# The development of BoSS XXI and its application in the Canadian Forces

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***Abstract***

In the measurement of anthropometrical dimensions, an automatic method has a number of advantages over a conventional manual method. However, it is key to establish, a correlation between these two methods, and to identify and understand the error sources, if any.

This paper describes the development of BoSS XXI, an automatic measurement system of anthropometrical dimensions and its application in the Canadian Forces.

Currently, BoSS XXI systems are installed at 13 Canadian Forces locations. BoSS XXI has become a useful tool in assisting the Canadian Forces in developing, procuring and issuing clothing and personal equipment systems.

## 1. Introduction to BoSS XXI

BoSS XXI, **Bo**dy **S**izing **S**ystem for the 21st century, is an image-based automatic anthropometrical measurement system. This system simultaneously captures two high-resolution images of a person one from the front and one from the side. The proprietary image processing software analyzes the images and automatically detects a number of anthropometrical landmarks. The 3-D location of each landmark is determined, and a sophisticated algorithm is used to calculate various body dimensions.

In addition to providing the anthropometrical measurements of subjects, BoSS XXI includes powerful features that manage the subject records as well as develop and apply garment sizing rules.

BoSS XXI was developed to combine the expertise of garment and equipment designers with the consistency and speed of a computer. BoSS XXI removes the guesswork from garment fitting, which can speed the entire process dramatically. The sizing recommendations of BoSS XXI are meant as a starting point when fitting a client. Individual preferences and requirements vary greatly, and some individuals prefer garments that are snug, while others prefer garments that are loose.

The development of BoSS XXI began in 1996 as a research project. The technology has been used at Canadian Forces bases since 2003 for anthropometrical data collection and clothing and equipment size allocation.

## 2. Development of BoSS XXI

### *2.1 Requirements analysis*

There are a number of approaches to describe a human body, some of which are; anthropometrical body dimension values, 3D surface data of the human body and dynamic models of the human body.

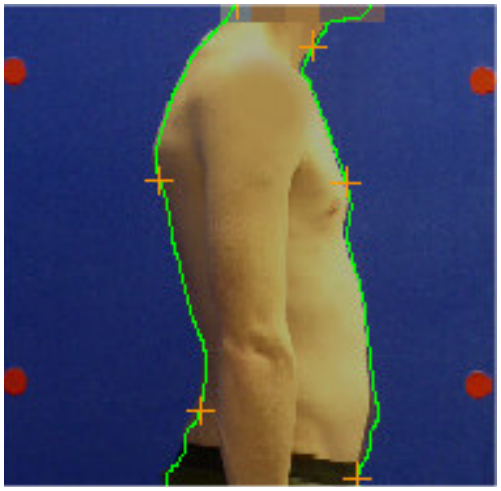

Fig. 1 Compensation on chest measurement

BoSS XXI provides direct anthropometrical body measurements, while a 3D surface model is generated using the anthropometrical data.

In the case shown in Fig. 1, the chest measurement is compensated in BoSS XXI as if the individual is standing straight, since a human measurer would instruct the subject to stand straight prior to measuring. The goals of BoSS XXI are to a) follow the measure-

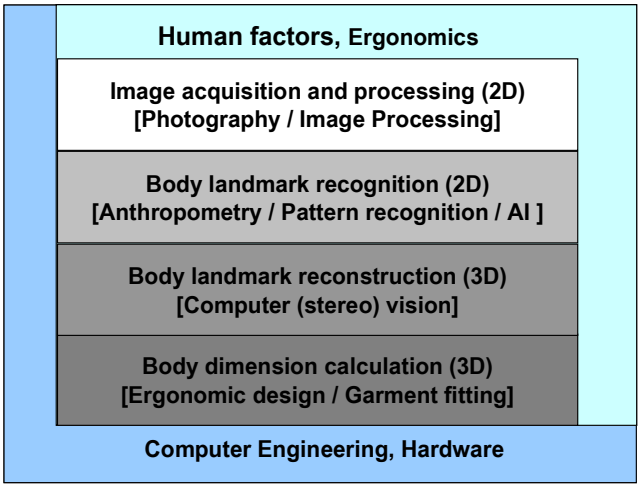


Fig. 2 BoSS XXI System Framework

ment approach a human expert would use; and b) detect body landmarks automatically without operator involvement in order to avoid possible human error and reduce measurement inconsistencies.

