Development of a 3D Polygonal CAD Model for DRDC Ottawa Human Phantom (Phil)

Ray M. Obidowski, M.Sc.
Array Systems Computing Inc.
1120 Finch Avenue
Toronto, Ontario

Contract Number: W7714-043015/001/SV
Contract Scientific Authority: Dr. Walid Chamma

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Defence R&D Canada - Ottawa

Contract Report

DRDC Ottawa CR 2005 - 170

December 2004

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Executive Summary

This document contains a summary of the processing, results and validation for the three-dimensional (3D) CAD model production of Defence Research and Development Canada–Ottawa's (DRDC-Ottawa) Phantom. Laser scanning was completed on November 29, 2004, and production of requested 3D Polygon models was completed on December 3, 2004.

The required Root Mean Square (RMS) accuracy of +/- 2.0 millimetres (mm) was successfully met, as shown in the validation section. The Polygon models of the Phantom, in several resolutions have been created and exported to the required DXF format, as confirmed by the Scientific Authority (SA).

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1. Background and Requirements

Defence Research and Development Canada-Ottawa (DRDC-Ottawa)/Radar Electronic Warfare (REW) is currently involved in various research and investigative projects that involve the geometry of the human body (e.g. detection of snow avalanche victims, Electro-magnetic (EM) fields inside a human body, etc.). A human body phantom was built for DRDC-Ottawa (shown in Figure 1), and was used in lab measurements. To compliment those measurements with computer modelling, a Computer Aided Design (CAD) representation of the human phantom is required. This will allow DRDC-Ottawa to conduct additional investigations through the less expensive computer modelling. The EM analysis software to be used will import the human phantom CAD file into its modelling space and illuminate it with the desired EM waves.

The EM analysis software requires that the CAD file be in specific standard formats such as: AutoCAD DXF Solids, SAT, STL, STEP, etc. Presently, using the "Laser Scanning" technology such three-dimensional (3D) CAD files of complicated objects can be generated for a specified accuracy.

Array Systems Computing Inc. (Array) was contracted by DRDC-Ottawa to produce the 3D CAD polygon model of the Phantom figure, shown in Figure 1.

