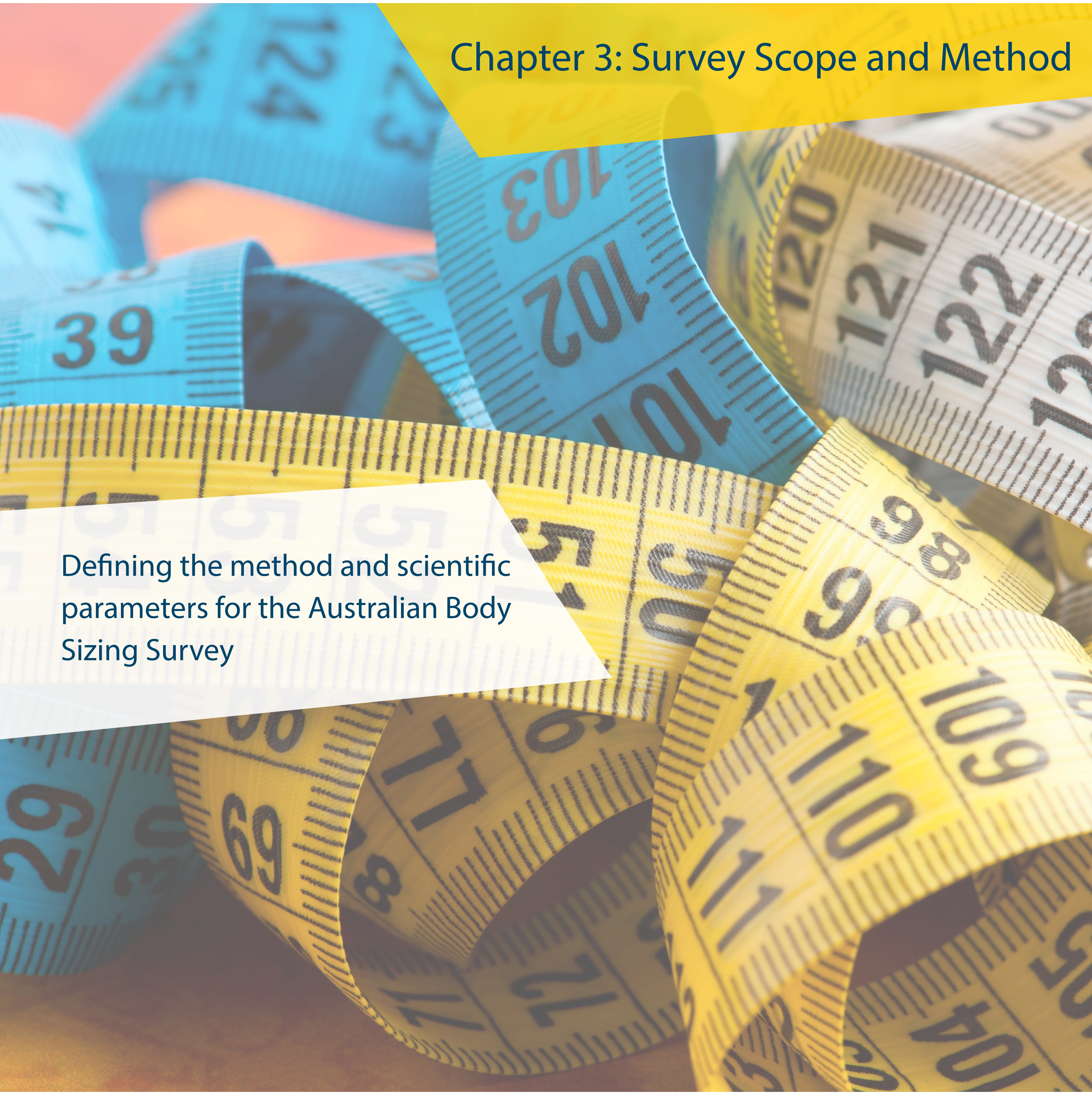
SIZING UP AUSTRALIA
- THE NEXT STEP



Chapter 3: Survey Scope and Method

Defining the method and scientific parameters for the Australian Body Sizing Survey

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Executive Summary

This report is a part of a larger project aimed at progressing the development of the Australian Body Sizing Survey. *Chapter 1* summarises and provides recommendations for action in the project. *Chapter 2* of this project is the research and preparation of a Literature Review that includes not only the refereed literature, but also an interrogation of grey literature; that is, unpublished reports about large-scale sizing surveys and reviews of hardware and software that have been conducted around the world. The Literature Review demonstrates that the Australian Body Sizing Survey will enable better design and safer and healthier work practices. This current report makes reference to the literature review and should be read with it as a companion document.

This document covers Chapter 3 of the project: *Defining the method and scientific parameters for the Australian Body Sizing Survey*. This chapter defines the scope of the Australian Body Sizing Survey. It addresses the key features of stakeholder engagement and how this will determine the range and type of measurements to be obtained. It also describes the systems engineering model that will be used to develop the testing required to finalise the survey method, business plan and costing. This is found in Sections 1-5 of this report. Section 6-8 of this report discusses possible sizing survey methods and recommends sampling method, recruitment strategy and data management.

The value proposition for the Australian Body Sizing Survey is compelling. The data from the survey would contribute to the well-being and welfare not only of working women and men, but also to the broader community. In this report we have put the focus on design for the workplace and the impact of the survey on work health and safety. We assert that the Australian Body Sizing Survey will contribute to at least three of the Action Areas of the Australian Work Health and Safety Strategy 2012-2022: healthy and safe by design, supply chains and networks, and health and safety capabilities (Safe Work Australia 2012). The impact will flow from the development of Australian body size information, in combination with the adoption of new methods of using these data, to influence the physical design of workplace environments and equipment. Investment in this approach can help to get designs right the first time to avoid dangers inherent in poor design, the costs of reducing mismatches, and the need to retrofit or refurbish. The survey may also have indirect influence on Safe Work Australia's other Action Areas by influencing the way we think about design and work health and safety.

The purpose of the sizing survey is to obtain representative body size data for the Australian population so that a wide range of stakeholders can use this to improve what they do for, or supply to, Australians. We regard stakeholder engagement in the project as a critical foundation for success, so this report outlines processes that will enable the systematic identification and involvement of stakeholders from the outset. Stakeholders would not only assist with funding the survey; they would also help to shape the survey and the selection of measurements included in it. As a result they would derive considerable benefit from their engagement that will lead to improvements in design for all Australians.

Regardless of the method selected to conduct the Australian Body Sizing Survey, there will be significant costs associated with it. We propose two user-pays funding models to initiate thinking about how the necessary finance to support the survey might be raised. They combine the allocation of a set number of measurements that would be determined by general consensus between all stakeholders, regardless of their level of funding contribution, with a second and larger allocation of measurements that survey sponsors can determine. The number of measures that a funding stakeholder could determine would be directly proportional to their level of contribution. The models differ in the number of agreed measures and the number available for negotiation. Both funding models allow for in-kind sponsor support such as use of facilities, manufacture of scanning garments or the provision of inducements and incentives for subjects. At the outset of the project we propose that only two measures be regarded as non-negotiable: standing height (stature) and weight. All other measures would be open to negotiation with stakeholders.

An additional funding model should be considered where the Australian government funds the basic survey and a consortium of partners concurrently contribute funding to the user applications. These applications can be specifically applied to the new Australian anthropometric data to get immediately useful outcomes.

Whilst stakeholder engagement is critical to the Australian Body Sizing Survey, the complexity and technical nature of the project cannot be denied. In order to establish clear and transparent processes for the development of the technical scope of the project, the selection of measurements, the investigation into the most appropriate landmarks and scanning options would need to be informed by subject-matter experts. Thus, we propose that an international Technical Committee, consisting of technical experts, would be established to provide technical input and act as an arbiter when technical decisions are being made. The project would need to assemble a multidisciplinary team at the outset and adopt this approach for the planning and co-ordination of resources and logistics. Risk and quality management systems would also be applied to establish effective management systems and methods to run the Australian Body Sizing Survey project.

This complex project would require a multitude of iterative steps: ongoing stakeholder consultation, determination of the measures to be obtained, review and selection of a whole body scanning device, testing of the method and equipment, recruitment and training of a project team, running an initial trial or pilot survey, subject recruitment, delivery of the main survey and the processing and management of the data. We propose that this systems engineering approach is used to manage this project and the interactions between these components.

Any contributor of funds to the Australian Body Sizing Survey will be seeking value for money. We have addressed this need in several ways in this report. We have considered the value proposition for stakeholder engagement, identified the trade-off between utility and cost, and considered where value for money lies in the selection of a scanner to do the work. We propose that spending on this project will deliver best value for money when a medium to high level of expenditure is made on the components of the project. That is, on the one hand, a low cost approach will be incapable of delivering results that are useable for design purposes, effectively defeating the purpose of the exercise. On the other hand, high cost in all components of the project is not necessary to achieve the desired outcomes. We weave the path through this maze by providing the information necessary to determine where to place the highest expenditure in order to gain the best outcomes.

Australia is well placed in the timing of the Australian Body Sizing Survey to take advantage of cutting edge scanner technologies. We are concerned that the best value for money in the selection of a scanner is an important part of the establishment of the project, so this report provides some basic information about the range of scanners currently available and includes information about leading edge technologies. These potentially allow for the collection of dynamic range data for the first time. These data would be of particular value in the work health and safety arena, especially if combined with biomechanical data. A large-scale Australian survey using these parameters would create the next gold standard for an anthropometric survey with concomitant competitive advantage for stakeholders.

Finally the report discusses the issues of subject selection and participation, including the ethical requirements that accompany involvement of subjects in a project like this. We discuss the importance of retaining high quality control on the data and effective data management for the long term. We also consider the importance of comparability of data, particularly in making the output of the Australian Body Sizing Survey available to designers through the existing online portal, WEAR.

The Australian Body Sizing Survey potentially opens new opportunities for Australian designers, data analysts, tool developers, manufacturers and other stakeholders in this important project. It has the capacity to place Australia at the leading edge in these fields providing new opportunities as well as healthy and safe workplaces.

Contents

Abbreviations

ABS	Australian Bureau of Statistics
AMI	Anthropometric Measurement Interface
ANSUR	U.S. Army Anthropometric Survey
ARIS	Anthropometry Research Information System
CAD	Computer Aided Design
CAESAR	Civilian American and European Surface Anthropometry Resource
ISO	International Standards Organisation
PPC	Personal protective clothing
PPE	Personal protective equipment
SD	Standard Deviation
SWA	Safe Work Australia
WEAR	World Engineering Anthropometry Resource
XML	Extensible Mark-up Language

Introduction

This document represents Chapter 3 (out of 3) of a report commissioned by Safe Work Australia (SWA) aimed at identifying the value of the Australian Body Sizing Survey and how it might be conducted.

Recently developed ISO standards, precedents set down by previous surveys and advances in scanning technology will be used to determine the technical parameters of the Australian Body Sizing Survey. However the final design of the survey and the data collected will be driven by stakeholder needs, moderated by subject-matter experts in combination with testing. The result will be that the Australian Body Sizing Survey will be a defensible process of gathering body size data about Australian people that can be used by stakeholders to develop better and safer design outcomes for Australians.

The survey scope and method relies on stakeholder input to define the range and type of data that will be obtained. Accordingly, it is difficult to fully define the scope of the survey ahead of this engagement with stakeholders. With this in mind, this report seeks to define a process that could be pursued with stakeholders to finalise the scope and develop the business plan for the Australian Body Sizing Survey.

About this report

Chapter 1 summarises the project and provides recommendations for action.

Chapter 2 is an international literature review. It demonstrates that the Australian Body Sizing Survey will enable better design and safer and healthier work practices. This current report is a companion document to the literature review as it builds upon and makes reference to the previous Chapter.

Chapter 3 defines the scope of the Australian Body Sizing Survey. It addresses the key features of stakeholder engagement and how this will determine the range and type of measurements to be obtained. It also describes the systems engineering model that will be used to develop the testing required to finalise the survey method, business plan and costing. This is found in Sections 1-5 of this report. Sections 6-8discusses possible sizing survey methods including sampling method, recruitment strategy and data management.

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1. Value proposition for the Australian Body Sizing Survey

1.1 What will the sizing survey deliver or “what’s in it for me”

The value proposition for the Australian Body Sizing Survey will need to be clearly outlined for potential stakeholders in order to gain not only their interest, but also their financial support. It will also need to demonstrate a strong potential to positively contribute to the current strategy areas of Safe Work Australia (SWA).

The seven areas in which actions are required to support current SWA objectives are (Safe Work Australia 2012):

1. healthy and safe by design
2. supply chains and networks
3. health and safety capabilities
4. leadership and culture
5. research and evaluation
6. government, and
7. responsive and effective regulatory framework

The development of Australian body size information, in combination with the adoption of new methods of using these data, can influence the physical design of workplace environments and equipment that, in turn, can have a direct impact on the first three items on this list. This was clearly shown in Chapter 2 - the Literature Review. For the Australian Body Sizing Survey to have maximum impact on these areas a range of work health and safety stakeholders will be need to be engaged in the process of its development.

The generic design cycle shown in Figure 1 (and discussed in detail in Section 5.3 of the literature review) can be applied to most physical environment/equipment design scenarios. Investment in this approach can help to get designs right the first time to avoid the costs of reducing mismatches or needing to retrofit or refurbish.

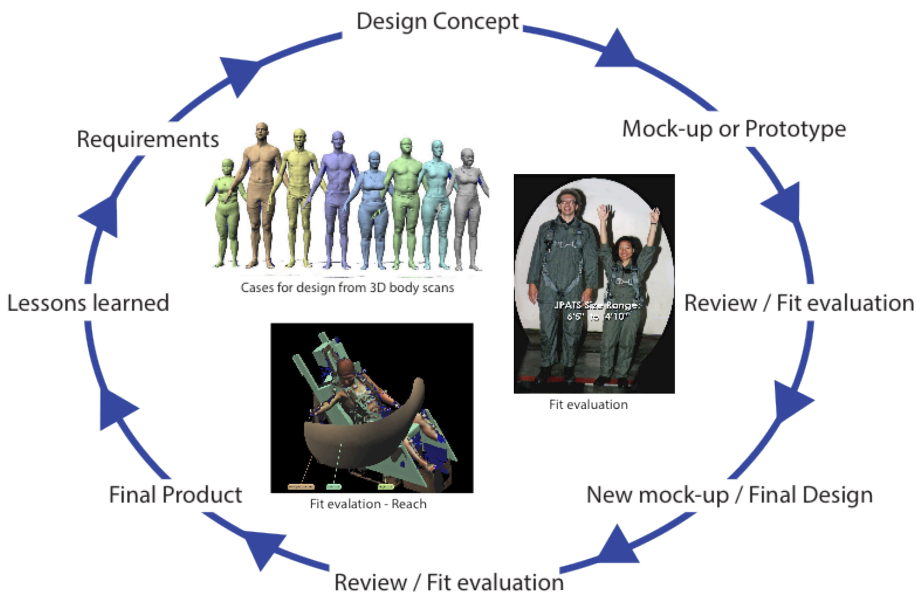


Figure 1: Shows the concept of fit-evaluation applied in the design concept stage to improve the design before production

The Australian Body Sizing Survey has a clear and key role in the design cycle and can directly influence the capacity of design to improve work health and safety outcomes. This section describes how this relationship between anthropometry and design works to improve outcomes by using case studies and by describing key concepts from design using anthropometric data.

1.2 Understanding value from examples

The examples presented in the follow sections demonstrate the use of anthropometric data in design that have achieved important and significant outcomes for users, developers and manufacturers. They highlight how these benefits can be achieved and the value proposition for stakeholders and sponsors of the Australian Body Sizing Survey.

1.2.1 Building safer physical environments

Anthropometry can add value to the design of built environments and equipment. A clear value proposition for the proposed Australian Body Sizing Survey is demonstrated by the example of the cockpit of a jet fighter (Zehner 2008) from the US military. This example used 1-D and 3-D anthropometric data in the 3-D environment to establish the relationships between the pilot and the cockpit's physical work environment. The case demonstrated the complex range of physical human dimension variables necessary for safe design and the impact that under- or over-estimating these can have on the effectiveness and safety of the design. For example, a pilot with a very long buttock-knee length can physically fly the fighter plane. However, the plane is fitted with an ejection seat, so if that pilot was required to eject in an emergency, their knees/thighs would hit the console during the egress. This would result in a serious foreseeable and avoidable workplace injury. In this case study seat ejection was difficult to take into consideration without the right anthropometric data being applied to the whole of the design.

Cockpit design may not seem like an obvious or common comparison to optimise safety in design for Australian workplaces, but in fact the principles of the application of anthropometry in design are relevant. It is only feasible to consider variations in human dimensions and their place within a system when accurate data are available. Our current ability to source Australian body size data in 3-D form is non-existent. As the Australian Body Sizing Survey is developed the ability to search and select critical variables of interest for design and representative cases, be they real or modelled, will improve. Our ability to grow the sophistication of our designs to include a wider range of people and to better consider design elements affecting safety will also grow.

The value case for the built physical environment for Australian workplaces is very strong. Providing high calibre Australian body size data with current and emerging anthropometry tools will introduce Australian workplaces to a new era of user-centred and smarter design. Those stakeholders who recognise this and actively engage with and support the process will stand to derive greatest benefit and return on their investment.

1.2.2 Fit-mapping and digital human modelling

The most cost-effective way to accommodate a population is by *early* incorporation of human dimensions in design. Either live models that represent cases within the target population and/or the use of virtual models to represent these cases within virtual design mock-ups. The static 3-D models can be combined with biomechanical models to represent both shape and motion. In addition models that have the capacity to include realistic information such as bulky apparel (PPE) and encumbrances (harness, backpack or shoes) all of which can dramatically affect the space occupied, the posture, and functional performance, would fundamentally increase the usefulness of virtual models. With the right tools, design functionality can be represented and tested in a virtual environment early in the design process, reducing the number of design iterations and associated prototyping costs and therefore improving the time-to-market of the product. This would also avoid very costly retro-fits.

For the assessment of existing products fit-mapping is very effective. The ground-breaking work done in fit-mapping (matching people to products) was documented in the Navy Women's Uniform study (Robinette, Mellian et al. 1991). The fit-mapping consisted of measuring the body size and assessing the fit of each of the garments on more than 1000 Navy women. Prior to the study the US Navy had added odd-numbered sizes in the uniform range in an attempt to improve fit, because *75% of all Navy women's uniforms had to have major alterations*. After fit-mapping, 15 of the existing sizes were found to be completely unnecessary and unused but were being bought and stocked anyway. By using the new size range alterations were reduced to less than 1% with the same number of sizes. The US Navy saved $2.5 million USD per year including savings from no longer purchasing and stocking unnecessary sizes. Female sailors, who pay for their own alterations, also benefitted from the improved size range. Collectively they saved about $1.8 million USD in the first year.