### *2.2 System framework*

The BoSS XXI system framework is shown in Fig 2. This framework contains 6 elements. 4 inner elements form the algorithm kernel for data processing and calculation. The element of computer engineering and hardware is the carrier and physical presence of the BoSS XXI system. The element of human factors is responsible for the operational interface.

This framework has the following characteristics: a) Anthropometrical knowledge is introduced at the early stage of the algorithm. BoSS XXI is specialized and reliable in its anthropometrical application; b) Direct-data-exchange among the elements in the algorithm kernel facilitates the feedback and error compensation; c) Algorithm kernel is separated from the hardware and operational environment and hence ready to be adapted to a new environment.

### *2.3 Validation of the measurement values*

The measurement values by BoSS XXI are validated in terms of repeatability and accuracy. In the repeatability study, the measurements by BoSS XXI, a single observer and two observers are compared.

The technical error of measurement (TEM), which is essentially a form of standard deviation, was used as the basis for comparison. The TEM, or *r*, was calculated using the following equation:

$$r = \sqrt{\frac{\sum_{i=1}^{n}\left(\sum_{j=1}^{k} x_j^2 - \frac{1}{k}\left(\sum_{j=1}^{k} x_j\right)^2\right)_i}{n(k-1)}}$$

The result is shown in Fig. 3.

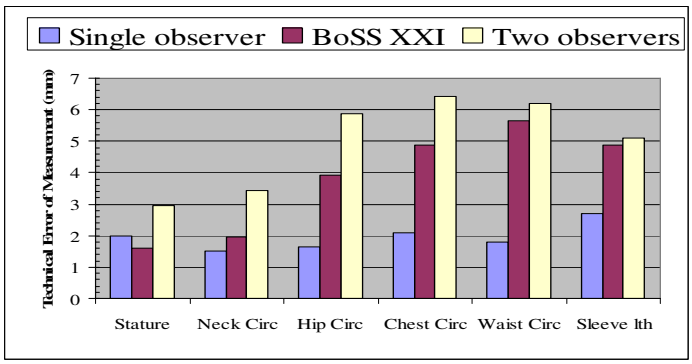


Fig. 3 Comparison of TEM (technical error of measurement)
Single observer is based on the survey on Canadian Land Forces personnel in 1997 [2]
BoSS XXI is based on experiment using BoSS XXI in 1999
Two observers is based on the survey on US Army personnel in 1988 [3]

In the accuracy study, the measurement values on the same subjects obtained by both BoSS XXI and human experts are compared. The means and standard deviations for the subjects measured manually and by BoSS XXI are listed in Table 1. T-tests did not indicate any significant difference between the manual and digital methods for either males or females. Table 1 also lists the Pearson correlation coefficients between manual and BoSS XXI measurements.

Table 1. Comparison of manual and BoSS XXI measurements

| | Females | | | Males | | |
|---|---|---|---|---|---|---|
| Measurement | Mean (mm) | Stdev (mm) | Correlation | Mean (mm) | Stdev (mm) | Correlation |
| Stature: | n=95 | | | n=254 | | |
| Manual | 1633 | 60 | 0.98 | 1747 | 64 | 0.98 |
| BoSS XXI | 1633 | 59 | | 17487 | 63 | |
| Neck circ.: | n=62* | | | n=254 | | |
| Manual | 329 | 18 | 0.88 | 395 | 23 | 0.94 |
| BoSS XXI | 329 | 16 | | 395 | 22 | |
| Chest circ.: | n=88* | | | n=254 | | |
| Manual | 956 | 87 | 0.95 | 1024 | 83 | 0.94 |
| BoSS XXI | 957 | 84 | | 1024 | 78 | |
| Hip circ.: | n=95 | | | n=238** | | |
| Manual | 1027 | 91 | 0.98 | 1005 | 72 | 0.94 |
| BoSS XXI | 1026 | 89 | | 1004 | 68 | |

