breadth (mm)	M55 Waist Circumference Preferred (mm)
M19 Chest Breadth (mm)	M56 Maximum Hip Circumference (mm)
M20 Chest Depth (mm)	M57 Waist-Hip Distance (mm)
M21 Bicristale Breadth (mm)	M58 High Hip (mm)
M22 Forearm-Forearm Breadth (mm)	M59 Hip (mm)
M23 Abdominal Extension Depth, Sitting (mm)	M60 Acromion-Radiale Length (mm)
M24 Hip Breadth, Sitting (mm)	M61 Radiale-Stylion Length (mm)
M25 Buttock-Knee Length (mm)	M62 Sleeve Outseam (mm)
M26 Buttock-Popliteal Length (mm)	M63 Wrist Circumference (mm)
M27 Foot Breadth, Horizontal (mm)	M64 Hand Circumference (mm)
M28 Head Circumference (mm)	M65 Hand Breadth (mm)
M29 Neck Circumference, Base (mm)	M66 Hand Length (mm)
M30 Shoulder Length (mm)	M67 Thigh Circumference (mm)
M31 Biceps Circumference, Flexed (mm)	M68 Knee Circumference (mm)
M32 Forearm Circumference, Flexed (mm)	M69 Calf Circumference (mm)
M33 Chest Circumference (mm)	M70 Ankle Circumference (mm)
M34 Chest Circumference Below Breast (mm)	M71 Foot Length (mm)
M35 Waist Circumference (Omphalion) (mm)	M72 Ball of Foot Length (mm)
M36 Buttock Circumference (mm)	M73 Seat Angle (°)
M37 Thumbtip Reach (mm)	M74 Outside Leg Length (mm)
M38 Stature (mm)	M75 Chest Level (mm)
M39 Sitting Height (mm)	M76 Bust Level (mm)
M40 Weight (kg)	M77 Waist Level Centre Front (mm)
M42 Head Length (mm)	M78 Hip Level (female) (mm)
M86 Hand Depth	M79 Waist Level Centre Back (mm)
M87 Wrist-Centre Thumbtip Distance	M80 Seat Level (mm)
M88 Wrist-Centre Grip Distance	M81 Trochanteric Height (mm)
M89 Ear Length	M82 Hip Level (male) (mm)
M90 Overhead Fingertip Reach	M83 Knee Level (mm)
M91Index Finger Breadth Distal	M84 Ankle Height (mm)
	M85 Torso Length (mm)

[11]

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17. ABSTRACT

In 2015 an Anthropometric Survey of the Royal Australian Navy (ASRAN) was conducted providing comprehensive female and male body size and shape data of the RAN operational workforce. That data was then developed into evidence based human factors engineering design guidance, presented in this document that can be used to tailor design solutions to optimise the fit between the RAN population and HMA Surface Ships and Submarines, and their systems, subsystems, and facilities. The main purpose of this guidance is to provide future and modified naval vessels with physical habitability requirements that reflect the physical and social needs of the personnel that use it. The end goal is to optimise performance, health and safety, quality of life, and satisfaction.