Fit-mapping has three parts: 1) anthropometry survey, 2) fit mapping survey, and 3) analysis. It is a powerful tool that can be applied to populations greater than 500 and, as demonstrated by this example, can have significant benefits along the supply chain. However, it relies on high quality anthropometric data.

1.2.3 Fit proportions of the population and clothing

Obtaining correct fit for garments and other worn items such as PPE is predicated on understanding the target market. Given Australia imports many of these items, comparisons of Australian and international sizing must be part of the assessment process. Section 5*. How are anthropometric data used in industry?* of the Literature Review outline various case studies for worn things, including apparel, and these are drawn on here.

There is considerable value to be gained from re-thinking the target market for things that people wear (including garments and protective equipment). As discussed in detail in the Literature Review (see Section 5.1.1: *Understanding your target market* and 5.3.2 *Fit-mapping*), anthropometric data about the target market allows designers and manufacturers to accommodate more people with fewer sizes; representing savings at each stage along the supply chain. This is achieved by moving the fit model to the centre of the distribution of the target market and adjusting the grading to match body growth as defined by the anthropometric data. A US example (see Section 5.1 of the Literature Review) showed that by using this approach an extra 14.7% of people (17.5 million women) could be accommodated in the same number of sizes. These women did not fit in existing sizes because of basic statistical errors. The adjustment was able to be made because CAESAR data provided the necessary information about the US population. To extrapolate from the example to Australia: the number of females in Australia aged 15-65 is about 7.8 million, then 15% of this number is roughly 1.2 million Australian women who may not fit in existing clothing sizes because of basic statistical errors and lack of a usable, good quality anthropometric database. The Australian Body Sizing Survey would provide the necessary data to achieve improved garment sizing outcomes.

Worn things are often imported into Australia. Australian data could be used for population comparisons to assess and compare the size range of items and match them for suitability to our population. This would result in more satisfied customers, reduced stock levels and less waste.

A common application of anthropometry to working populations is the fit and function of personal protective equipment (PPE) and clothing. The development of uniforms, helmets and gloves and protective equipment for the head and face has been the focus of numerous studies (Mellian, Ervin et al. 1990, Blackwell 1993, Choi, Zehner et al. 2010). For many items of PPE the calibre of the fit is tied to its function and in many work environments fit is critical to protect workers' health and safety. Also where multiple items of PPE need to be worn the effectiveness of fit for one item can impact on the quality of fit, and ultimately operational effectiveness, of other items of equipment worn, whether they are operational items of equipment or other items of PPE such as helmets combined with goggles.

The Country Fire Authority in Victoria, Australia is one of the largest volunteer populations in Australia and indeed the world. Of the 60,000 registered volunteers about 35,000 are active and of those 22% are women. All volunteers are required to have one set of PPC for wildfires and those responding in urban areas require another set for structural fires. There is no known data about this sub-population of Australian workers although there are known risks that they face where the fit of PPC is vital to maintain their protection for exposure to hazards. Australian body size data would enable a greater understanding of the requirements of fit to ensure that personal protective clothing is effective but not cumbersome or creates secondary hazards. This is a common theme for Australian industry and workplace health and safety.

Amongst other things, face masks are worn to protect against biological hazards. Recent research conducted in the Size China head study showed significant differences between the head and face shape of Western and Asian groups. The fit of masks and glasses designed for the Western face are a specific concern for the fit of PPE to classic Asian-shaped faces (Ball, Shu et al. 2010). Australia, with its significant ethnic diversity, needs to safely accommodate different ethnic groups in its working population. This is impossible to achieve unless designers of PPE have access to high quality anthropometric data on our working population.

1.3 Providing value for money: balancing the survey's features and costs

In designing the method for the Australian Body Sizing Survey is important to consider how the features of the survey impact on the value for money invested in the project. Obtaining best value for money can be obtained by judicious decision-making in the survey design stages so that the best quality and most useable anthropometric data are obtained for the least investment. The following matrix (Table 1) outlines the desirable key features for the Australian Body Sizing Survey that will help define the scope of the Australian Body Sizing Survey project.

1.3.1 What would be our future needs?

The Australian Body Sizing Survey needs to deliver the technical outcomes required by the stakeholders and sponsors. It is likely there will be a combination of requirements for 1-D traditional style measurements and 3-D data. 1-D will deliver the strengths outlined in Chapter 2 of this project as well as comparability - the capacity to cross-reference our data internationally with past and future surveys. High-quality 3-D imaging will deliver the strengths outlined previously as well as the capability to provide a library for future reference and data mining. 2-D can be mined from 3-D.

Table 1, below, outlines the level of expenditure needed to get best value for money against the key features of the Australian Body Sizing Survey. Various combinations of outcomes will help inform the decisions about value for money. The table identifies features that are high/low tech and high/low fidelity; these are not the same. Sometimes low-tech solutions have high fidelity. The advantages and disadvantages of high and low tech solutions need to be known and actively managed to get high fidelity solutions. Any combination of technology that produces good outcomes should be allowed.

The cells highlighted in green we regard as optimal and some detailed explanation for this choice follows the table. This table indicates that low expenditure will not give good value for money because the results will be too poor quality for design purposes. On the other hand there is no need to overspend on some key features, as the benefit obtained would not represent value for money, or may not adequately address stakeholders' needs.

Features	Expenditure		
	LOW	MEDIUM	HIGH
Technical equipment	Hand measuring – no obsolescence of equipment	Combination of traditional-style and scanning techniques	Automated scanner/computers/ modelling (has high obsolescence and low comparability)
Type of measures	Low tech 1-D only – high accuracy but limited usability	Combination of 1D and 3D – the best of both worlds	High tech 3-D only – low or unknown accuracy/quality
Predictive value of data for outcomes	Low fidelity - Not much ability to predict outcomes	Ability to predict but some error	High fidelity - Ability to predict to high precision) (needed in absence of the real person)
Flexibility	Only fulfils the stated requirements, no extra data	Required uses plus other uses	Data can be mined for multiple extra uses with very little additional cost – acts as a data "library" (possibly unforeseen at this point)
Ongoing capability	Get experts in to do it all and then they go home	Get trained by experts, who transfer their knowledge and can act as consultants in the future	The project group develops the expertise and it stays with the survey project group
Thinking time	Don't need to think because you copy	Mixture of both – use lessons learned from other sizing survey, and problem solve what is best for this project and the stakeholders	Needs problem solving from scratch and this requires time

Table 1: Summary of the value for money against expenditure on an anthropometric survey

Technical equipment and type of measurements:

- Medium expenditure levels are desirable so that the Australian Body Sizing Survey is long term, has maximum accuracy, scope, accessibility and usability. Comparability to other data is also essential. In addition ISO 20685 provides in Annex A the marking of a minimum set of anatomical landmarks. The ISO also recommends validation of both scanner hardware and software measurement extraction and gives instructions on how to do this. That is, a testing phase for each particular combination of software and hardware where 1-D scanned extracted measurements are compared for accuracy against 1-D traditional-style measurements taken by a skilled anthropometrist. Any scan-extracted measurements that do not correspond to the defined acceptable error for that measure should be taken using the most accurate method, which might be traditional. This means the combination of traditional style and scanner-extracted measurements is consistent with high fidelity outcomes.

Predictive value:

- A high level of expenditure is desirable so stakeholders can have the best accuracy for applications.

Flexibility:

- High expenditure is desirable here so that maximum benefit can be derived from the data collected.

Ongoing capability:

- High expenditure for this feature would only be an option if the survey delivery group was a research institution that needed to conduct ongoing projects with the scanner to amortise cost. However, the group selected to conduct the Australian Body Sizing Survey is likely to be focused on outcomes for the survey and the optimal way of achieving those as its primary objectives, requiring medium expenditure. This would be a better option for this project.

Thinking time:

- Using the expertise of others and lessons learned is desirable so that the group conducting the Australian Body Sizing Survey can conduct the project efficiently, avoid pitfalls and be focussed on the outcomes. Medium expenditure will allow the development of the Australian Body Sizing Survey to have an outcome focus taking into consideration the needs of stakeholders.

2. Defining the survey scope

In this Section we describe the approach that needs to be taken to ensure that the Australian Body Sizing Survey meets the needs of stakeholders and funders. We also outline the scope of the Australian Body Sizing Survey project and the key features of the project that need particular consideration.

2.1 Stakeholder-driven process

The purpose of the sizing survey is to obtain representative body size data for the Australian population so that a wide range of stakeholders can use this to improve what they do for, or supply to, Australians. Accordingly, the process needs to have "continuous user (customer) feedback and support from concept to delivery" (Robinette and Daanen 2003). The Australian Body Sizing Survey will require stakeholder input at the outset. This Section defines the process for developing the scope of the survey, its key parameters, and the business plan that would be used to attract funding to deliver the Australian Body Sizing Survey.

In addition, we propose a number of funding models to initiate thinking about how the necessary finance to support the survey might be raised. These are based on a user-pays model and they are outlined in Section 3.7. In summary they combine the allocation of a set number of measurements that would be determined by general consensus between all stakeholders, regardless of their level of funding contribution, with a second and larger allocation of measurements that survey sponsors can determine. The number of measures that a funding stakeholder can determine would be directly proportional to their level of contribution.

Alternatively a funding model should be considered where the Australian government funds the basic survey and a consortium of partners concurrently contribute funding to the application of the anthropometric data directly addressing their user needs. This provides a valuable verification that the proposed survey data are fit for purpose. These applications could be used to deliver useful outcomes for the partners' specific needs such as sizing, design and simulation. These outcomes are often achieved with the addition of fit-mapping and dynamic data. This funding model, which delivers an extra high usability component fits very well with Option E – see Table 6 - which is outlined later in this Chapter in Section 5.1. Value for money: usefulness versus cost.

It is likely that stakeholder engagement and consultation would take up to 18 months. The initial process to engage and educate stakeholders and then select measurements would take 6 to 9 months. An additional 6 to 9 months would then be needed to conduct the pilot project to test and finalise the method and present the results back to the stakeholder group.

2.2 Project Technical Committee

Whilst stakeholder engagement is critical to the Australian Body Sizing Survey, the complexity and technical nature of the project cannot be denied. In order to establish clear and transparent processes for the development of the technical scope of the project, the selection of measurements, the investigation into the most appropriate landmarks and scanning options would need to be informed by subject-matter experts. Thus, we propose that a Technical Committee would be established to provide technical input and act as an arbiter when technical decisions are being made. This Committee would be likely to consist of international subject-matter experts with experience and expertise in areas such as: large-scale anthropometric surveys, scanner evaluation and selection, statistical analysis, tool development, including human modelling, and so on.

2.3 Systems engineering approach

This complex project would require a multitude of iterative steps: ongoing stakeholder consultation, determination of the measures to be obtained, review and selection of a whole body scanning device, testing of the method and equipment, recruitment and training of a project team, running an initial trial or pilot survey, subject recruitment, delivery of the main survey and the processing and management of the data. To operate this project and the interactions between these components, this systems engineering approach needs to be taken.

The project would need to assemble a multidisciplinary team at the outset and adopt this approach for the planning and co-ordination of resources and logistics. Risk and quality management systems would also be applied to establish effective management systems and methods to run the Australian Body Sizing Survey project.

2.4 Focus on quality

A key feature of the level of success of previous large-scale body survey outcomes has been their varying focus on quality. Surveys that have taken a rigorous approach to establishing and maintaining quality provisions appear to have been successful. One recent large-scale national survey was not able to use the data that was collected, largely reflecting a failure to adopt quality-based procedures in the conduct of the survey.

The Australian Body Sizing Survey would embed quality-based standards and strategies within the survey. Many of these are outlined in Section 3 of this report where we describe the survey method. At the conclusion of data collection for the Australian Body Sizing Survey reviews of the process and improvements that could be made should be published, like those published after the CAESAR survey, to provide a reference for others planning this type of survey and to improve future iterations of the Australian Body Sizing Survey.

2.5 Use of standard terminology for measurements and landmarks

Standard terminology would be used for the measurements and landmarks in the Australian Body Sizing Survey. These will be based on the standardised terms used in AMI and the ISO series. AMI defines measurements in such a way that they can be output in XML format (see Section 8.3 for details). This enables integration with WEAR, rapid online searching and comparisons with other international datasets. Comparability is not limited to a simple yes or no answer to the question - are two measurement definitions the same? When using AMI two measurements can be compared side-by-side for an exact listing of differences. The difference might be small or large. For example, one definition might have the person wearing tight shorts and another definition loose clothing. If the measurement was stature this difference could be ignored. So detailed and accurate information gives the user sufficient information to make informed decisions. AMI has the added advantage of automatically creating detailed documentation and quality control. These features are critical in producing data that has comparability with international surveys and to improve the usefulness of the data to international designers who design products for the Australian market.

2.6 Assembly and training of the project team

A project team would be selected and trained to undertake the pilot project. This would involve selecting and developing a broad team of people to ensure that there are sufficient numbers to cover all roles and provide contingency for those who might leave or become unavailable during the project. This project would assist the team to develop the required expertise to undertake the Australian Body Sizing Survey project.

The recruitment of the pilot project team would anticipate the Australian Body Sizing Survey project and would involve people from different states of Australia to match the different locations that would be used for the survey.

Training of the team would be continue throughout all stages of the project to provide ongoing support for the development and maintenance of team members' skills as well as the periodic validation of their measurements to optimise inter- and intra-rater reliability.

2.7 Pilot project and testing

Once the range of measurements to be taken is finalised via the stakeholder consultation process the project method would be finalised. It would then be necessary to test the method to refine it and confirm the capability of the project team to obtain the required measures within the allocated time frame (Robinette and Daanen 2003, International Standards Organisation (ISO) 2010, Robinette, Veitch et al. 2013). The attendance time frame for subjects would have been predetermined by surveying potential participants.

To test and finalise the survey method, a pilot project would be conducted, nominally of approximately 600 people. These participants would be included within the overall project sample. This testing should be thorough and be conducted in at least 3 States to fully test the mobility capabilities of the project resources and the performance of the team.

This pilot project would be conducted independent of the Australian Body Sizing Survey project to follow and should have a separate budget. The focus of the pilot project would be to test and refine the survey system and demonstrate the quality and useability of data outputs. It would also be used to confirm the scope and budget of the Australian Body Sizing Survey project to ensure that the project is properly resourced.

The pilot would extend for 6 to 9 months. Activities would include: preparation, measurement, review, and feedback to sponsors and the stakeholder group. The project team running the pilot project would be expected to maintain their involvement and run the Australian Body Sizing Survey project.

2.8 Opportunities from advances in scanning technology

To date, whole body scanners used for body sizing surveys have predominantly used laser technology (see Section 5.1 *Quality requirements of purchase of a scanner*). Recent developments in (rapid) stereophotogrammetry technology, as provided by the new 3dMD scanner, have produced compelling advances in capture speed, resolution and image quality. These improvements are also bringing scanning towards 4-D or dynamic movement capture capability, a feature that should be considered for the Australian Body Sizing Survey if it is available. Movement capture could be used, for example, to define functional zones of arm reach as well as static body size and shape. There is potential with such a system to incorporate biomechanical data into the Australian Body Sizing Survey data. Making use of these features would place the Australian Body Sizing Survey at the cutting edge of anthropometry.

The continuing advances and capacities of scanning technology will need to be considered at the outset of the stakeholder process so these capabilities are reflected in the survey method, the range of measures that can be obtained via scans and the landmarking needed to support data extraction from scanned images. As discussed elsewhere in this report, landmarking will remain an important feature of the Australian Body Sizing Survey method regardless of the scanning technology, because it is an essential part of quality assurance and improves the useability and comparability of scanned data.

3. Selecting demographic data and survey measurements

In this Section we discuss the decisions that would need to be made about the collection of demographic data from the Australian Body Sizing Survey participants. We also discuss the measurements that would comprise the survey and the factors that would influence their selection.

Any anthropometric survey needs people as subjects; people who will allow themselves to be landmarked and scanned wearing a minimum of clothing. Whilst participation in an anthropometric survey is not invasive, it might be regarded as intrusive and it takes a moderate amount of time when conducted in a high-quality manner. Thus, it would be necessary to ensure that subjects are kept for a minimum amount of time and that there are clear protocols for the survey process. There would be limited availability of each subject within the measurement process. Historically the time taken to measure subjects ranges from 60 to 90 minutes. This timeframe can be expected to restrict the number of measurements that can be taken per subject to between 100 and 150. While this may seem like a large number of measures, historically it seems to be usual. The inherent limitations on time and the number of measures means that each measurement that is selected for inclusion in the Australian Body Sizing Survey requires justification. As a corollary, there would need to be a predefined, transparent process to “deselect” measures from a list should it grow to greater than 150 once stakeholders are engaged.

To identify a starting point for the process of selecting survey measurements, the recommendations of ISO 15535 is the most suitable reference. This standard outlines minimum data to be obtained for background or demographic data, which are: sex, date of birth, date of examination, and exam location. Specific anthropometric data are not listed as they are described in ISO 7250-1, however a standardised method of coding and recording formats for these data as well as strategies to maximise quality and to reduce measurement error are recommended. The recommended minimum demographic information and measurements to be obtained are outlined in the following sections.

3.1 Stakeholder participation and sponsorship data selection model

We propose a model for stakeholder engagement, participation and sponsorship. This encompasses consultation and a collaborative approach to determining the data and measures to be obtained while providing a clear incentive for different stakeholders to contribute reasonable funds to support the survey and enable it to proceed. The overall funding model for the Australian Body Sizing Survey project is based on generating at least 50% of the funding from the stakeholder sector and then seeking equivalent funding from the Commonwealth Government of Australia.

Several different funding models have been presented in Section 3.7 below. These define the expected level of funding required and provide a basis for further considering how the survey might be supported in partnership between the Commonwealth Government and non-government and private sectors. These models endeavour to provide a combination of broad stakeholder input to the selection of the measurements, regardless of their level of sponsorship, with the additional option of major sponsors being able to select a number of measurements consistent with their level of direct funding support for the survey.