* Some subjects were rejected due to interference of hair with landmarking
** Some subjects were rejected due to clothing interference (boxer shorts)

While a high degree of accuracy in anthropometric measurements is always desirable, it is not always necessary. The requirement for accuracy should be established on the basis of the application. Short-term body changes, clothing design, fit, and manufacturing tolerances were used as guides to estimate this requirement for the clothing sizing application. For comparison purposes, the typical garment manufacturing tolerance, the normal body variation [4] and the TEM of BoSS XXI are listed in Table 2.

Table 2. The requirement on measurement accuracy （mm）

| *Typical garment manufacturing tolerances (Canadian military )* | | | *Normal body variation* | *TEM of BoSS XXI* |
|---|---|---|---|---|
| | Variable | Tolerance | | |
| Trouser | Waist circ. | ± 13 | 10.7 | 5.6 |
| Shirt | Neck circ. | ± 6 | 2.5 | 2.0 |
| | Chest circ. | ± 13 | 7.6 | 4.8 |
| | Sleeve length | ± 13 | | 5.0 |

### *2.4 Implementation development*

The system has gone through various iterations from its initial design to the present configuration. The initial design incorporated a wooden structure, two


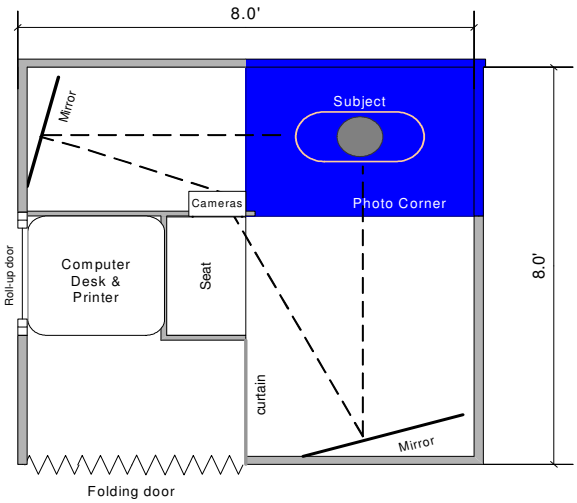


Fig. 4. An overview of BoSS system

Sony digital cameras on tripods and a laptop. This resulted in a cumbersome unit that occupied a large footprint. Although footprint and size were not major factors initially, they became paramount when implementation was considered.

It was evident that the system could be installed in anything from a post World War II warehouse to a modern office environment. The area could have a variety of light sources, low or high ceilings, an uneven concrete floor or carpeting. A small footprint would allow for easier installation. The system had to be compact and self-contained. Initially the system footprint was 15 X 15 feet. By incorporating a mirror system, the footprint was reduced to 8 X 8 feet. The approach ensured that the proper projection was maintained and limited the perspective distortion in terms of image capture and 3D measurement calculation.

Infrastructure changes to existing facilities were not to be considered, therefore the system had to adapt to the installation site, specifically with respect to the lighting sources. In order to achieve optimal resolution, the system had to be adjustable to account for the various lighting systems which included fluorescent, tungsten, natural and other types of lighting. The lighting readings are recorded and entered into the system during initial installation and can be manipulated through the software when required.

Individual privacy and system security was incorporated into the design. Since subjects are required to dress down to underwear for the scanning procedure, maintaining privacy for the individual is very important. The physical system needed to be designed with this in mind. The BoSS XXI shelter was designed somewhat like a change room, with an inner area consisting of the imaging platform, cameras, seat, hooks for hanging clothing articles and a privacy curtain. The outer area holds the computer and can be completely enclosed with sliding and locking doors, as shown in Fig. 4.