Some measurements would be necessary to fulfil the requirements for international comparability between surveys; height and weight being absolutely essential. This would be achieved by allocating a set number of measurements that would be determined by all stakeholders on a consensus basis. If full agreement could not be reached within the group, then the decision would be deferred to the Technical Committee. This group would apply transparent criteria, which include reviewing the cost versus need and other trade-offs to finalise the selection. The remaining number, and greater proportion, of measurements would then be available for the sponsorship group. This would involve a set number of sponsorship positions being available at a range of different funding levels. In summary, this sponsorship group could select a number of measurements that they want to have included in the survey that is in line with their level of funding contribution.

The Technical Committee would consider all things that determine the number and type of measurements, and would ask questions such as: Why is it needed? How is it going to be used? How critical is it? How long will it take to collect? Can it be extracted automatically from a scan to the precision outlined in ISO and ANSUR? Does it need to be taken using the traditional methods? Can it be derived from other measurements? Could it be extracted manually from a scan at a later date (meaning the subject doesn't have to sit there while it is collected)? How much will it cost in time and money?

The Technical Committee would also help educate and provide guidance to the stakeholders. Therefore, stakeholders would derive benefit from engagement in the project by simply being part of the group. This is part of the stakeholders' value proposition.

3.2 Demographic and background data

ISO 15535 specifies the following minimum of 6 items of demographic or background data. It also recommends an additional 4 items as optional.

Minimum data

Exam/measurement:

- Location
- Date

Subject:

- Number within the survey
- Gender
- Birthdate
- Decimal age

Recommended data

- Birthplace
- School
- Occupation
- Population section or ethnicity

Other demographic data could be added according to stakeholder requirements (Blackwell, Robinette et al. 2002). These can be very diverse as demonstrated in the CAESAR survey where a balance was obtained between two of this survey's biggest stakeholder groups, the automotive and apparel industries. Examples of demographic data collected in the CAESAR survey included:

- Whether the subject is an active member of the armed forces
- Net family income
- How many children the subject has
- Model year of the car the subject drives
- Make of the car the subject drives
- A range of apparel sizing questions, some only applying to specific genders. Subjects were asked to nominate their most common sizes for shoes and garments.

Demographic and background information about a subject would most likely be collected at the outset of their measurement session. The timing of this data collection within a subject measurement session would be determined as part of the overall design of the survey method. In the CAESAR project the time allocation for subject greeting and completion of the demographic data questionnaire was 20 minutes or 33% of the total processing time for each subject. The actual time taken for these initial activities were 15 minutes, representing 29% of the total attendance duration of 52 minutes. In the Australian Body Sizing Survey, options for obtaining the demographic data would need to be developed and tested to accommodate subjects with a range of literacy skills and to ensure that the number of questions and questionnaire design deliver a consistent completion time frame. For example, some participants may be able to complete a preliminary, online survey to speed up the demographic data collection phase. If this were possible, the interview phase might be shortened to a verification of already supplied data. The actual time frame for completion would be determined during the development and testing period of the survey method.

Three main determinants of the range of demographic data collected would apply:

- The **time allocated** for this type of data collection within the overall subject attendance and measurement period and the time taken to complete the questionnaire or interview. This completion time frame would also be influenced by the calibre of the questionnaire design to provide clarity and minimise ambiguity in the questions.
- The **range of demographic data requested by stakeholders** and the prioritisation of these data to establish an ordinal list. The final selection of these data for the survey would be determined by a combination of the allocation of a fixed number, nominally 10 of these questions being determined by stakeholder consensus and the remaining questions being determined by stakeholders according to their level of project sponsorship – essentially giving those making the greatest financial contribution a greater opportunity to nominate demographic questions most relevant to their needs. The balance of how many questions within the demographic questionnaire that would be available would be finalised prior to the stakeholder engagement process.
- The **value of the demographic data to the Australian Body Sizing Survey** as a national resource for use by a wide variety of designers. Careful consideration would need to be applied to the selection of demographic data to ensure that the aims of the project were primary and not subsumed to stakeholders' or others' commercial interests that could use other surveys to obtain this information.

3.3 Measurements

While the survey should aim to obtain between 100 and 150 body measurements, only two measurements for each subject are recommended as a non-negotiable minimum for the survey. These are:

- Stature (standing body height)
- Weight

All other measurements to be included in the survey would need to be determined by the stakeholders during the consultation process with input from the Technical Committee as outlined in Sections 2.2 and 3.1.

To the reader of this report stipulating only two measures as mandatory may seem to be insufficient. This is not the case and instead should be seen as the starting point of a process that provides maximum opportunity for stakeholders to think about their needs and then have input to identify the measurements they want or need to be included in the survey. This model provides substantial scope for stakeholders to engage with the survey and influence its overall "shape". The survey Technical Committee would assist stakeholders to separate their needs from what they would like as part of the facilitated process.

A method of managing this process would be to establish fair guidelines, including a prioritisation and justification table for measures and, consequently, the landmarks needed to obtain those measurements. Table 2 below indicates how such as list could be used to justify and prioritise measurements.

Measurement (number and name)	Geometric or palpated	Why is it needed? (examples)	Priority rating (1= highest, 5= lowest)
1 – Standing head height	Geometric	For ISO comparison	1
23 – Hip breadth (sitting)	Palpated (flat sticker)	For CAESAR comparison	1
31 – Knee height (sitting, right)	Palpated (raised sticker)	For segmental axis system	2
Etc	etc	etc	Etc

Table 2: Example of a landmark justification table

The rationalisation would be progressively developed during consultation with stakeholders and in preparation for the Australian Body Sizing Survey project. This approach places great importance on stakeholder engagement to maximise inclusion and opportunity to establish a range of measures that are useful and present good value to sponsors while educating them during the process.

The measurements selected would be obtained by a combination of traditional measurements and 3-D scans using at least three scans of different body positions. Additional measurement options would include different postures (ie. not standing or sitting) and the inclusion of 4-D (dynamic movement) measurements if this capability was available at the time the Australian Body Sizing Survey was conducted.

However, we appreciate that listing only two measurements will not serve as a sufficient prompt for stakeholders to understand the measurement process, the range of measurements that could possibly be taken, how they could be used in design, and how to identify the ones that would be most useful to them. Stakeholders would need to be educated in contemporary approaches to anthropometry, the types of measures that can be obtained, how they are obtained and how they can be used to drive design processes.

A testing process to accompany the selection of measurements would be required. Which combination is the fastest? How do measurers compare to themselves and others in the team? How can we make the poses exactly the same each time? Can we replace a traditional–style measurement with a scan-derived one to reduce cost and improve speed? Questions such as this will be iterative and will inform the ongoing discussion with the stakeholders.

The alternative to a stakeholder-driven process for measurement selection would be the determination of the list of measurements by the Technical Committee in consultation with a smaller group of stakeholders. Using this model, selections would be based on establishing an overlap with ISO and CAESAR datasets as well as determining additional measurements on a best-estimate basis. This process would need to be adopted with caution as it may be perceived to limit stakeholder input and therefore reduce the value to stakeholders.

3.4 Examples of anthropometric measurements

The ISO standards and previous surveys, such as CAESAR, have defined standard postures, landmark references and 1-D, 2-D and 3-D measurements that are obtained by traditional style measurements and 3-D scanning.

These data and how they are used in raw form and within extended analyses to guide design processes would be conveyed to stakeholders in training and education presentations. Examples of measurement postures, the range of traditional measurements and 3-D whole body scanning landmarks are outlined in Figures 2 - 6 below. These have been obtained from the ARIS database (World Engineering Anthropometry Resource 2013).

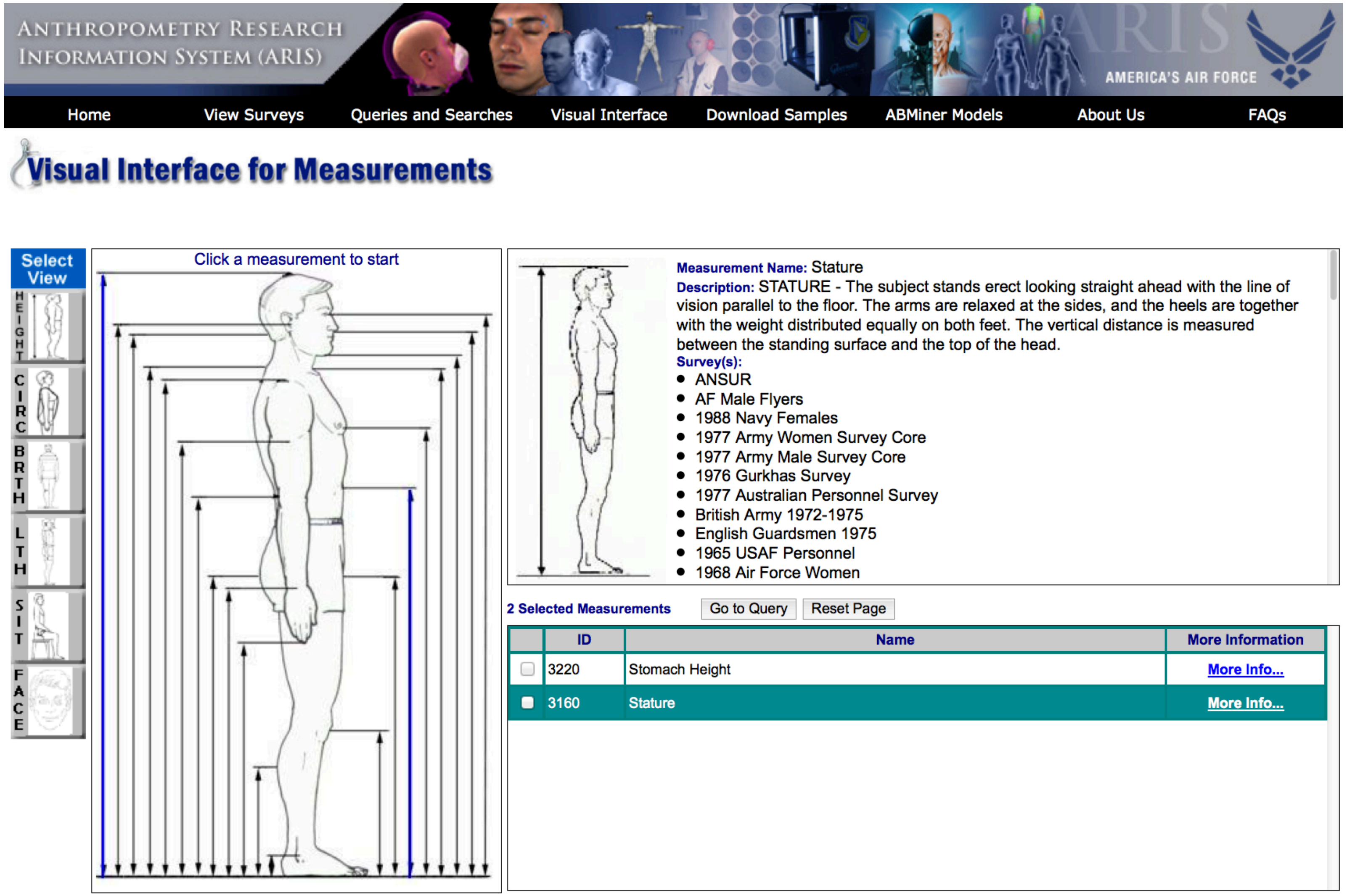


Figure 2: Examples of height measurements (Source ARIS)

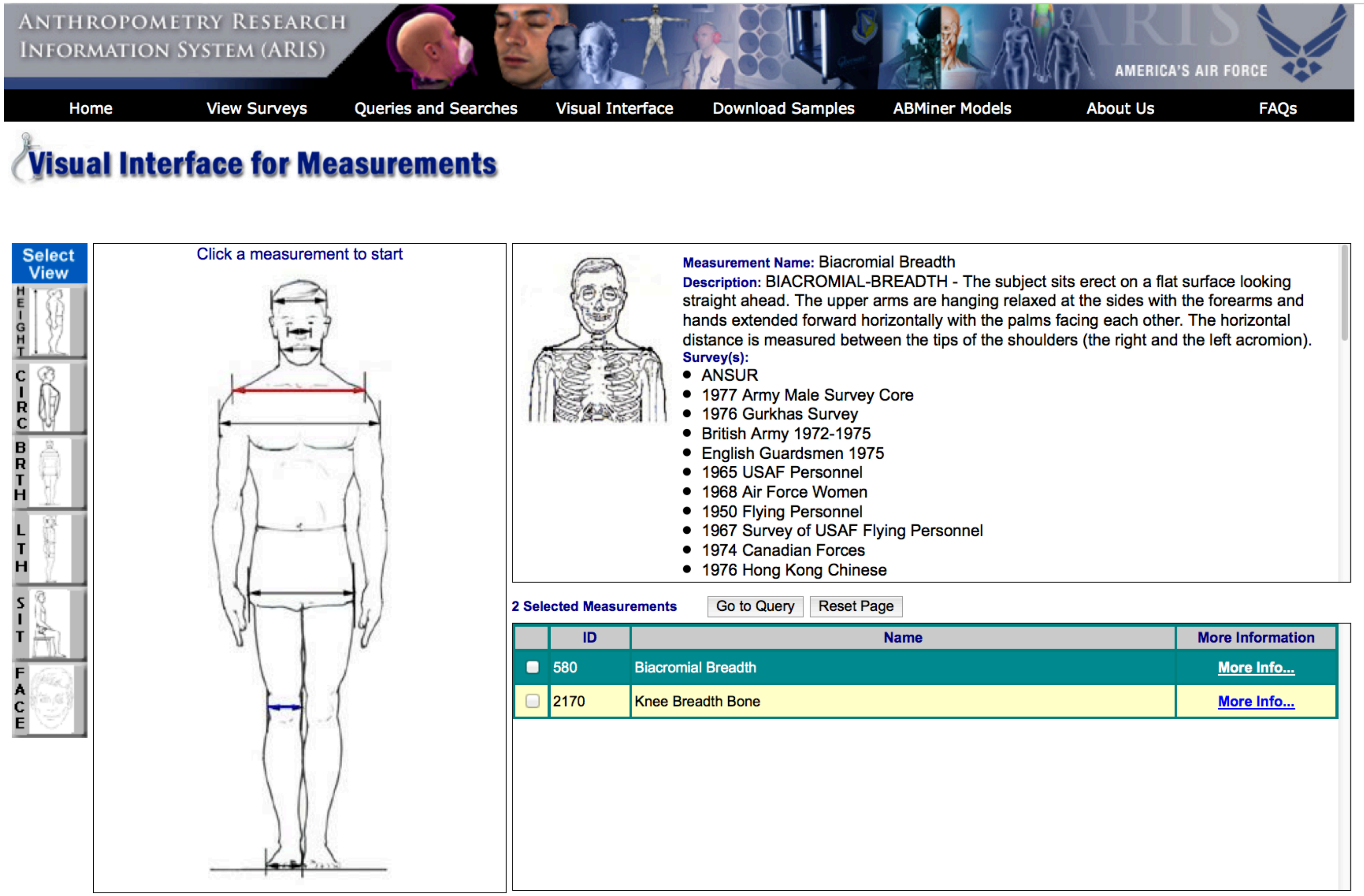


Figure 3: Examples of point to point measurements (Source ARIS)

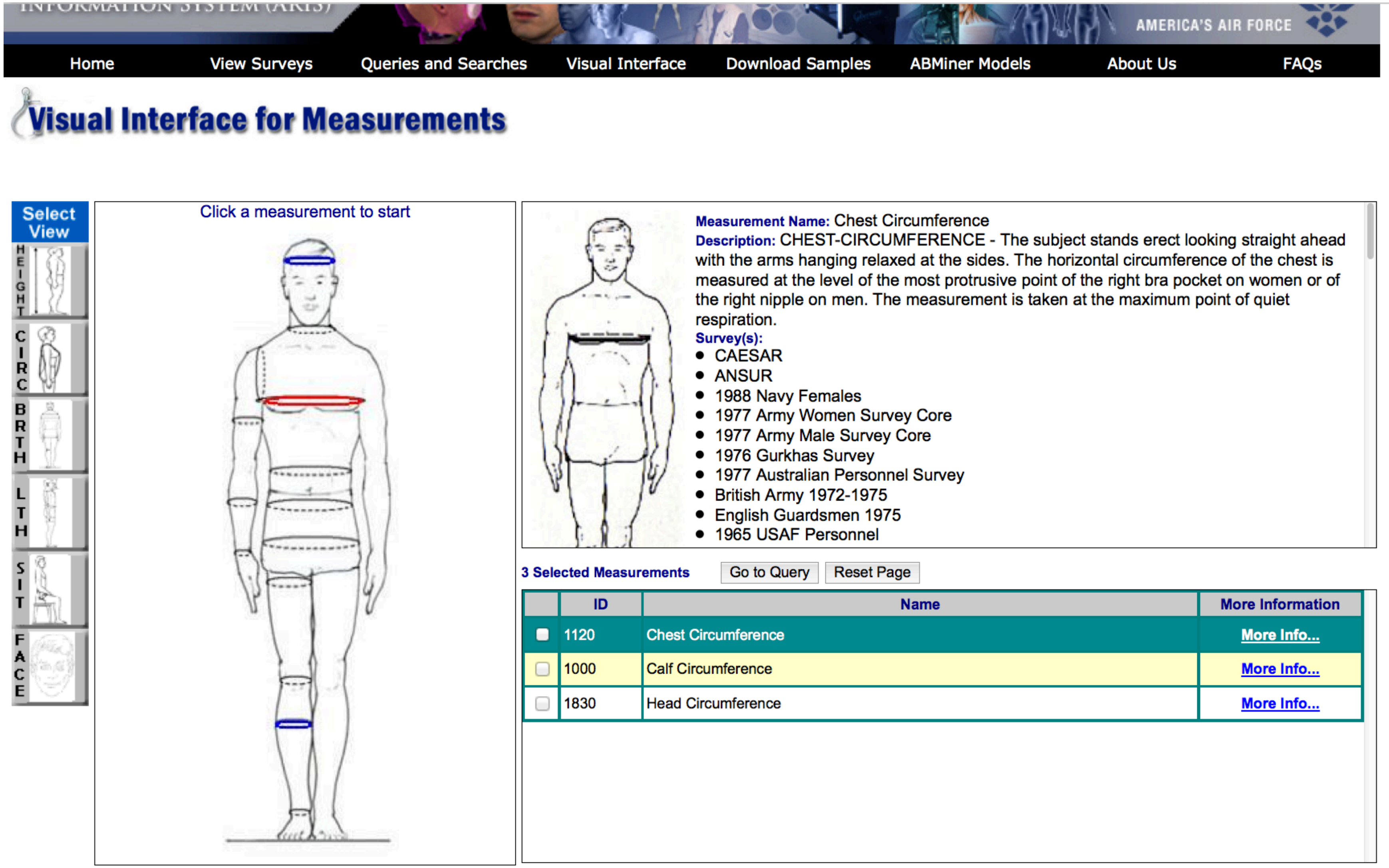


Figure 4: Examples of cirumferential measurements (Source ARIS)