The intent was to develop a system that could be self-operated or controlled by a system operator. This would allow individuals to scan themselves in privacy with minimum instruction. The best scenario is to have a well-trained operator perform the scanning. This results in the highest accuracy as well as the fastest throughput time. Keeping constantly changing military personnel trained to a high caliber is problematic. The preservation of a consistent knowledge base is best achieved by training permanent civilian employees, who can be augmented by military personnel.

Since the scanning procedure can be done either by self-scanning or by a trained operator, the system allows you to perform image capture in two ways. Image capture can be initiated by the individual being scanned through the use of a handle button, or by the operator at the computer. The development of the handles served two purposes, to assist with proper posture during scanning and to initiate image capture. Proper standing posture is one of the key elements in successful scanning and the handle positioning ensures that the arms remain at a proper distance away from the body. This enables the system to identify the body outline against the backdrop. Fig. 5 illustrates the key elements of scanning, taken from the Quick Reference Guide.

## 3. BoSS XXI application in the Canadian Forces

As a new technology, there were some misconceptions initially. Some employees felt that the system was meant to replace them. Some felt that the system was an affront to their abilities. It was discovered that BoSS XXI had a higher acceptance rate amongst a younger, more technology savvy segment than those who had been working in the supply field for a long

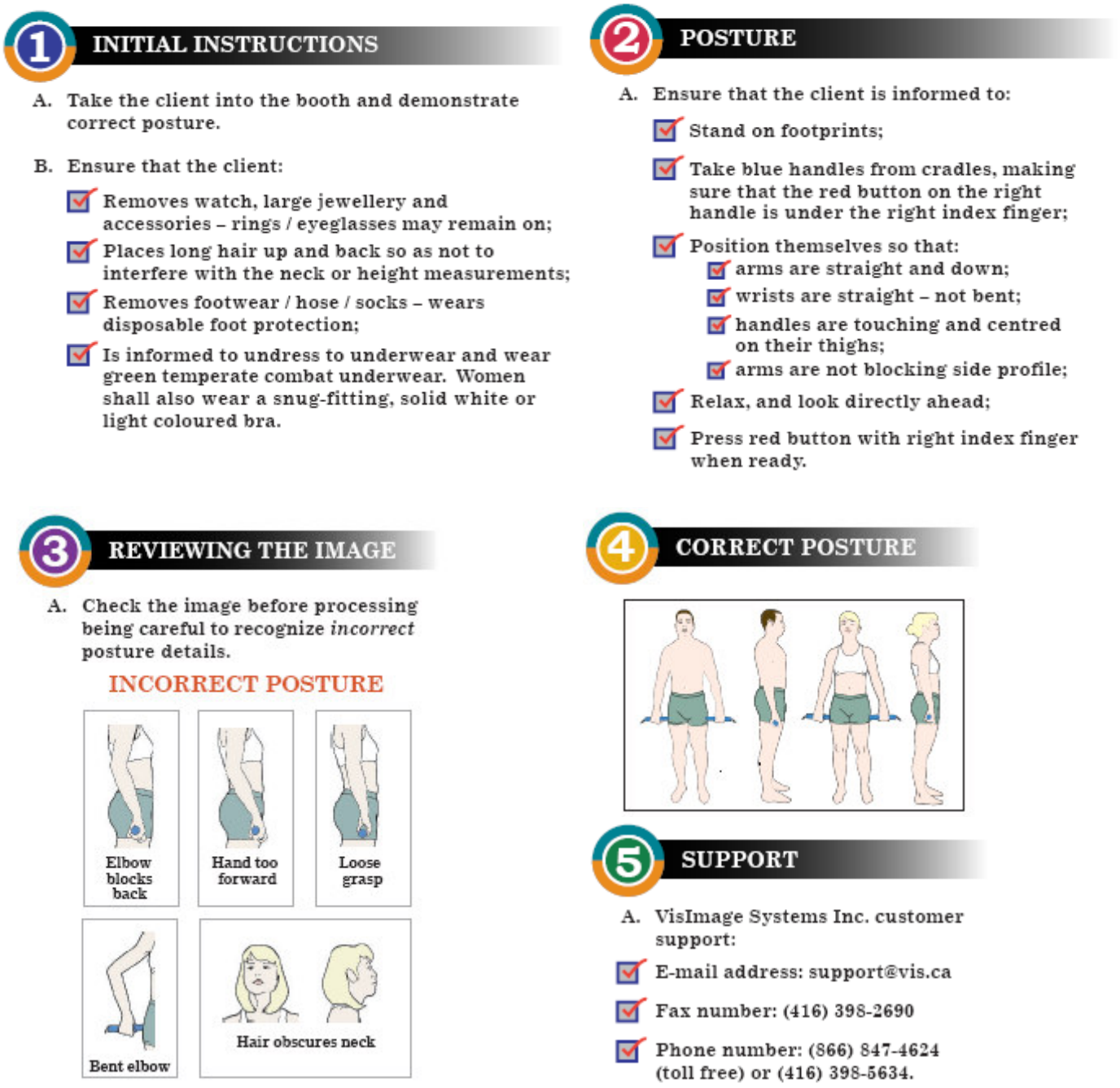


Fig. 5, The Quick Reference Guide

time. It is important to consider the acquired knowledge of the clothing stores staff and empower them to take ownership of the BoSS XXI technology.

To the user, the system is presented as a tool to assist with sizing. The resulting information can be provided to tailors and manufacturers to assist with sizing. The designers and procurement specialists use the information to identify size ranges and sizing tariffs not only for garments but also for personal equipment.

The application of BoSS XXI in the Canadian Forces environment involved many factors. Some key issues are detailed as follows:

### *3.1 Defence Wide Area Network*

The systems are connected to the DWAN (Defence Wide Area Network) in order to facilitate email communication between the bases/sites. The average file size for each scan is 55K. Approximately 200 scans per week are performed at all locations.

The BoSS XXI runs on Windows XP operating system. The BoSS XXI system is connected to the DWAN and is operated as per an individually assigned work station or as a stand alone system. All information from the various Wings and Bases is sent as email attachments to and from the central BoSS XXI. Each location exports the scan data to the Headquarters