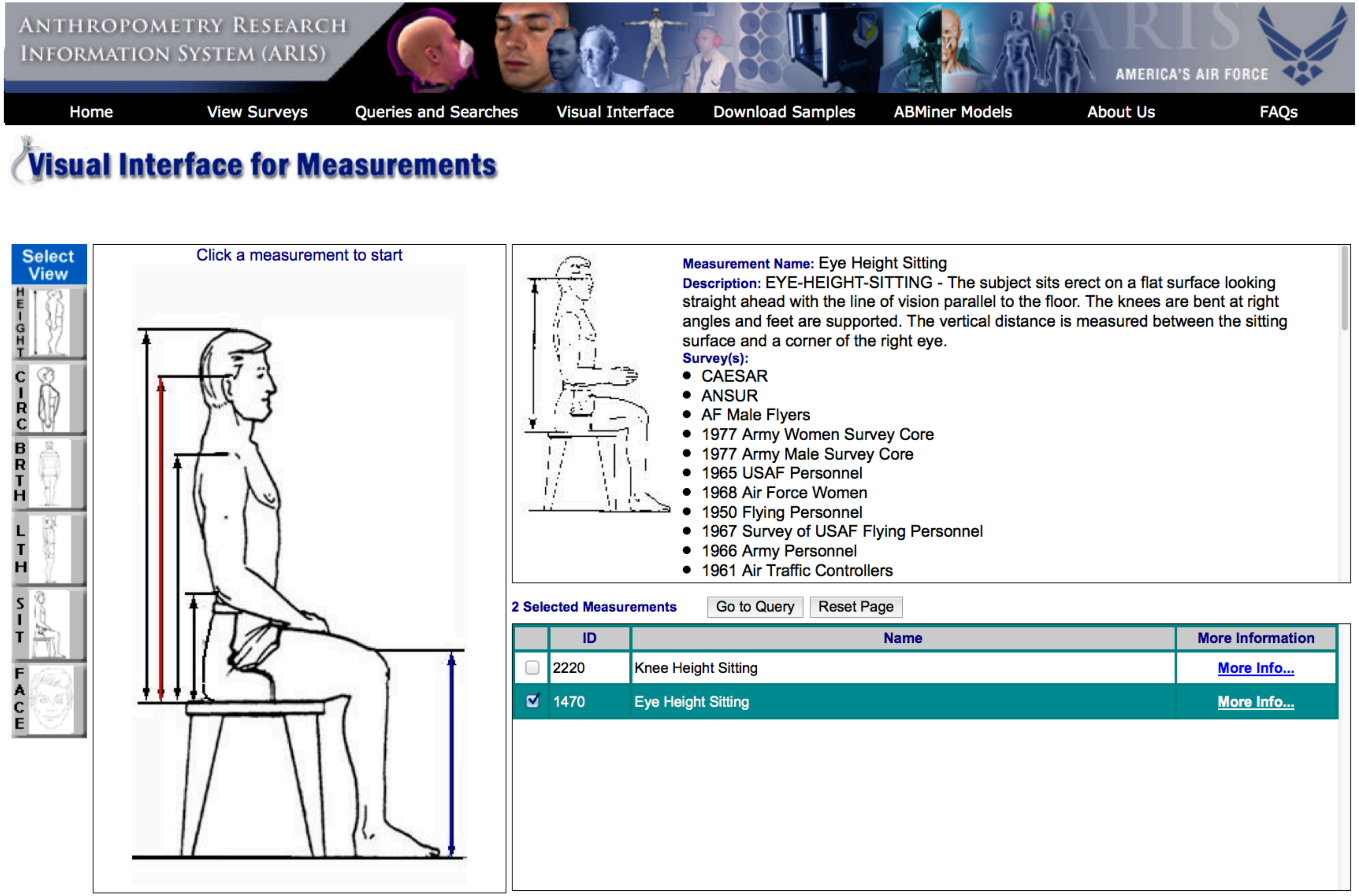


Figure 5: Examples of sitting height measurements (Source ARIS)

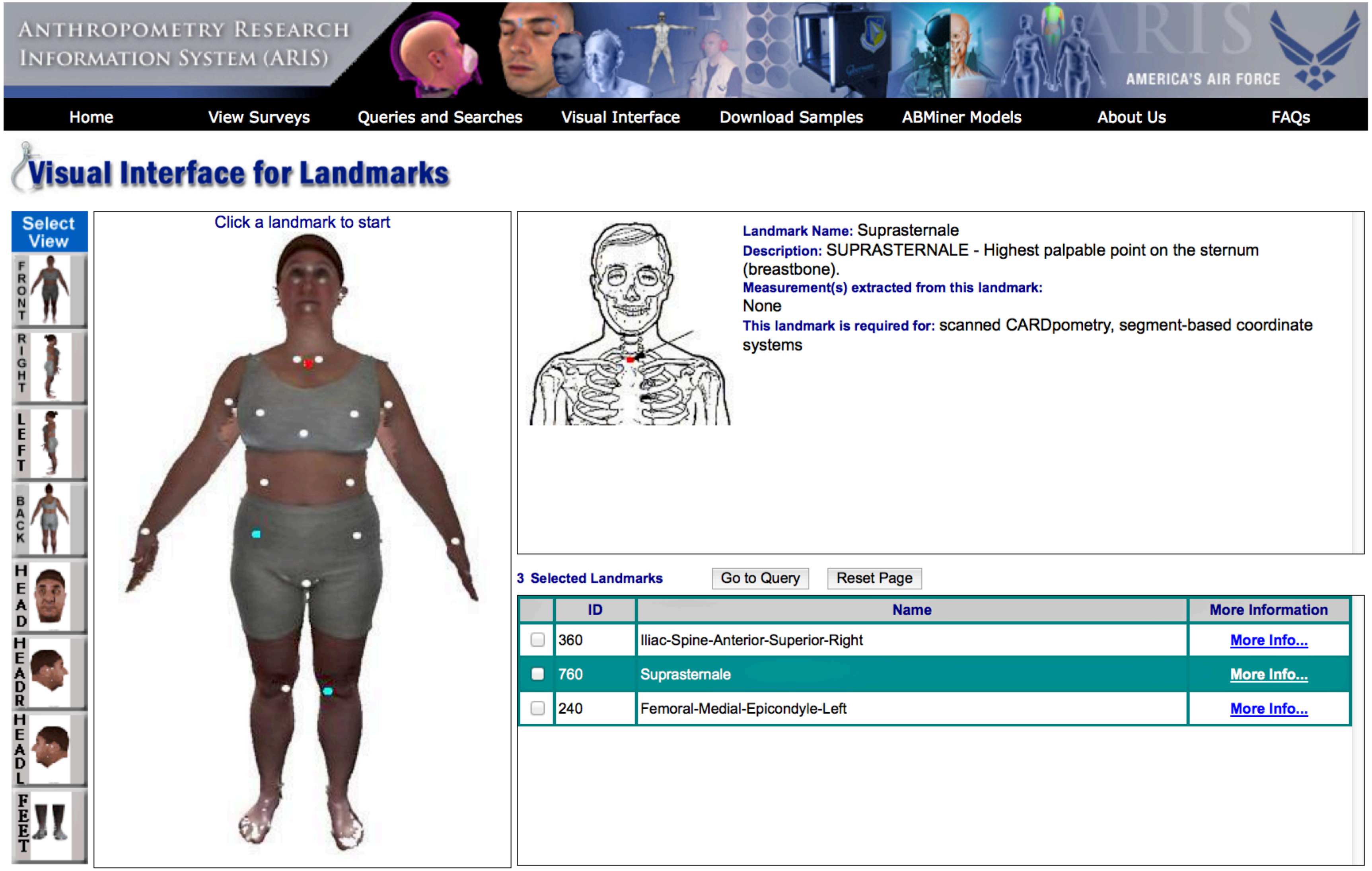


Figure 6: Examples of landmarks for a scanned image(Source ARIS)

3.5 Landmarks

Once the list of measurements to be obtained is finalised, the landmarks that are needed to enable these measurements to be obtained would be finalised. Landmarks are placed in specific anatomical locations to give measurement locations which improve the accuracy and precision of measurements extracted from scanned images (Robinette and Daanen 2006, Veitch 2012). Strategies such as providing set numbers or packs of landmarks per subject can be effective to minimise error (Robinette, Blackwell et al. 2002). Landmark positioning is an important element of assessor training to ensure accuracy, consistency and to reduce inter- and intra-rater placement error.

Landmark types will largely depend on the detection capabilities of the whole body scanner. This would be predetermined by testing and during the final selection of the survey scanner. Indeed, this specific feature of the scanners being reviewed would be one of a number of evaluation criteria.

Figure 7: Examples of landmarks on the subject and how they appear in the scanned image (Cyberware)(Source Veitch)

Two different types of landmark devices are likely to be used. One a flat disc sticker shown in Figure 7, and the other a pyramidal shape shown in Figures 8 and 9.

Figure 8: Pyrmidal landmark

Figure 9: Landmark applied to Metatarsal-Phalangeal-1-Left

3.6 Stakeholder education

With only two measures being defined as mandatory and the remaining measures to be determined by stakeholders, the stakeholder engagement and consultation process would need to start with an extensive education program. This would involve providing initial information to prospective stakeholders to help them determine if the Australian Body Sizing Survey is of interest to them and then running an educational program as they become interested and engaged.

The development of these marketing and information resources would occur at the outset of the stakeholder engagement process to ensure they are in place to support the promotion of the Australian Body Sizing Survey. This information would provide details about contemporary anthropometry in order to develop a common understanding about body size data, how it is obtained and how it can be used. It would be important to emphasise the availability and use of 3-D data to assist stakeholders to update and extend their knowledge beyond the use of 1-D data and percentiles, and to establish a clear understanding about how they could benefit from advances in the field and the data that would be derived from the Australian Body Sizing Survey.

The initial information would be disseminated via a range of different media and it would overlap the initial promotional material and marketing campaign seeking stakeholder involvement in the survey. This information would also be used during the subject recruitment phase of the project so prospective subjects are well informed about the survey, what their involvement would require and the benefits to be obtained for Australians. These media could include:

- Development of packages of promotional and educational information.
- Distribution via conventional media, such as print, radio and television.
- Electronic distribution via social media, stakeholder networks, professional, employer, industrial, and community associations and educational institutions.

Detailed training packages would be developed and presented directly to stakeholders. They could also be made available electronically as podcasts and for webinar recordings. This training would involve a series of presentations that would cover:

- Basics of anthropometry
- How anthropometric data are obtained
- Contemporary tools and uses of body size information to influence design
- Future directions in anthropometry and using body size information for design
- Case studies on successes stemming from the suitable use of anthropometry as well as those illustrating the limitations or failures because of the absence or poor use of body size information
- How the Australian Body Sizing Survey would work and how stakeholders can become involved in the process.

3.7 Determining the survey funding model relative to stakeholder engagement

The process to identify, select and prioritise measures to be included in the survey would stem directly from the funding model that is adopted. While it was not a requirement for this current project to define the budget needed to run the survey, it has become apparent during the project that the stakeholder engagement process would be intertwined with the method of funding the survey.

With this in mind, three funding models have been developed. We intend that that these act as a basis for a conversation between SWA and other possible major interest groups so that the funding pathway is considered up front and is developed prior to the commencement of the stakeholder consultation process. If the funding model is not developed prior to the stakeholder engagement, then it will not be possible to work with any surety with the stakeholders about the capacity of the project to proceed and deliver the expected outcomes. This would be a major risk to the overall project that should be eliminated at the earliest point.

The general approach taken in developing these funding models has been to combine the capacity for all stakeholders to equally engage and have a say in determining “foundation” measures that will be obtained within the survey with a user-pays component. Those who are likely to derive greatest gain from the survey should contribute financially and they would able to nominate a certain number of measurements relative to their level of sponsorship.

Three broad funding models are proposed. The first two of these are based on a government and private sector partnership. It would seek a 50% (indicatively) contribution from the non-government and industry sectors, with the goal of that funding being matched by the Commonwealth Government. This model is based on previous research and development funding partnerships that have used this approach to support industry improvement. The third option proposes that the Commonwealth Government fund the survey and that stakeholders fund the use and further development of applications that utilise the data.

1. The first model maximises engagement of all stakeholders in the measurement process by allocating a set number of measurements (indicatively 30) for selection via consensus. This would leave the remaining number of measures (70-120) available for sponsors to nominate. A package of sponsor options would be available to match the number of measures they wish to nominate.
2. The second model seeks a more equal level of engagement across sponsors where all would pay an equal share and be able to select an equal number of measurements. This would be 2 or 3 depending on the size of this pool and the level of funding that needs to be raised. In this model a core number of measures would still be preserved to ensure that all stakeholders, regardless of their ability to fund the project, are able to have a voice at the table to determine these measures.
3. The third model proposes that the Australian government funds the basic survey and a consortium of stakeholder partners concurrently contribute funding to the user applications which specifically apply anthropometric data to get immediately useful outcomes. This fits with Option E in Table 6 and this model seems to be the best fit with the overall desire for this project to a national infrastructure project that delivers a data resource that can be used for the national good.

All funding models embed involvement of all stakeholders in the process while developing different mechanisms of raising funds to conduct the survey. We acknowledge that other types of sponsor support may be sought or offered. These would include the provision of in-kind resources during the survey such as use of facilities, manufacture of scanning garments or the provision of inducements and incentives for subjects. These would have to be included with a sponsorship package to maximise the different levels of value that can be offered by stakeholders.

3.8 Process and criteria for selecting and prioritising measurements

As previously stated, stakeholders would drive the selection of measurements. While two funding models for stakeholder engagement that would provide a financial basis to run the survey have been proposed, both use the same basic structure relative to the selection of measurements. This structure involves:

- Allocating a minimum number of measures that would be selected and prioritised by all stakeholders involved in the process, using a consensus approach. This component of measurement selection will guarantee broad representation for all stakeholders irrespective of the resources they can bring to the process. A nominal number of 30 measurements have been selected. This could increase if the survey method is able to obtain a higher number of measures, such as 150, or if broad consensus was obtained on a higher number of core measures. This number would also be influenced by the number of measures that would be allocated to stakeholder sponsors and total funds that can be raised relative to those needed to deliver the survey. If a higher number of sponsor-selected measures is needed, then a lower number of preserved measures may only be achievable. However, a minimum of 30 is recommended to provide opportunity for all stakeholders to influence the selection process.

- The remaining measures would be allocated to sponsoring stakeholders. It expected that this would be at least 70 measures and could increase in line with the overall survey capacity to obtain measures. The two sponsorship models outlined in Section 3.7 propose different models that are either equitable in the distribution of measures that can be selected by all sponsor stakeholders or use a market-driven approach where the number of measures that can be selected is proportional to sponsorship contribution (including in-kind contributions).

The key reasons for inclusion are expected to be:

- Compatibility with the ISO dataset
- Compatibility with the CAESAR dataset
- Use for body segmentation and post-measurement analysis of 3-D scans and data
- Use for seated reach values

This process to identify and select the broad stakeholder group of measures would be facilitated by the project team and overseen by the Technical Committee. As measurements are nominated they would be described and recorded as per the ISO recommendations and other requirements such as compatibility with CAESAR measurements. They would be recorded in a list along with the rationale for their inclusion and their expected value to the survey.

This process would combine input from stakeholders about why they want this measurement with technical input about the value of the measurement. Two different levels of priority rating, one from each group would be generated. These ratings would largely represent perceived or expected usefulness of the measure.

These scores could be combined to create a general rating of priority. Where both groups rate a measure as a top priority, that measure would be given a top priority for inclusion. Where these scores vary between the two groups the general rating score would be used to establish a priority rating for all measures. Once the list is finalised, if the number of available allocations exceeds the number of requested measures the consensus process would be applied to achieve a decision. If it were not possible to reach consensus, the matter would be referred to the Technical Committee for review and representation for consensus or for a final decision to be made about its inclusion.

The project team would also facilitate the process of sponsor stakeholders nominating their preferred measures. The same rating system would be applied to establish an objective view about the likely usefulness of each of these measures, but the selection process would largely rest with that stakeholder.

If a sponsor nominated measures that did not seem to make sense, then the project managers and/or Technical Committee would work with them to understand their needs and expectations. If the rationale justifies the measures then their choices would prevail. If they do not, then they would be provided with further support to ensure that their choice reflects their needs. In this case they would either change or retain their selection. Only in an extreme situation would a stakeholder be asked to change their selection. This would require a critical and objective review of it to be presented to them for their reconsideration.

Where two different sponsor stakeholders select the same measure they would both be included in the survey and occupy one of each sponsors' allocation. That is, measurement selection between sponsors would be mutually exclusive.

Some flexibility within this process would be required as it will only be possible to progressively establish the actual number measures that can be included via the method testing that will occur in conjunction with the selection process.

It would be critical to walk stakeholders through the measurement process to ensure that they understand the need to prioritise measurements. The benefits of education in anthropometry and collaboration with other stakeholders within this process should be highlighted as one the main benefits for participants.

The true total number of measures that can be obtained in the survey, and therefore the allocation between the two different groups of stakeholders, will not be known until:

- The capacity to accurately and consistently extract dimensional data from the scanned images is known as this may reduce the overall number of measurements obtained using traditional methods.
- The durability of subjects with regard to how long they will be prepared to attend and participate in the different elements of the survey.
- The "demand" for measurements by stakeholders.

4. Stakeholders consultation process

The objective of the process of stakeholder identification and engagement is to define the process of developing the business plan with stakeholders that would define the range of measurements to be collected within the Australian Body Sizing Survey. This proposed process is outlined in this Section. It is predicated on the early identification and engagement of stakeholders in the process.

4.1 Establish a project platform for the stakeholder engagement process

The scoping of the Australian Body Sizing Survey to finalise the method will require the initial engagement of one or more overarching stakeholders. These stakeholders would fund and support the scoping project.

Within the context of this current project with Safe Work Australia (SWA) as the sponsor, this could involve SWA extending their support to the incorporate the stakeholder engagement project. However, limiting the scope and stakeholders of this project to the work health and safety realm would limit the breadth of stakeholders available and would require funding to be generated within that realm. Expanding the scope of the Australian Body Sizing Survey to include other stakeholder groups, such as health, the apparel industry and non-work-related design industries, would increase the stakeholder range and expand the resource pool for funding. It would however, introduce greater “competition” within the process to finalise the range of measures to be taken. It may also introduce new requirements for sampling where sub-groups within or beyond the mainstream workplace sampling group might be targeted.

Whatever the model that the stakeholder engagement project takes, the process of accommodating the needs of stakeholders and including their measurements would need to be predictable, fair and equitable.

The confirmation of the sponsors and the allocation of budget, performance criteria and time frames for the stakeholder engagement process would establish the platform and service provider(s) and enable the project to proceed. For the purpose of this report we have retained a focus on work health and safety stakeholders and SWA being a key sponsor. Other stakeholder groups could be engaged and consulted on the basis of the method outlined in the remainder of this Section. This approach could also enable stakeholder groups to be identified and approached in waves, although their early engagement in the process would be optimal.

4.2 Identify stakeholders

Stakeholders can be expected to have a range of different types and levels of interest in the Australian Body Sizing Survey which will drive their level of involvement and support for the survey. These would not be determined until the stakeholders were approached. Other stakeholders would be targeted relative to their likely role as participants. Flexibility in how stakeholders are bought together will need to be maintained to enable groups with common interests to collaborate and co-ordindate their involvement and consideration of measurements that are most relevant to them.

The first step of the Australian Body Sizing Survey project would be to consolidate the type and range of sponsors that would be approached and then identify the specific stakeholders within these groupings. As outlined in Section 7.3.1 of the literature review, one method of categorising stakeholders can be according to how they are likely to interact with the survey data. Four classifications were proposed:

1. Data: 1-D, 2-D, 3-D
2. Database Systems

3. Applications
4. Consumers

These categories are expanded below.

4.2.1 Data: 1-D, 2-D, 3-D

The following stakeholders with a focus on the data would include:

1. National Measurement Institute
2. Australian Bureau of Statistics
3. CSIRO
4. Human Factors and Ergonomics Society of Australia
5. Scanner manufacturers
6. Others as identified

4.2.2 Database systems

The following stakeholders with a focus on database systems would include:

1. Tool developers such as visualisation-software, DHM, statistical analysis and fit-mapping software.
2. Universities, particularly those with a focus on work health and safety, Human Factors and Ergonomics or design (eg. Central Queensland University, University of NSW, VIOSH at Ballarat, La Trobe University, University of Queensland, Curtin University).

4.2.3 Applications

The stakeholder group most likely to benefit from applications of the survey data is the largest of all stakeholder groups. Tables 3 and 4 would be populated to include the widest possible range of stakeholders including representation from:

1. Federal government
2. Safe Work Australia
3. Comcare (Federal WHS regulator)
4. State governments
5. State government WHS regulators
6. Standards Australia
7. Industry bodies (see table 3 below)
8. Industry organisations (see table 4 below)
9. Suppliers (see list below)

Suppliers of equipment and resources that are used for safety purposes and/or have products that will be enhanced by the application of body survey data. These will include:

- PPC/E manufacturers and suppliers
- Built environment providers, such as architects and designers
- Vehicle builders
- Equipment manufacturers and suppliers.

Industry	**Government**	**Industry Body**	**Union**
General		AIG	ACTU
Specific			
Agriculture, Forestry & Fishing			
Mining			
Manufacturing		AIG	AMWU
Electricity, gas and water and waste services			
Construction			CFMEU
Wholesale trade			
Retail trade			TCF, SDA
Transport, postal and warehousing			
Accommodation and food services			United Voice
Information media and telecommunications			
Financial and insurance services			
Rental, hiring and real estate services			
Professional, scientific and technical services			
Administrative and support services			
Public administration and safety			
Education and training			
Health care and social assistance			
Arts and recreation services			
Other services			

Table 3: Some examples of industry bodies as possible stakeholders per ANZSIC codes

Industry	Example of Possible Industry Organisation
Agriculture, Forestry & Fishing	
Mining	Multi-national mining firm
Manufacturing	National manufacturing firm
Electricity, gas and water and waste services	
Construction	Large construction firm
Wholesale trade	
Retail trade	
Transport, postal and warehousing	
Accommodation and food services	
Information media and telecommunications	
Financial and insurance services	
Rental, hiring and real estate services	
Professional, scientific and technical services	
Administrative and support services	
Public administration and safety	
Education and training	
Health care and social assistance	Private and public health service providers
Arts and recreation services	
Other services	

Table 4: Some examples of industry organisations as possible stakeholders per ANZSIC codes

Industry organisations, predominantly larger employers or services providers, would be targeted as a separate but parallel group of stakeholders in a tripartite manner. Relevant stakeholders would be sought across these industry categories to maximise inclusion and ultimately the usefulness of the Australian Body Sizing Survey data.

4.2.4 Consumers and community

In a WHS context it is expected that the consumer stakeholders would be mostly represented by industry bodies such as unions and employers. Individual consumer groups have not been included but could be if relevant groups were identified. Similarly, particular community groups may be regarded as stakeholders, particularly given that they may be able to assist in encouraging participants from particular ethnic groups to take part in the survey.

4.3 Develop the resources needed for the stakeholders engagement process

The steps that need to be taken prior to this process would include:

- Recruitment of the project team.

- Recruitment of the Technical Committee.
- Review and selection of the 3D scanner to be used in this project.
- Initial testing of the scanner to determine its capabilities and the capacity to maximise the user of scanned data to minimise (not eliminate) the use of traditional measurement. Testing to validate set up and pack down logistics, speed and flexibility of data acquisition, data quality and data management (see Section 5.2 re scanner selection criteria).
- Confirmation of the marketing strategy.
- Development of marketing information.
- Development of information and training references.
- Development (purchase and set up) of a stakeholder management database system.
- Establishment of a stakeholder engagement schedule.
- Consolidation of the stakeholder target list.

4.4 Engage stakeholders to develop the project scope

The following sequence of activities is proposed to facilitate the engagement of stakeholders for the Australian Body Sizing Survey.

4.4.1 Complete preparations

The following elements would be completed to prepare for this process:

1. Confirm the intended scope of the survey with regard to any involvement from other stakeholder groups such as health, apparel or the military.
2. Prepare reference and educational materials that will be used during stakeholder meetings. See Sections 3.6 and 4.3 for the development of information, education and other stakeholder engagement resources.
3. Survey potential subjects to determine their acceptance threshold to participate in the survey with regards to:
   a. Willingness to allow their scans to be incorporated into the Australian Body Sizing Survey (that is, providing informed consent).
   b. Willingness to travel to the survey site.
   c. Preparedness to wear the scanning garments during the measurement.
   d. Willingness to provide demographic data.
   e. How long they would be prepared to be involved in a measurement session.
   f. Any special needs that they might have to support their participation in the survey.
4. Evaluate and select the 3-D whole body scanner and test it to determine its capabilities and any limitations.
5. Confirm the initial range of measures to be obtained in the survey, as the starting point.
6. Confirm stakeholder funding model(s) to be used.
7. Confirm measurement selection process to be used.
8. Prepare stakeholder surveys that will be used to elicit and record stakeholder feedback.
9. Develop the information mechanisms used within and to support for the process. Such as the stakeholder management database system and how records of stakeholder engagement will be maintained and publicised.
10. Develop and consolidate the database of stakeholders to record stakeholder details such as ANZSIC classification, profile, basic details, contact details, type and level of interest and engagement as a project stakeholder. Records of contact activities and outcomes with each stakeholder would be recorded within this project management database.

11. Prioritise the list of stakeholders in collaboration with the project sponsors (SWA and others as relevant).
12. Establish a schedule of stakeholder meetings in each capital city. These would be used to launch the project and stakeholder engagement process in each State.

4.4.2 Commence stakeholder involvement

1. Stakeholders to be contacted according to listing information and geographical location and invited to participate in a state/territory-based meeting to launch the project.
2. Initial contact with stakeholders would be made to determine their initial level of interest.
3. Information provided to assist stakeholders familiarise themselves with the subject matter.
4. Commence stakeholder meetings with introductory and education meetings.
5. Commence the stakeholder engagement process.
   - Make initial contact
   - Lobby major stakeholders to commence the process. Initial focus on likely funding bodies.
   - Run stakeholder meetings and training sessions
   - Segment stakeholders into groups with common interests and themes to maximise potential for interaction and like-mindedness and to pick up on the CAESAR outcome that stakeholders reported key benefits from the collaboration stemming from stakeholder meetings.
6. Continue and extend the stakeholder engagement process
7. Consolidate the scope of the survey (ie. define what will be measured and how) to develop the business plan for the survey.
8. Develop, consolidate and finalise the survey method and data storage.

4.4.3 Select measurements and finalise the survey method

1. Test the survey method and revise as required via stakeholder involvement as part of the process of finalising the measurements (and surveyed demographic data).
2. Engage with and support stakeholders in the measurement selection process.
3. Critically review measurements via the process outlined in section 3.8.
4. Finalise the measurements and demographic data that will be obtained in the Australian Body Sizing Survey.

4.4.4 Test the survey method with a pilot study

1. Undertake a pilot test to fully evaluate and revise the method (see Section 2.6 for details).
2. Consolidate results.
3. Provide feedback to stakeholders.
4. Revise the method if required.

4.5 Finalise the stakeholder input to define the survey scope and method

Once the details of what will be measured and how these measurements will be obtained the design of the survey method will be finalised. This will form the basis for the scope of the Australian Body Sizing Survey. A business plan will then be developed to define how and when survey would be conducted and the resources and funds required to deliver it.

Once the business plan is completed and submitted to stakeholders the other funding partners would be secured to finalise the plans for the Australian Body Sizing Survey. With the final funding and time frames are finalised the next phase, conducting the survey, would commence. Stakeholder consultation would continue during the survey and until it is completed and the last elements finalised.

5. Measurement technology options

Measurement technology, in particular the choice of scanner to be used to conduct the Australian Body Sizing Survey, represents a crucial decision-making point in the design of the method and scope of the survey. This Section canvasses the means by which measurement technology decisions might be reached. Necessarily this Section requires a level of technical detail to support the arguments contained within it.

5.1 Value for money: usefulness versus cost

Various combinations of the use of traditional style measurements and scanning technology could be used to conduct the Australian Body Sizing Survey. The choice of approach would depend largely on the reason for conducting the survey and the intended use of the data. Clearly, if the survey data are to be used for design purposes, then high quality data that can be interrogated and that are compatible with international surveys is highly desirable. Here we consider value for money as expressed by the relationship between usefulness and cost.

An overall approach to the various combinations of use of traditional style measurements and scanning technology can be represented in a matrix where the Y—axis has Predictive Value (the usefulness of the data) and the X—axis has Cost of the Survey. Predictive value means the ability to accurately predict who will fit into an equipment environment under various conditions. It has two components, both concerning the ability to predict. High predictability also has two components as outlined in Table 5 below.

Predictive value components	High predictability components
1) for the population of people and equipment and/or built environments sampled,	1) 3-D surfaces and postures including seated poses,
2) beyond the people and equipment and/or built environments sampled.	2) fit mapping of environments/apparel with actual subjects, and 3) must have measuring accuracy as defined for anthropometry – approx. 10mm (International Standards Organisation (ISO) 2008, International Standards Organisation (ISO) 2010)

Table 5: Matrix of the predictive value of the survey data versus the costs to conduct the survey

Table 6 summarises five options (A, B, C, D and E) that are explored below. B and E are the preferred options. The pros and cons of each option are presented in the text following Table 6.

		Matrix of Technical Solutions showing different possible approaches		
Ability to accurately predict future body shape and size	Extra High			E. Buy best current technology equipment, Calipers and Tapes. Collect 1-D and 3-D. 100 landmarks, 100-150 1-D measures from scanner and traditional-style as per testing, scan in standing and seated poses. Conduct fit-mapping/ accommodation study with stakeholder/partners, collect 4-D dynamic data to facilitate new DHM with stakeholder/partner input.
	High	A. Lease all equipment including scanner and software. Collect 1-D and 3-D. 100 landmarks, 100-150 1-D measures from scanner and traditional-style as per testing, scan in standing and seated poses.	B. Buy best current technology equipment, Calipers and tapes. Collect 1-D and 3-D. 100 landmarks, 100-150 1-D measures from scanner and traditional as per testing, scan in standing and seated poses (like CAESAR).	
	Low	C. Buy or lease scanner like TC2 scanner(s). Automated 1-D measurement extraction. 100-150 1-D measurements (like Size UK, Size USA).	D. Buy calipers and tape measures with PC data entry, (no scanner). 100-150 1-D measurements.	
		Low	Medium	High
		Expenditure		

Legend: Future Capability: Low = Yellow | High = Green

Table 6: Matrix of the technical solutions and approaches to run the survey

A. Leasing of Best Current Technology Equipment: High Precision, Low Cost, Low Future Potential Anthropometry Survey:

Tools:

- Scanner leased from supplier,
- Calipers and tape measures leased or borrowed.
- Integrate® software (free) and landmark markers.

Immediate Data Products:

- 100-150 1-D measurements with precision within the 10 mm limit
- 100 3-D landmarks with precision within the 10 mm limit
- automated and manual data editing and measurement extraction with precision within the 10 mm limit

Pros:

This solution provides 3-D models of all subjects in the survey. These data would be the most accurate possible with current technologies. The costs are low because the expensive equipment is borrowed. The tools could be purchased later if necessary and perhaps a more advanced technology might be available at that time.

The use of the ISO 20685, 7250 and AMI would allow data collection to be done with an existing data collection protocol and a small data collection team. This would further minimise labour costs.

Cons:

With borrowed equipment is the potential for the future is minimal. The Australian companies would have the knowledge and methods for a future capability, but not the tools. This option is dependent upon getting a large amount of money to fund a follow-on study to make the survey useful in the long-term. There would be some future potential for the data obtained because: 3-D models permit re-evaluation based upon new fit criteria and extraction of almost unlimited new kinds of dimensions, such as body segment masses and moments of inertia. However, one of the biggest advantages of 3-D scanning is the ability to measure the relationship between the body and the equipment worn, which cannot be done with traditional tools.   Therefore, this option will have limited ability to examine human system integration options for future systems.

B. This is one of the Preferred solutions: Purchase of Best Current Technology Equipment: High Precision; Medium Cost; High Future Potential

Tools:

- Best Current Technology Equipment, anthropometer, calipers and tape measures all purchased.
- Integrate® software (free) and pre-marked landmark markers.

Immediate Data Products:

- 100-150 1-D measurements with precision within the 10 mm limit
- 100 3-D landmarks with precision within the 10 mm limit
- automated and manual data editing and measurement extraction with precision within the 10 mm limit

Pros:

This solution provides 3-D models of all subjects in the survey. The data would be the most accurate possible with current technologies. The data would be the most accurate possible with current technologies. The use of the ISO 20685, 7250 and AMI would allow data collection to be done with an existing data collection protocol and a small data collection team. This would further minimize labour costs such that it will be the same cost or less expensive than option D, even with the purchase of the equipment. 3-D models permit extraction of almost unlimited new kinds of dimensions, such as body segment masses and moments of inertia. In addition, having the 3-D scanner available would permit the measurement of fit-mapping and or accommodation data in the future.

Cons:

The lease or purchase of equipment would add expense to this option. However, this cost would represent a relatively small fraction of the overall cost of the project.

C. Purchase of Inexpensive Equipment and Less Accurate Current Technology Equipment. Low Precision: Low Cost: Low future Potential

Tools:

- TC2 or Vitronic Vitus Pro scanner(s) with no pre-marking of landmarks
- TC2 auto-extraction software purchased

Immediate Data Products:

- 100-150 1-D measurements with precision outside the 10 mm limit (approximately 200 mm precision)
- No seated measurements due to limited scanning volume in scanner

Pros:

This is a very inexpensive solution and the data collection can be extremely rapid. Subjects can be processed in a few minutes making it possible to run thousands of subjects through within the time frame of this effort.

Cons:

This method would provide very inaccurate data that may be good enough for size selection but are not accurate enough for good equipment design or evaluation. Scanner volume is not large enough to capture seated scans – so standing scans only. Of the auto-extraction software tools available it is believed that the TC2 software is the best, but it still is very inaccurate compared to pre-marking and landmark identification with manual intervention. It would not pass the criteria set out in ISO 20685 or ISO 15535. Fully automated measurement extraction creates systematic errors that makes the scans of people with extreme body types/measurements the least reliable and therefore the least usable – see Chapter 2, Section 2.2.4 for an example. Unfortunately boundary cases for design rely on exactly the same people that this system is unable to capture accurately. Having the very people that are necessary for design testing missing from the database or their data being unusable due to inadequacies of the technology defeats the stated goal of this survey. It fails the fundamental question – is the anthropometric data fit for purpose and will it work? Accordingly, this option is not recommended.

D. No 3-D scanning equipment. Low predictability, medium cost, low future potential Anthropometry Survey

Tools:

- Calipers and tape measures with PC data entry.

Immediate Products:

- 100-150 traditional (1-D) measurements with precision within the 10 mm limit
- Like older survey such as US Army ANSUR

Additional Future Potential:

Minimal: no data on the location of the 1-D measurements

Pros:

Good anthropometry measurement precision. Inexpensive and very portable tools.

Cons:

Manual measuring would require a larger measuring team than scanning, with additional labour and travel costs. High labour cost for future use as data are indicators only and all design work needs verification. Minimal future potential because once the subject is gone no new information can be obtained, also the ability to measure equipment interfaces will not exist. Low predictability because there is no 3-D body location information.

E. This is one of the preferred solutions: Purchase of Best Current Technology Equipment: High Precision; High Cost; High Future Potential, Extra-High Usefulness for Industry and Government

Tools:

- Best Current Technology Equipment, anthropometer, calipers and tape measures all purchased. Integrate® software (free) and pre-marked locations for landmark markers.
- Polyworks – software.

Immediate Data Products:

- 100-150 1-D measurements with precision within the 10 mm limit, derived both from the scan and traditional-style measurement.
- 100 3-D landmarks with precision within the 10 mm limit.
- Automated and manual data editing and measurement extraction with precision within the 10 mm limit.

Facilitate the collection of 4-D (dynamic) data to facilitate the new DHM with stakeholder/partner input.