where the information is centrally managed and dispersed. On a monthly basis, the system administrator updates the database and then sends it to the BoSS XXI locations. In addition, new clothing sizes, grading rules and designs are sent as an email attachment for import to the BoSS XXI data file, so that all locations have the most recent information with respect to clothing sizes and personnel data.

### *3.2 Security architecture*

The following provides a general description of the BoSS XXI security architecture required for the deployment of the system in Canadian Forces facilities:

a. **Personnel Security**. The BoSS XXI user community consists of Wing and Base clothing stores personnel. All users must have at the very least an enhanced reliability security clearance.

b. **Physical Security**. At all locations the BoSS XXI system resides within the confines of a military installation and are protected under the applicable local Security Orders;

c. **Procedural Security**. Information System Security Officers (ISSO) are appointed at each location. The role of the ISSO is to provide security advice, produce and coordinate C&A documentation, to ensure that the conditions of accreditation are maintained and to respond to any security procedural changes.

In addition, the system software and hardware were required to meet the following basic security requirements established by the Canadian Forces.

**Information Technology Security (ITSEC)** The following highlights individual security features of the implemented BoSS XXI ITSEC facets:

1) **Computer Security (COMPUSEC).** The following lists the existing COMPUSEC features:
   (a) Formal access approval is enforced. Only those individual that have a functional need to access the system are granted an application password;
   (b) Users can only access the BoSS XXI with a valid LAN ID and password;
   (c) with a valid application password;
   (d) Passwords must be changed as per the existing procedures for DWAN users, and

2) **Transmission Security (TRANSEC)**. Communication on BoSS XXI system via the DWAN, requires TCP/IP and strong access control (user ID authentication and password) to two stages: access to the network, and access to the application, and

3) **Network Security (NETSEC)**. The protection of the BoSS XXI topology and routing is ensured by using the DWAN as the backbone. It is therefore assumed that any real threat would originate internally. To combat an internal threat the following security is applied:
   (a) Strong Identification and Access control, and
   (b) Separate application passwords

4) **Personnel Data Security**
   (a) once an individual is processed, the image is converted to body measurements and the image is deleted from the computer, and
   (b) the print screen button on the computer system is disabled as an additional security measure.