Conduct fit-mapping/accommodation. Scans of the subjects in the environment and/or the apparel and/or PPE as required by stakeholder involvement.

Pros:

This solution provides 3-D models of all subjects in the survey and how they fit into apparel/PPE and/or environments. It provides functional measurements such as reach envelopes that can provide a library for the selection of cases for design purposes. Can lead to understanding the underlying principles of fit that have maximum applicability in industry and Government. The data would be the most accurate possible with current technologies. Depending on the sampling strategy either 4512, for a stratified sampling strategy with 24 strata, or many more if a random sample would be needed (as stipulated by ISO 15535). The use of the ISO 20685, ISO 7250 and AMI would allow data collection to be done with an existing data collection protocol and a small data collection team. The standardization would allow international comparability and the entry into WEAR database that has search tools and other functionality to make it rapidly accessible by users. This will further minimize labour costs such that it will be the same cost or less expensive than option D, even with the purchase of the equipment. 3-D models permit extraction of almost unlimited new kinds of dimensions, such as body segment masses and moments of inertia. In addition, having the 3-D scanner available would permit the measurement of additional fit-mapping and or accommodation data in the future. This is a new and very valuable type of survey and it would be the first time 4-D and fit data would be collected in a large-scale civilian anthropometric survey. Being at the cutting edge of technology would add value add to the partners, stakeholders and industry. This would give Australia the best dataset in the world making Australian data the base for tool development. It would give Australia further competitive advantage.

Cons:

The lease or purchase of equipment would add expense to this option. Adding 4-D data collection would increase the amount of data that needs to be processed which would add labour costs. Fit-mapping and accommodation testing would add data collection time for the subjects.

5.2 Value for money: choosing a scanner

There is a wide variety of scanners on the market today, but their quality and scanning capabilities varies considerably. Although there are very inexpensive options available, the quality of the data produced means that they are of no value for designers. In this Section we examine 5 scanners that represent the spread of technology available today. The findings are summarised in Table 7 and further explanation can be found in the text following Table 7.

Brand:	3dMD	Vitronic	Space Vision	TC2	Cyberware
Type:	**Whole body scanner**	**Vitus Smart XXL**	**Cartesia**	**KX-16**	**WBX**
Website	http://www.3dMD.com/3dMDbody/	www.vitronic.de	http://www.space-vision.jp/E-HOME.html	www.tc2.com	discontinued
Type	Active Stereo Photogrammetry	Laser	http://www.tc2.com/pdf/spacevision.pdf	infrared	Laser
Country of origin	UK/USA	Germany	Japan	Cary, USA	USA
Price	$200,000 standard configuration for research (8 pods)	$90,000	$200,000	$13,000	$240,000
Software	Yes	Yes	TC2	Yes	Yes
Suitable for large scale surveys	Yes	Yes	Yes	No	Yes
Safety: eye and skin safe,	Yes – optics-based	Class 1 laser	Laser	Infrared	Class 1 laser
High speed: avoid movement effects,	1.5 millisecond at highest resolution	10-15 seconds	2 seconds	3 seconds	17 seconds
Data output type is point cloud: allows viewing and calibration of raw data,	Yes	Yes	To be advised	To be advised	Yes
Data output format in public domain (not proprietary): allow freedom to choose a third party software if required,	.tsb file (proprietary): VRML, OBJ, X3D, STL and .ply (generic)	ASCII/.obj/.stl	.obj	derived body dimensions	.ply (generic)
Point - point distance	depends on scan volume and format	27/cm3	3mm	1mm	
Precision: high accuracy of 3D points,	Excellent - Sub-millimetre (≤0.2mm depending on configuration)	excellent	Excellent but low resolution so smooths edges like face	Low accuracy	excellent

Brand:	3dMD	Vitronic	Space Vision	TC2	Cyberware
Type:	**Whole body scanner**	**Vitus Smart XXL**	**Cartesia**	**KX-16**	**WBX**
Ease of calibration: allows adjustment of raw data to fine tune accuracy	Yes, required after set-up and once daily, takes 10 minutes	Not included, $19,000 extra for specialist calibration system	To be advised	To be advised	Yes, hardware required only after initial set-up, also software has fine calibration of every scan – 2 seconds/scan
Field of view (desirable 2m x 1.5m x 1.2m or close: accommodates large subjects)	Flexible: Min. 0.793m x 0.76m x 2.134m (1.286m3) and scalable (Modular Camera pods)	0.9 x 0.9 x 2.1m	0.7 x 0.6 x 2.0m	0.9 x 0.7 x 2.1m	1.3 x 0.5 x 2.0m
Good surface coverage: avoids holes in the field of view (minimal occlusion)	Good. flexible pods placement makes optimisation possible	good	large holes	To be advised	good - minimal holes
Good landmark recognition capability: ability to recognize flat markers	excellent colour/texture in most lighting conditions	YES	To be advised	To be advised	Yes
4-D capable	8 seconds to recharge*	No	No	No	No
Warranty and support	1 year warranty** with $TBA/year support contract after that	$6,100/year	To be advised	To be advised	To be advised
Current clients	WPAFB – USAF Max Planck - Germany	ADF - Australia	Kangan TAFE - Australia	RMIT - Australia	FMC - Australia

Table 7: Whole body scanner equipment options

3-D data in a future study will have certain requirements. A priority list needs to be determined to enable the assessment of each scanning system relative to performance against these criteria. For example, if it were certain that the survey requires seated scans and reach postures then an initial elimination could occur based on size of the field of view volume. There are only two with a large volume: Cyberware and 3dMd (see Figure 10). All other scanners are too small for this when the subjects are big people (which are usually the people of interest). Cyberware went out of business in late 2012, so that leaves 3dMD.

The 3dMD scanner can also capture 4-D – motion or dynamic data, but only at this stage for the head scanner. This is a new capability at a high resolution (see Figure 11). Prior to this only low resolution MoCap (motion capture) was possible and then this was matched to higher resolution 3-D data which was very labour intensive. Currently this body scanner can capture very high resolution 3-D data very rapidly (1.5 milliseconds) but is limited by an 8 second recharge time for the flash (Ennis 2011) see Table 7. *The developer is working to improve this capability by reducing time between captures and has advised that the next-generation sequential-3D 3dMDbody System is 60fps (frames per second). For seamless motion capture the scanner would need 25 to 30 captures per second. In addition, any scanner would need to pass all other criteria relating to accuracy and quality. The selection criteria prioritisation will drive the testing and outcome.

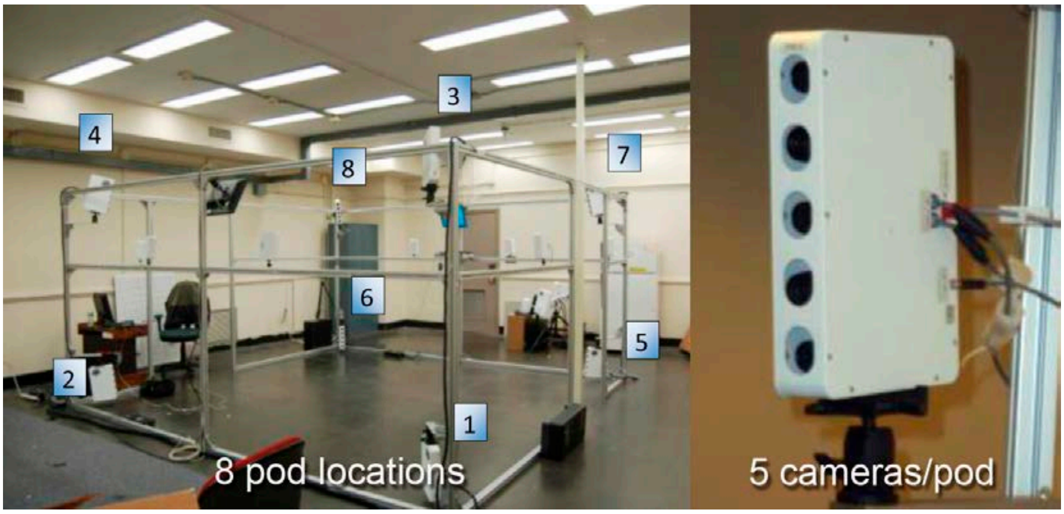


Figure 10: 3dMD scanner set up and camers pod (Source Zehner)

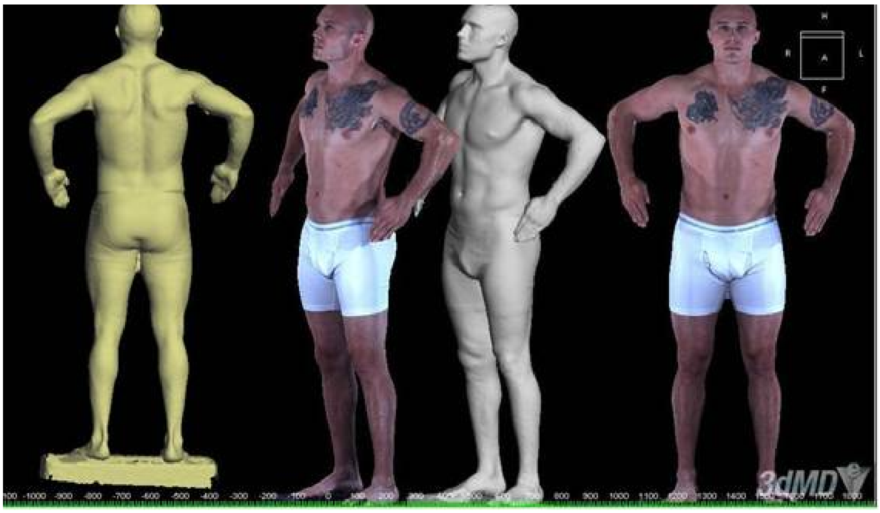


Figure 11: 3dMD scanner images demonstrating resolution and colour (Source (3dMD 2013))

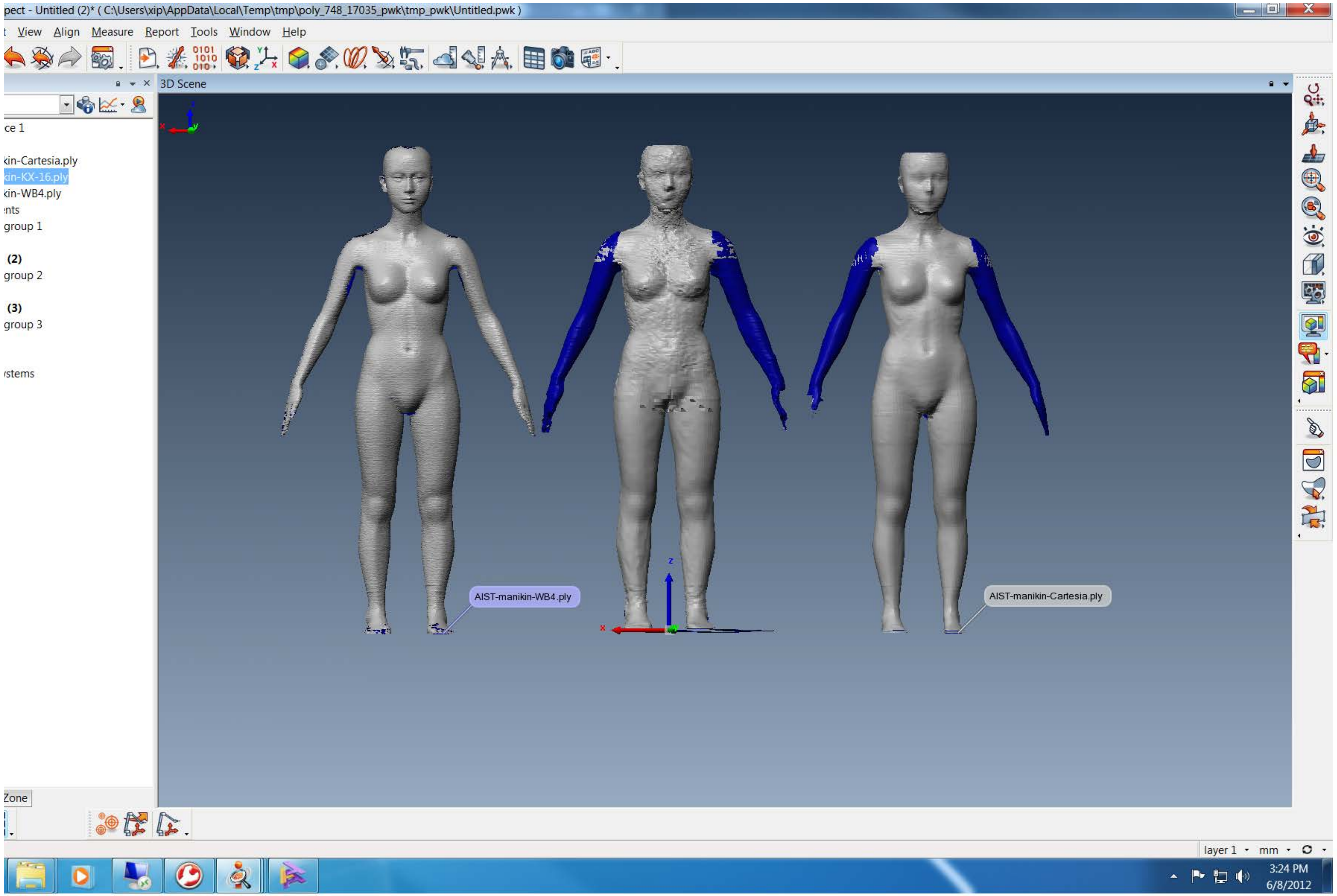


Figure 12: An example of a simple test (viewing the data) illustrating the quality of various scans acquired in different scanners. Source Kouchi, Shu and Veitch

Figure 12 shows the same object, a manikin, scanned in 3 different scanners. The scan on the left was done by the Cyberware (now discontinued), right is Space Vision – Cartesia and in the middle is the TC2 scanner KX-16. Both Cyberware and Space Vision are laser-based systems. The quality of the two laser-based systems is acceptable, although the difference in resolution is obvious in the face. The higher resolution Cyberware has a sharp focus and the lower resolution Space Vision has a smoothing effect over the facial features as is apparent in Figure 12. If the data were to be used for clothing design only, then the Space Vision scanner might be acceptable, but if the data used were to include the face, then better options might be more appropriate.

TC2 is based on time-of-flight infrared sensors like the Kinect cameras. The TC2 scan is visibly “noisier” than the other two and some of points are as much as 8mm from their true location making measurement inaccurate as illustrated in the heat maps in Figure 13 below. If quality were a priority then this TC2 scanner would fail because not only would the 3-D data itself be hard to work with, but also the 1-D extracted measures would contain the errors in the poor 3-D data; these would be compounded by any other software errors making them poorer quality than that deemed acceptable by the ISO.

The nature of 3-D data makes it very easy to quantify error in quality tests. The manikin on the left in Figure 13 is the TC2 data overlaid on Cyberware. Cyberware can be used as a gold standard as it has been subject to rigorous testing which has been published. Although the Cyberware scanner is one of the oldest on the markets it is still one of the best quality. The scan has a legend showing error which is colour coded. Blue/green is the least error; that is, the best result. Red is the most error and shows the TC2 data is larger than the actual manikin. This is especially a problem around the ankle in this scan and it can clearly be seen the ankle is much thicker than it should be. This would make the 1-D extracted measurement around the ankle much larger than the ANSUR acceptable error (just from the scan alone).

Thus the requirements for the survey would include: best available scanner, computers, anthropometer, tape measures, scanning shorts and tops, wig caps, landmarking markers (flat white dots and geometric markers if required). There might be additional tools such as a neck chain, foot box, tent and uniform for staff. Workstations and chairs would also be required at each location to accommodate measures and waiting subjects.

Once the scope of the Australian Body Sizing Survey is decided, a series of tests should be undertaken to determine the best tools. Considerations for the scanner might include: quality, scanning volume (this determines what poses can be collected), data formats (should be generic not proprietary), calibration process, portability (time to disassemble and reassemble), reliability and image acquistion time (time taken to perform the scan). At this stage the 3dMD looks the most promising but thorough testing of all proposed systems should be conducted prior to the final decision to ensure the desired outcomes will be achieved.

The quality and therefore accuracy and usefulness of traditional and 3-D scanned data are paramount to the ability for the data to be used as a predictor in engineering designs. The provisions for obtaining high quality and accurate traditional-style data has been clearly defined (Pederson and Gore 1996, Blackwell, Robinette et al. 2002, International Standards Organisation (ISO) 2008). This should be used in conjunction with AMI to build or preselect the measurement definitions (Ennis and Robinette 2011) and WDN to provide a database system for the functionality of searchable online and comparability with other datasets (Cheng, Robinette et al. 2007). Any data collected in a future survey should pass these quality tests.