### *3.3 Training and maintenance*

It is important to train as many people as possible at each installation site. As mentioned earlier, it is also crucial to train a civilian member to maintain the knowledge base at that location. The staff is empowered to train new people and to use support mechanisms when necessary, such as the user guide, on-line help and the 1-800 support line. Refresher training is provided during each visit to a site location to ensure that the important aspects of the scanning procedure are retained as well as to glean any concerns or potential problems.

A Canadian Forces Technical Order will be developed to provide guidance and procedures on the proper maintenance of the system. Due to the nature of digital image technology, it is important to maintain a clean and tidy system. System operators are directed to reduce dust and lint as much as possible from the backdrop and mirrors.

### *3.4 BoSS XXI deployment and benefits*

Currently BoSS XXI has been installed at 13 Bases and Wings in Canada. A central database containing all of the body measurements and uniform sizing data is updated regularly and shared across Canada at all BoSS installation sites. If an individual is transferred, his/her sizing information is readily available at another BoSS XXI location. As shown in Fig. 6, the central database is used for customer fitting, special sizing, garment design and inventory management.

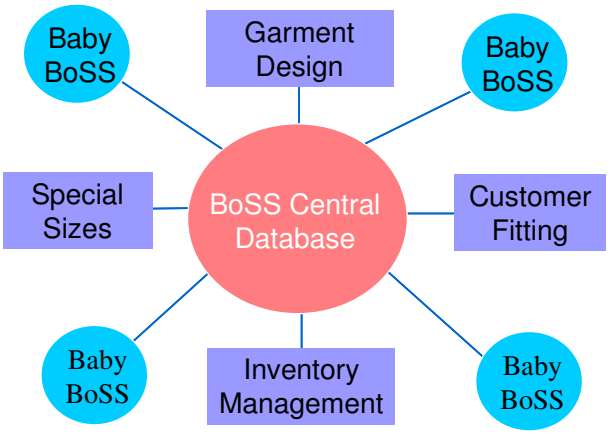


Fig 6. A central DB is shared cross Canada

BoSS XXI has been used in the development, sizing and procurement of protective garments such as Firefighter Bunker Gear and CBRN items where garments require a more exacting fit.

The data generated by the system assists in identifying any shortfalls or excesses in size ranges. This allows for adjustments to future design and procurement decisions. As shown in Fig. 7, it is possible to overlap an existing size range onto collected body data information.

As indicated earlier, the system assists the clothing stores staff in obtaining accurate measurements for the management of special sizes (sizes either outside the normal range or ones that require non-standard alteration). The system is also being used regularly to verify special sizes by reviewing the outline and body measurements. The body outline provides insight into non-standard alterations that may be required. The system provides valuable information in an environment where skilled tailors are declining in numbers.

The database is being used to identify sizing tariffs to accurately predict the numbers of each size that need to be procured. Sizing information can also be cross-referenced with military occupation so that specific sizes of items can be ordered based on the occupational group. Searches of the database can be made using the following data analysis criteria: gender, element, date range, single measure range, location, garments and body measures.

## 4. Future development

Algorithms are currently being developed to calculate hand and foot dimensions for hand wear and footwear applications. In future, algorithms will be developed to identify additional body landmarks and measurements for the purpose of fitting new garment items and personal equipment. Also, additional scanning systems will be procured for deployment at other Canadian bases.

## 5. Summary

Initial development of the BoSS XXI automatic body sizing system began in 1996. The system is in use today at military Bases across Canada.

1) BoSS XXI provides objective and accurate body measurements.

2) Through the application of BoSS XXI systems, anthropometric data can be collected and used to design, size and procure clothing and personal equipment, thereby reducing the need for traditional manual anthropometric surveys.