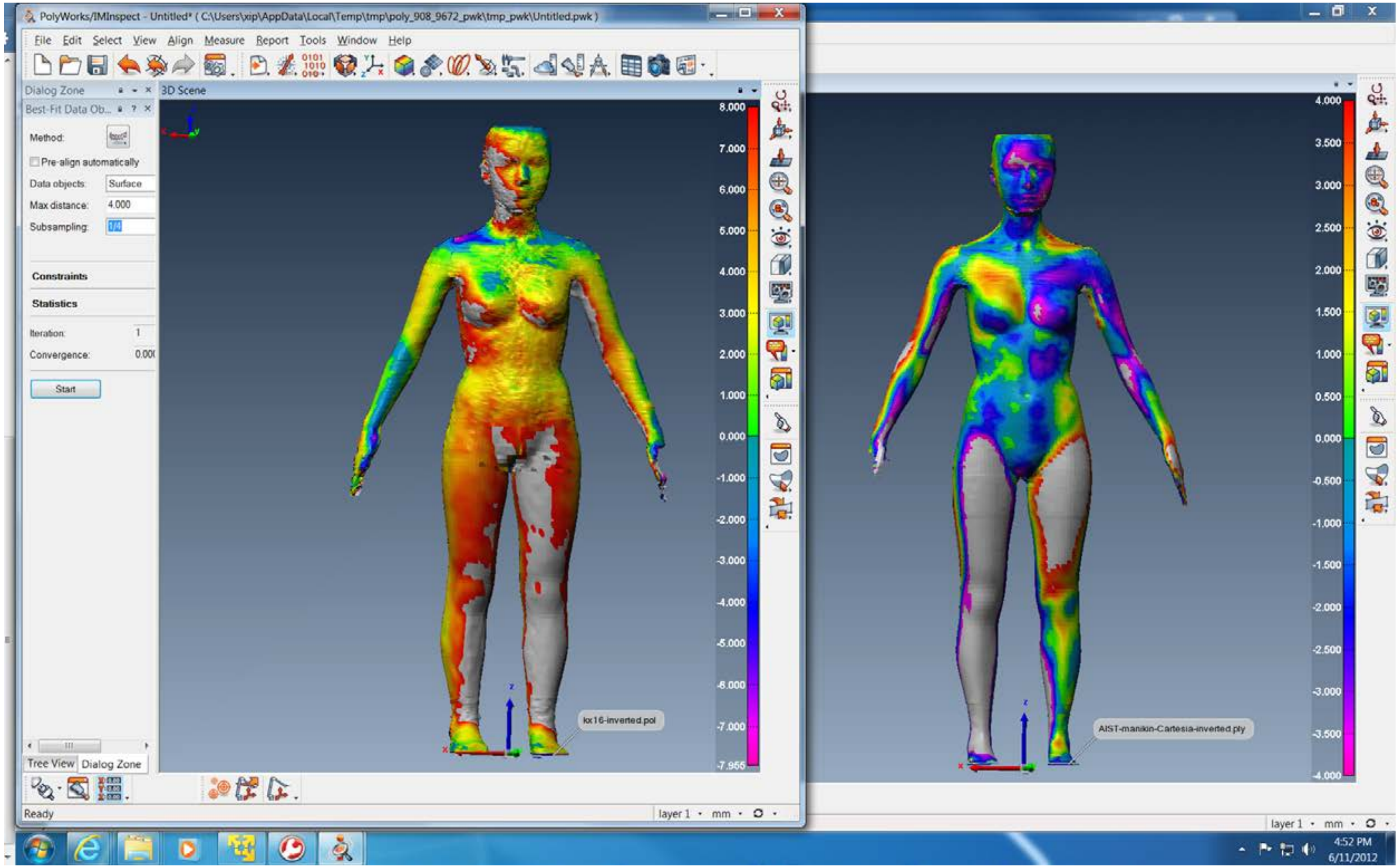


Figure 13: The 3-D scans overlaid and measured – TC2 on right vs Space Vision on left. Source Shu and Veitch

5.3 Quality requirements for purchase of a Scanner (Hardware)

At the moment there is no ISO standard to define the terminology, methods and validation of 3-D scanner hardware or software. However there is a New Working Group, NWG1, for ISO 159 assigned to develop this, see Chapter 2 Section 3.1 for further detail. In the meantime a proposal was put forward to the ASTM by Kathleen Robinette in 2005. A set of purchasing criteria was developed to select and test the whole body scanners using the following requirements:

- safety: eye and skin safe,
- high speed: avoid movement effects,
- data output type is point cloud: allows viewing and calibration of raw data,
- data output format is in the public domain (not proprietary): allows freedom to choose third party software if required,
- resolution of 1mm in all directions (or similar): closeness of 3-D points to each other,
- precision: high accuracy of 3-D points - ease of calibration: allows adjustment of raw data to fine tune accuracy,
- field of view at least 2m x 1.5m x 1.2m or close: this accommodates large subjects and seated scans
- good surface coverage: avoids holes in the field of view (minimal occlusion),
- good landmark recognition capability: ability to recognize flat markers, and
- warranty and support.

(Robinette 2005)

6. Sampling and recruitment method

The selection of survey participants and the nature of their recruitment are crucial to the quality of the Australian Body Sizing Survey. In this section we outline these important parts of the survey method. Some of this section builds upon Sections 6 and 7 in Chapter 2, the Literature Review in this series of reports.

6.1 Population sampling strategies

Ideally any sample would be randomised. Random means every person in the population has an equal chance of being selected. This is the best way to get a true representation of a population. From an implementation perspective, however, selecting people who are randomly spread across the country and who, for example, live in a remote location in Australia is likely to be expensive. In addition, to get sufficient numbers in minority groups many more people need to be measured. This can be inefficient because once there are sufficient people to get a good estimate of the body measurements in a particular sub-group (such as European males), any extra that are measured in that group do not provide the user with any more useful information. So any additional people measured in full sub-groups cost additional money but do not give useful additional information. This might not be an important consideration if the data collection method was inexpensive, but with a high priority in this survey placed on useful, high quality data, this is unlikely to be the case here. This means that a truly random sample is likely to be too expensive.

The ISO also recommends stratified sampling. The advantage of this method is that it provides a way to reduce the size of the sample needed. So, for example, once you have enough people to get a good estimate of your measurements for a sub-group such as European males, it would be more beneficial to concentrate on minority populations to get their numbers up so you can make good estimates of their measurements. The disadvantage of stratified sampling is that the sample needs to be corrected to match the overall population by weighting when aggregate statistics are needed. However, if raw data are available to build queries for design using tools in WEAR, the capacity to tailor a population is more powerful with a stratified sample. That is why a stratified sampling technique was explored in the literature review. This is the method proposed here and the sample size is expanded in Section 6.2.

One method of controlling cost by using stratified sampling and reducing bias is using a systematic sampling within clusters. For example, recruitment might involve using an electoral roll, selecting a random starting point in the first 1000 people, then selecting every 1000^{th} person thereafter. This is akin to randomisation because the order on the electoral roll will effectively be randomised with respect to body size.

Possible sample bias is dependent upon the recruitment method so until the sampling method is finalised this section cannot be definitively written and vice versa. In the final method there will be trade-offs related to cost and practicality.

Recruitment methods will be developed which aim to minimise bias. Compromises might need to be considered and advantages and disadvantages weighed along with management strategies to manage any possible bias created by the recruitment method. If bias in the sample is unavoidable then it should be noted and how the bias will be corrected later needs further consideration, such as weighting.

The CAESAR sample was biased however this was known and a strategy for counteracting the bias by weighting the sample to the US census after collection was used. It was also stratified by region of the country, but this did not require weighting as the US was divided into four sections that had approximately the same population size and the sample was matched to get approximately equal numbers of people from each.

In addition the CAESAR project had some difficulty recruiting enough subjects to fill their minority ethnic groups' strata. For this group a financial incentive had to be offered to establish a sufficient number of participants in the strata and there were advertisements placed written in the language of the target group – for example an ad placed in Chinese in a publication aimed at the local Chinese population (Robinette and Daanen 2003). Information like this is very valuable as it enables active management to avoid potential problems right from the start in the planning of a future survey.

Apart from developing a statistical method, the Australian Body Sizing Survey might employ a pre-survey questionnaire that asked potential participants questions like: how long would you be prepared to participate in the survey, say 60 or 90 minutes? What incentive might be suitable to gain your participation?

Just conducting a pre-survey questionnaire would give the project team a flavour of any likely difficulties they might have in recruiting participants. So if no potential participants could be recruited to fill out the pre-survey questionnaire that would be the time to ask – how to reach these people to gain participation at this very early stage? Feedback from an early pilot would be applied early to the larger project.

Advance surveying of the targeted sub-groups within the broader sample group should help to effectively plan recruitment strategies using their own suggestions, to increase response rates across all sub-groups. This should help to set up and keep the survey period for each location on schedule and avoid additional costs and use of resources caused by extending the measurement period to obtain sufficient data to represent specific sample sub-groups.

Because of the stratified sampling strategy, the overall mean values do not accurately reflect an accurate mean for a given country. In order to achieve a *representative* sample for a country, the data have to be weighted using the census data (Robinette, Blackwell et al. 2002). Weighting is a process by which the sample units are multiplied by their probability of selection. In Australia stratified sampling would match the data to the overall population according the distribution outlined in Australian Bureau of Statistics documents (Australian Bureau of Statistics 1995).

CAESAR used stratified sampling (Robinette, Blackwell et al. 2002). In addition to the strata, height, weight, education and within country geographic region were also monitored to ensure that the volunteers were roughly matched to the civilian populations as measured in a recent census study. In Australia measuring might occur in major population centres such as Brisbane, Sydney, Melbourne, Adelaide, Perth, Hobart and Darwin or only a portion of these centres and monitored as suggested above. Stratified sampling is more efficient than a random sampling method and there is likely to be very little difference in accuracy.

6.2 Sample size

CAESAR used a stratified sampling plan with equal sample size in each cell according to the recommendations of ISO 15535 (Robinette, Blackwell et al. 2002) and we propose the same method for the Australian Body Sizing Survey.

The method required for estimating the number of subjects needed in a sample is summarized in a straightforward and detailed manner in ISO 15525: 2012 Annex A. The method is outlined in Section 6.1.2 of the Literature Review. The example given there gave a 1% relative accuracy. For the Australian Body Sizing Survey we propose also 1% relative accuracy. A wider range of strata for age would be added, as there is a trend in Australia toward working longer and retiring or semi-retiring later so this would be more representative of the Australian working population.

The minimum sample size for each cell was calculated using the following formula:

$$\frac{\left|\overline{X} - \upsilon\right| * \sqrt{n_i}}{\sigma} \geq \zeta$$

The total number target for the sample is the sum of the sample sizes in the sub-groups. Variability of most linear measurements of the large parts of human body, such as sitting height, limb length or chest circumference, is such that standard deviations typically lie in the 50 mm range. Smaller dimensions have proportionately smaller standard deviations. In case of 3-D scans position of pixels, or distances between pixels located on various body parts will have similar size of standard deviations, provided the accuracy of measurement extraction software is good. A review of within age group standard deviations measured around the world indicates that 50 mm is a reasonable within-cell standard deviation estimate. For CAESAR the desired within-cell accuracy for the mean was set at 10 mm.

The calculation of within cell sample size as outlined in Annex A of ISO 15525: 2012 becomes:

$$\frac{\left|\overline{X} - \upsilon\right| * \sqrt{n_i}}{\sigma}$$ or

$$\geq \zeta = 188$$

This value was then left at 188 and 188 was set as the target number of subjects per cell. This number represented the number that should provide a sample mean value that is within 10 mm of the true population mean with 99% confidence.

As mentioned before the total number of subjects equals the number of subjects in each cell multiplied by the number of strata.

There are two main things which need to be considered in defining strata: 1) Stratification is most effective when we can split the target population into groups (strata) such that the groups are as different as possible with regard to whatever is being measured. 2) For each stratum, or subgroup within a stratum (eg European males aged 18-24), we need to know how many of the target population belong to the sub-group, so that sub-group estimates can be combined correctly. If the sampling were to be truly at random, we would also need to know which members of the target population they were, so that we could select a random sample of them.

Some background research information and thought needs to be given to justify the stratifying variables used, and why others have not been used.

Strata might be by age, gender and ethnicity.

Age: The example below uses four age strata, however thought needs to be given to how these strata relate to variation in the main body measurements to be made, and if the groups maximise the variation between groups. Australian Bureau of Statistics (ABS) census data is commonly available in 5 year age groups, eg …,10-14, 15-19, 20-24,… which is at variance with the age group of 18-24 used below. This means that population tables will have to be specially extracted from the census data to match the 18-24 age grouping (and all the subgroups of that age group specified by other stratifying variables). However note that the Australian Health Survey information is published with an 18-24 age group.

Ethnicity: The example in Table 1 mentions white/Asian other, but details of how these are defined should be thought about as well as whether these groups are adequate to cover the diverse mix of ethnicities found in the Australian population. Anthropometric literature gives a guide to where the main ethnicity measurement differences lie, but these would have to be related to ABS census data so that population estimates in the stratum sub-groups could be obtained. The 2011 census contains information on country of birth of the individual and their parents, and on their ancestry, so it would probably be necessary to frame the definitions in these terms. The methods of defining ethnicity also need to be culturally sensitive, so that the ethnicity of individual subjects can be determined – the CAESAR summary report details such considerations in its Experimental Design section. In addition, the 2005 ABS publication 1249.0 (Australian Bureau of Statistics 2005) provides useful background information on defining ethnicity.

Providing that strata are defined with reference to ABS census questions, then there will be little trouble in getting population estimates for the subgroups. The ABS website provides tools to do this, either free-of-charge or on a paid basis, depending on the complexity of the task. It is recommended that an experienced statistician be involved in the project the Australian Bureau of Statistics is involved during the stakeholder consultation time.

It is likely that stakeholder input may have an effect on the survey design. For example, some stakeholders might want detailed information on particular age groups or on particular population subgroups. These types of requests can be incorporated into the design provided estimates of the numbers in each group can be obtained.

The CAESAR survey was designed with equal subgroup sizes for all groups, and the advantage of this is that all subgroup estimates would have similar precision. (The more usual procedure for a stratified survey would be to have sub-group sizes proportional to the numbers in each sub-group, so that combining sub-group estimates is much simpler). However using this equally-sized sub-group approach, it is relatively easy to include extra or enhanced strata if necessary, without destroying the validity of the whole survey.

It is also possible that the nature of stakeholder requirements may also affect the sample size calculations, in that some of the measurements they require may have different levels of variability or require greater or lesser precision. This means that the sample size is only an example here and will almost certainly change once stakeholder involvement emerges. Table 8 shows an example of a calculation to determine specific strata in the Australian population.

Strata type and number	Strata details
Age Strata = 4	**18-24,25-44,45-64 years, above 65 years (Australian Bureau of Statistics 1995)**
Gender Strata = 2	**Male and Female**
Ethnic Group Strata = 3	**European, Asian, Other**

Total = 4 x 2 x 3 = 24

Table 8: Example of a calculation for the strata proposed for an Australian survey

The total number of subjects is calculated by multiplying the number of sampling cells (strata) by the number of subjects in each cell, so for example if the total number of sampling cells is 24 and if the number of subjects in each cell was 188 then the total number of participants in the survey would
be 4512.

7. Measurement logistics

Once the stakeholders have been engaged, landmarks and measurements narrowed and decided, pilot testing has been completed, the design of the Australian Body Sizing Survey would be finalised. A training manual would be completed along with other documentation of the survey methods, which is compliant with ISO and AMI protocols. Any additional members of the survey teams would then be recruited and trained.

This section cannot be written in the absence of the testing, but nevertheless we attempt to give some examples of how the logistics of a survey would pan out, principally based on the experience of CAESAR. In part the logistics would depend on the outcome of the pre-survey questionnaire, which would indicate how long a participant would be willing to spend being measured.

For our purposes here we will assume one hour as this process has already been the subject of extensive testing and documentation during the CAESAR survey.

Some of the elements to be tested are listed in Section 7.4.1 of Chapter 2 – Literature Review. This includes data features, subject features, scanner hardware features, scanner software features and the pre-subject questionnaire. In addition the logistics section is repeated here and expanded.

Logistics:

- Time taken to construct and deconstruct the scanner at each location
- Space planning, scanner and change room locations.

Availability, transport, storage and laundering of suitable garments for scanning:

- Subject flow from location to location within the survey site, "staggering subjects" see Table 9 below.
- Subject throughput and any threats to smooth transition.
- Team composition (number and genders of team members).
- Competency requirements for team members for subject management, measurement, landmarking and general tasks.
- Number of landmarks able to be placed in a certain time.
- Number of traditional-style measurements able to be taken in the time allowed.
- Number of scans – postures.
- Quality control procedures for the survey process and processing and managing data. These would include measuring the inter-rater reliability between team members for both traditional and body scanning measurement methods.

Time	Paperwork station	Get changed/landmarking and scanning	Manual anthropometry
Approx. 20 mins	Subject 1		
Approx. 20 mins	Subject 2	Subject 1	
Approx. 20 mins	Subject 3	Subject 2	Subject 1
Etc	etc	Subject 3 etc	Subject 2 etc

Table 9: The flow of subjects through the different measurement stations and the time frames. Source Robinette

This might be a starting point for the costing. So one person takes an hour to cycle through the stations, but we have 3 stations going simultaneously. We anticipate best case scenario of 15 people per day, worst case of 10 people per day, thus a costing could be estimated on 12 people per day.

Data collection:

Demographic station: paperwork involves, meet and greet, signing forms, filling in questionnaires etc. One person in the room could handle this on the day.

Manual anthropometry needs a 2 person team.

Landmarking and scanning can be done by two people.

Total of 5 people per hour.

There should be costing allowance for another administrative person who is responsible for recruiting and also phones the person the day before and confirms all arrangements to minimise “dead time” caused by a participant not being on time or failing to turn up for their appointment. This resource might be sought as a partner contribution, but in the meantime could be costed at a fixed price per unit – a call centre rate of say $1.50 per phone call.

Potential cost savings/efficiencies should be explored such as the possibility of an on-line booking system and an on-line demographic survey to maximise value. This might allow the proportion of time allowed for face-to-face paperwork to be substituted for additional measuring time.

Data processing and quality control of the 3-D scans should be costed separately and would depend on the type of scanner, software used and the number of scans collected. Data processing for CAESAR took approximately 15 minutes per scan and there were 3 scans per person measured.

8. Methods of survey data management

8.1 Data obtained from a survey

Data obtained from the survey should be accessible by the maximum number of potential users. It is proposed that access be negotiated with the potential stakeholders but that all will agree that data should be released for general use after a maximum specific time period, say one year.

Data should be available in its raw form as well as summary statistics weighted to the ABS data. It should also be provided through the WEAR portal.

WEAR tools allow:

- Rapid online access and searching of raw data,
- Building queries built on demographic variables that combine and recombine the data from the original raw datasets to make the data relevant, i.e. reflect the target group, and downloading these raw 1-D data in Excel and csv formats, as well as providing summaries of data such as means, SD etc. all in real time,
- Searching and viewing of images of 3-D scans matched to the 1-D files, and
- Downloading selected 3-D scans.

If available and sought by stakeholders, other data such as functional reach, 4-D and fit data would be provided.

8.2 Data quality control

Part of a systems engineering approach requires quality, safety and accountability measures to be clearly defined against which project management and performance would be measured. A number of these provisions are described in the ISO standards. However, other approaches to prevent or limit error at the measurement and recording phases would need to be bought to the Australian Body Sizing Survey. These approaches would establish systematic training and assessment requirements and criteria for assessors as well as establish smart quality control provisions within data recording systems.

In order to provide clarity in this report, some of the following is repeated from of Section 6.1.3 of Chapter 2 – Literature Review and is built upon Section 3 of the Literature Review. Section 3 describes the work in progress – New Working Items of ISO TC 159.

With regards to quality criteria for measurement technologies and obtaining measurements there are currently no standards for 3-D body scanning technology, both hardware and software, and a buyer beware situation prevails. The Australian Body Sizing Survey will need to develop performance criteria for scanners and any scanners being considered for use within the survey would need to be tested against these criteria. It would not be sufficient to rely on manufacturer's specifications and promotional material (Robinette 2005).