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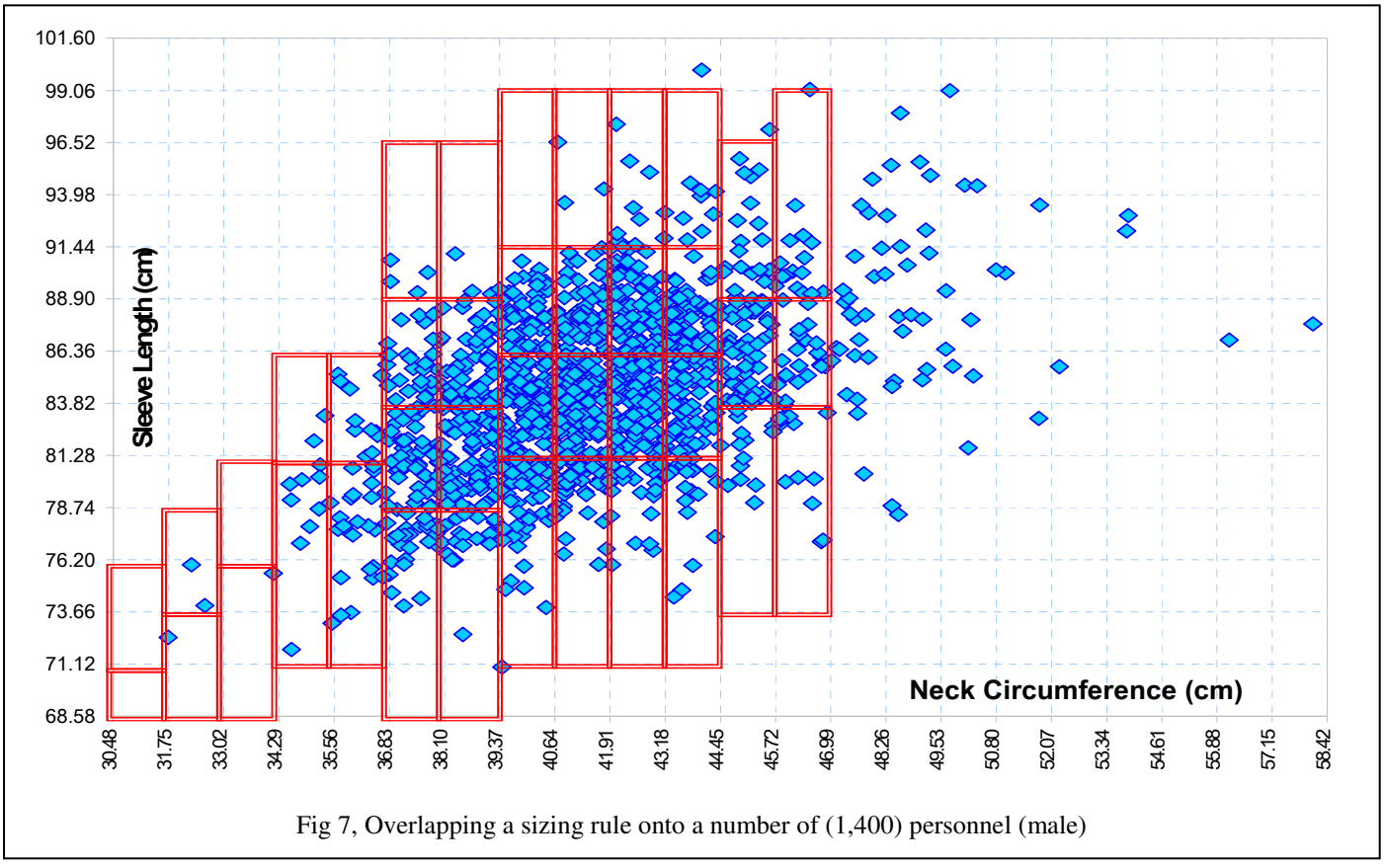


Fig 7, Overlapping a sizing rule onto a number of (1,400) personnel (male)

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