Gordon and Bradtmiller have a comprehensive study describing magnitudes of inter-observer error for individual measurements that should be used to determine whether a measurement is within an acceptable range for quality (Gordon and Bradtmiller 1992). This can be very usefully applied to 1-D measurements extracted from a scan to compare them to 1-D measurements taken by an expert anthropometrist to determine whether they can be reliably taken using this tool or need to be taken using the traditional – style, with a tape measure (International Standards Organisation (ISO) 2010).

For 3-D scanning, the CAESAR project used a number of quality control strategies to minimise error (Robinette, Blackwell et al. 2002, Robinette and Daanen 2003). These included:

- Checking that the electronic file data completeness and assignment to the correct subject at the final data collection station to confirm that the required scan and data had been satisfactorily completed.
- Error trapping the subject landmarking process by issuing landmark stickers in a roll that had the exact number of landmarks needed. Having too few or spare stickers at the end of landmarking would highlight that an error had occurred which would prompt the assessor to find and fix the error.
- In two of the three CAESAR countries the scanned images of a subject were checked within one minute of the scan to ensure they were of good quality and all of the landmarks were visible. If the scans were not good enough then they were repeated until the required quality was obtained.
- An audible beep being generated by the computer when a value that was beyond the range expected for that variable was entered.
- Subjects carrying a clipboard with records of their traditional measurements from station to station in addition to these measurements being recorded on a database so these were available if the computer system failed.

These examples reflect the highly proactive approach that was used to prevent or limit errors across the survey (Robinette, Blackwell et al. 2002) that could be applied to the Australian Body Sizing Survey.

Anthropometrists in the Australian Body Sizing Survey project should have appropriate training to minimise any inconsistency in the measuring techniques employed by the team. Due to the nature of anthropometry and measuring something as changeable as a human body (e.g. breathing and posture variations) there are acceptable levels of precision for most anthropometric variables used to evaluate performance, both intra- and inter- measurer. The measures of precision and reliability – technical error of measurement (TEM) — and intra-class correlation coefficient (ICC) are described by Pederson and Gore (1996). This report does not seek to repeat this work but instead recommends that the expert anthropometrists employed to conduct the Australian Body Sizing Survey be trained and tested according to the technique outlined by Pederson and Gore. In addition they should follow the ISO and WEAR/AMI quality guidelines and ANSUR error tables.

The method of scribe and measurer working together, the anthropometric equipment and standardised ways of holding the equipment are described by Norton, Whittingham et al (1996), and should be followed during the conduct of the Australian Body Sizing Survey. Although these physical techniques of anthropometry come from the field of sports science it is appropriate to use these guidelines because the technical methods for collecting traditional style measurements are the same in both fields. The actual measurements collected may not be the same and the applications will be different. The measurements will be fit for purpose and appropriate to engineering anthropometry and will be decided in conjunction with the stakeholders in the future survey.

There should be additional systems in place to improve quality. For example in CAESAR all data were recorded on paper as well as on the computer. When the data were entered in the computer it would beep when an outlier appeared to alert the investigator about any potential errors. There was a system for determining the range of outliers based on previous surveys. The 3-D data files were checked at the final measuring station to ensure they were correct and for the right subject. The 3-D land marking had a heuristic checking system. There was a final check of all traditional style measurements (including scan-extracted measurements) using a regression outlier analysis. For a full description of the statistics used Robinette, Blackwell et al (Robinette, Blackwell et al. 2002).

8.3 Data formats, software and data storage

In general, data formats should be in generic not proprietary formats. For example if the raw scan data were in a proprietary format this would force potential users to:

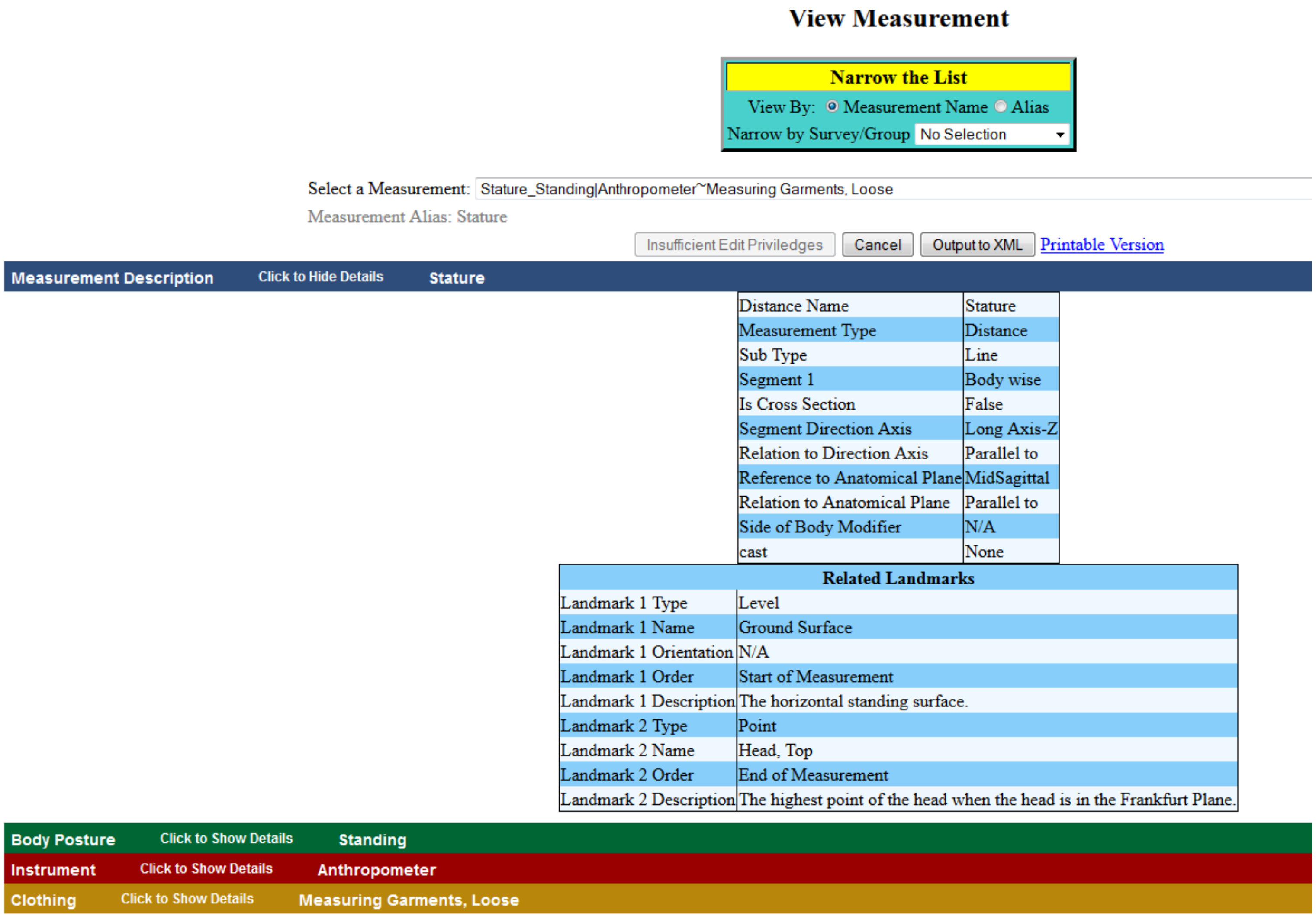
1) Buy software that is capable of reading that format, or
2) Use a conversion tool, which would change the original data to make it readable.

The former case restricts the user to the proprietary software, and in the latter case, conversion might change or smooth data in an unknown way possibly degrading the fidelity of the data. Both these scenarios are undesirable.

The best option is to acquire scanning technology that outputs generic files that can be read by the broadest range of software, including free applications, making the data accessible to the broadest range of potential users. The recommended generic output format is .ply. This format was principally designed to store 3-D data from 3-D scanners. It supports a relatively simple description of a single object as a list of nominally flat polygons. A variety of properties can be stored including: colour and transparency, surface normals, texture coordinates and data confidence values. The format permits one to have different properties for the front and back of a polygon (Wikipedia 2013).

1-D data could be output in .csv and .xls or .xlsx formats. .csv is generic and although .xls(x) is proprietary to Microsoft most people have access to Excel.

Measurement definitions should conform to the XML language used by the AMI tool that is used to search the datasets that are housed within the WEAR database – see Figure 14 for an example of the search to build Stature. The example shows the degree of detail required to make measurements comparable. They should include measurement descriptions, landmarks used, body posture, instrument and clothing. For illustrative purposes only the measurement description and landmarks used are shown. This is a critical feature as this compatibility would enable the Australian Body Size Survey data to be aligned and compared with other international datasets making them rapidly accessible and searchable on-line. Having the Australian data within the WEAR database and searchable by the AMI system will provide invaluable access for end users. XML language and the AMI search tool are described in depth in the Literature Review.



View Measurement

Narrow the List

View By: Measurement Name Alias

Narrow by Survey/Group No Selection

Select a Measurement: Stature_Standing|Anthropometer~Measuring Garments, Loose

Measurement Alias: Stature

Insufficient Edit Priviledges | Cancel | Output to XML | Printable Version

Measurement Description | Click to Hide Details | Stature

Distance Name	Stature
Measurement Type	Distance
Sub Type	Line
Segment 1	Body wise
Is Cross Section	False
Segment Direction Axis	Long Axis-Z
Relation to Direction Axis	Parallel to
Reference to Anatomical Plane	MidSagittal
Relation to Anatomical Plane	Parallel to
Side of Body Modifier	N/A
cast	None

Related Landmarks	
Landmark 1 Type	Level
Landmark 1 Name	Ground Surface
Landmark 1 Orientation	N/A
Landmark 1 Order	Start of Measurement
Landmark 1 Description	The horizontal standing surface.
Landmark 2 Type	Point
Landmark 2 Name	Head, Top
Landmark 2 Order	End of Measurement
Landmark 2 Description	The highest point of the head when the head is in the Frankfurt Plane.

Body Posture | Click to Show Details | Standing

Instrument | Click to Show Details | Anthropometer

Clothing | Click to Show Details | Measuring Garments, Loose

Figure 14: Detail required by AMI to build a measurement – Stature

For 3-D data software, packages that can edit, segment, compare, create feature envelopes and conduct statistical analysis would be needed. There are a number of currently available software packages that could be used. Integrate is specialist software written for CAESAR and is free, however several off-the-shelf packages could be used as well. It is likely that 3-D data editing packages such as Polyworks would be needed because it has a compelling range of features. To provide and analogy; Polyworks is to 3-D is like Adobe Photoshop is to photos. Others include such software as Meshlab and Geomagic. Meshlab is a free Windows, Linux and Mac OS X application for visualizing, simplifying, processing and converting large 3-D meshes to or from a variety of 3D file formats.

The following desirable editing/analysis features should be found in most:

- General point cloud visualization, including pan, tilt, and zoom,
- Ability to make measurements such as distances, angles, areas and volumes,
- Ability to best-fit lines, planes, and other shapes to point cloud clusters,
- Ability to make profiles and cross sections through a point cloud; and
- Ability to handle various import and export formats (to CADD programs, for example)

The following advanced features are found in some, but not all of the software packages:

- Have edge detection technology to determine boundaries of solids, planes and other shapes,
- Ability to drape a digital image over a triangulated surface,
- Automatically compute a full 3D polygonal mesh from a point cloud, and
- Ability to make fly-throughs and other types of advanced visualizations.

In addition a Computer-Aided-Design package might be needed and at least one statistical analysis package such as Statistica, STATA or SAS.

8.4 Summary

Regardless of the nature of the scanner and other methods used for data collection, storage and analysis, there are some key organisational issues that would need to be addressed in the conduct of the Australian Body Sizing Survey. These are not described in detail here but are outlined in Table 10 below.

Requirement	Action
Ethics approval	The survey method would have an ethics approval compliant with the National Human Research guidelines and in keeping with the requirements of various regional jurisdictions where the research will be carried out. All the standard information would be outlined during the process including de-identifying individual data, etc. Daisy Veitch has successfully been granted ethics approval in Australia for the previous surveys but our experience is that time should be allowed for the process – at least 3-6 months.
Creation and storage of the master data, as opposed to second generation or altered data	All master data would be backed up on several separate hard drive and stored in multiple locations (perhaps including the cloud) so that the entire data recovery would be straightforward in the event of equipment failure.
Data synchronisation with equipment and databases (s)	All systems acquired would permit interfacing of hardware and synchronisation of databases.
Data archive and restore, equipment and databases (s)	2TB networked back up such as a Drobo, that provides multiple disc failure redundancy, and interfaces with multiple computer types and operating systems would be used to backup the entire system, data and all, making system restore reliable and efficient.
Security of the equipment and database (s)	The equipment would be stored in locations that satisfy the agreed security level. All personnel working on the teams would have an Australian police clearance.
Hardware failure	A risk analysis would be performed on the scanner to anticipate any possible breakdowns or glitches and spare parts would be on hand in readiness, if required. This might include a spare scan head. Staff would be trained in troubleshooting and it would be desirable to have a support contract in place with the supplier. This would minimise any downtime in the data collection.
WEAR interface	It is proposed that raw data would be available through the WEAR network. This would add functionality of applications especially the rapid searching of data, building queries and statistical analysis functionality. This would also constitute another backup location for the raw data.

Table 10: Survey organisational issues

9 Conclusion

In this report Chapter 3 of the project: *Defining the method and scientific parameters for the Australian Body Sizing Survey*, we have addressed the key features of stakeholder engagement and how this will determine the range and type of measurements to be obtained for the Australian Body Sizing Survey, and describe the systems engineering model that will be used to develop the testing required to finalise the survey method, business plan and costing. We have also discussed possible sizing survey methods, and recommended sampling method, recruitment strategy and data management.

We conclude that the value proposition for the Australian Body Sizing Survey is compelling. The data from the survey would contribute to the well-being and welfare not only of working women and men, but also to the broader community. We have put the focus on design for the workplace and the impact of the survey on work health and safety and assert that the Australian Body Sizing Survey will contribute to at least three of Safe Work Australia's Action Areas: healthy and safe by design, supply chains and networks, and health and safety capabilities. The impact will flow from the development of Australian body size information, in combination with the adoption of new methods of using these data, to influence the physical design of workplace environments and equipment. Investment in this approach can help to get designs right the first time to avoid the risks and dangers inherent in poor design, the costs of reducing mismatches, and the need to retrofit or refurbish. The survey may also have indirect influence on Safe Work Australia's other Action Areas by influencing the way we think about design and work health and safety.

Stakeholder engagement in the Australian Body Sizing Survey is a critical foundation for success, so this report describes the processes that will enable the systematic identification and involvement of stakeholders from the outset. Stakeholders would not only assist with funding the survey; they would also help to shape the survey and the selection of measurements included in it. As a result they would derive considerable benefit from their engagement that will lead to improvements in design for all Australians.

Regardless of the method selected to conduct the Australian Body Sizing Survey, there will be significant costs associated with it. We propose two user-pays funding models to initiate thinking about how the necessary finance to support the survey might be raised. They combine the allocation of a set number of measurements that would be determined by general consensus between all stakeholders, regardless of their level of funding contribution, with a second and larger allocation of measurements that survey sponsors can determine. The number of measures that a funding stakeholder could determine would be directly proportional to their level of contribution. The models differ in the number of agreed measures and the number available for negotiation. Both funding models allow for in-kind sponsor support such as use of facilities, manufacture of scanning garments or the provision of inducements and incentives for subjects. At the outset of the project we propose that only two measures be regarded as non-negotiable: standing height (stature) and weight. All other measures would be open to negotiation with stakeholders.

Whilst stakeholder engagement is critical to the Australian Body Sizing Survey, the complexity and technical nature of the project cannot be denied. In order to establish clear and transparent processes for the development of the technical scope of the project, the selection of measurements, the investigation into the most appropriate landmarks and scanning options would need to be informed by subject-matter experts. Thus, we propose that an international Technical Committee, consisting of technical experts, would be established to provide technical input and act as an arbiter when technical decisions are being made.

The Australian Body Sizing Survey project would need to assemble a multidisciplinary team at the outset and adopt this approach for the planning and co-ordination of resources and logistics. Risk and quality management systems would also be required to establish effective management systems and methods to run the Australian Body Sizing Survey project.

This complex project would require a multitude of iterative steps: ongoing stakeholder consultation, determination of the measures to be obtained, review and selection of a whole body scanning device, testing of the method and equipment, recruitment and training of a project team, running an initial trial or pilot survey, subject recruitment, delivery of the main survey and the processing and management of the data. We propose that this systems engineering approach is used to manage this project and the interactions between these components.

Any contributor of funds to the Australian Body Sizing Survey will be seeking value for money. We have identified several areas where value for money lies in this project. We have considered the value proposition for stakeholder engagement, identified the trade-off between utility and cost, and considered where value for money lies in the selection of a scanner to do the work. We propose that spending on this project will deliver best value for money when a medium to high level of expenditure is made on the components of the project. That is, on the one hand, a low cost approach will be incapable of delivering results that are useable for design purposes, effectively defeating the purpose of the exercise. On the other hand, high cost in all components of the project is not necessary to achieve the desired outcomes. We have plotted the path through this maze by providing the information necessary to determine where to place the highest expenditure in order to gain the best outcomes.

Australia is well placed in the timing of the Australian Body Sizing Survey to take advantage of cutting edge scanner technologies. We are concerned that the best value for money in the selection of a scanner is an important part of the establishment of the project, so this report provides some basic information about the range of scanners currently available and includes information about leading edge technologies. These potentially allow for the collection of dynamic range data (4-D) for the first time. These data would be of particular value in the work health and safety arena, especially if combined with biomechanical data. A large-scale Australian survey using these parameters would create the next gold standard for an anthropometric survey with concomitant competitive advantage for stakeholders.

Finally the report discusses the issues of subject selection and participation, including the ethical requirements that accompany involvement of subjects in a project like this. We discuss the importance of retaining high quality control on the data and effective data management for the long term. We also consider the importance of comparability of data, particularly in making the output of the Australian Body Sizing Survey available to designers through the existing, international online portal, WEAR.

The Australian Body Sizing Survey potentially opens new opportunities for Australian designers, data analysts, tool developers, manufacturers and other stakeholders in this important project. It has the capacity to place Australia at the leading edge in these fields providing new opportunities as well as healthy and safe workplaces.

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