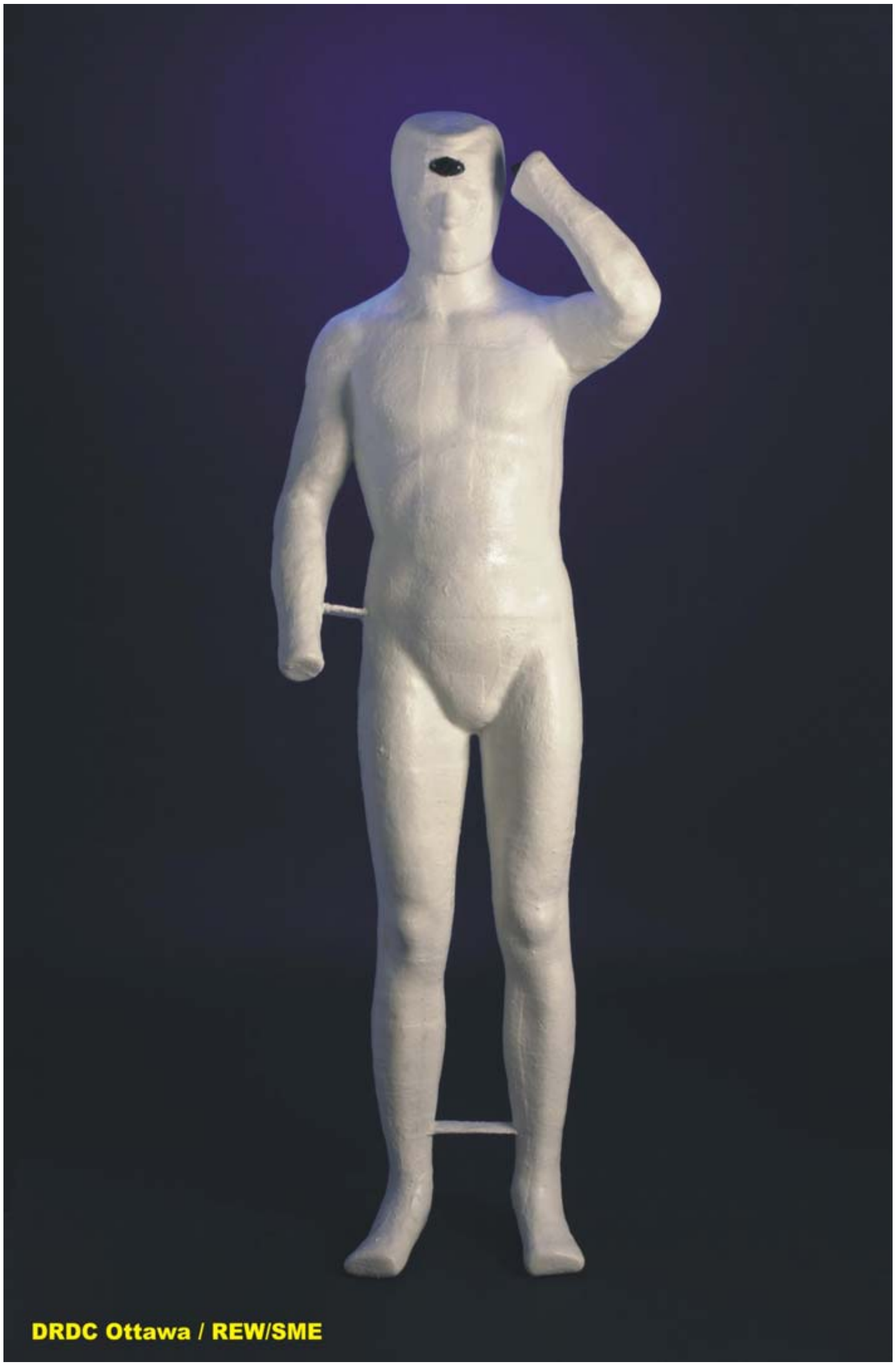

Figure 1. *DRDC-Ottawa Phantom (Phil)*

The detailed requirements and deliverables from the Statement of Work (SOW) are:

Tasks

1. The human phantom model will be shipped to the contractor's facilities to perform "Laser Scanning" and then returned back to DRDC-Ottawa after completion.
2. The contractor will communicate with the SA to examine which CAD formats will represent the human phantom accurately. This can be done by testing on sample objects that the contractor might already have. The supported CAD formats are: DXF Solids, SAT, STL, STEP.
3. Produce 3D polygonal model, with 2-millimetre (mm) Root Mean Square (RMS) accuracy.
4. Produce a simulated shell for the human phantom (in EM modelling the human phantom will be filled with a specified material) with 8.0-millimetre thickness.
5. In "Laser Scanning" holes and defects might result in the CAD model. The contractor will repair such deficiencies.
6. The CAD file will consist of two graphic (material) layers: a) the human phantom shell, b) the interior of the human phantom. In EM modelling each will be assigned a specific physical material.

1.1 Deliverable Items

1. A geometry CAD file representing the DRDC-Ottawa Human Phantom in a format(s) compatible with the EM simulation software on a CD-ROM.

7. Three hard copies of the Final Report and one electronic copy using MS Word 2000 on a CD-ROM for the Technical Authority and 1 hard copy of the Final Report for the Contracting Authority. In addition to the disclosure obligation under Section 02 of the supplemental general conditions 9601-7, any Foreground Information shall be fully disclosed and documented by the Contractor in the technical reports delivered by the Contractor to the Technical Authority under this Contract.

2. Report on Laser Scanning and Data Processing

Laser Scanning of the Phantom took place on November 29, 2004. Originally, we planned to do the scanning using a ShapeGrabber Portable laser scanner, but due to technical problems and malfunctions with that instrument, we instead used a more robust Cyrax 2500 laser scanner, shown in Figure 2.

Figure 2. *Cyrax 2500 Laser Scanner and Controller*

The laser scanning required approximately 5 hours, collecting over 800,000 data points in a 2-mm grid. A total of 21 scans of Phil were collected, from various angles, achieved by rotating Phil to various positions. Overlapping geometry between the scans enabled them to be aligned to each other. At all times, the scanner itself remained stationary.

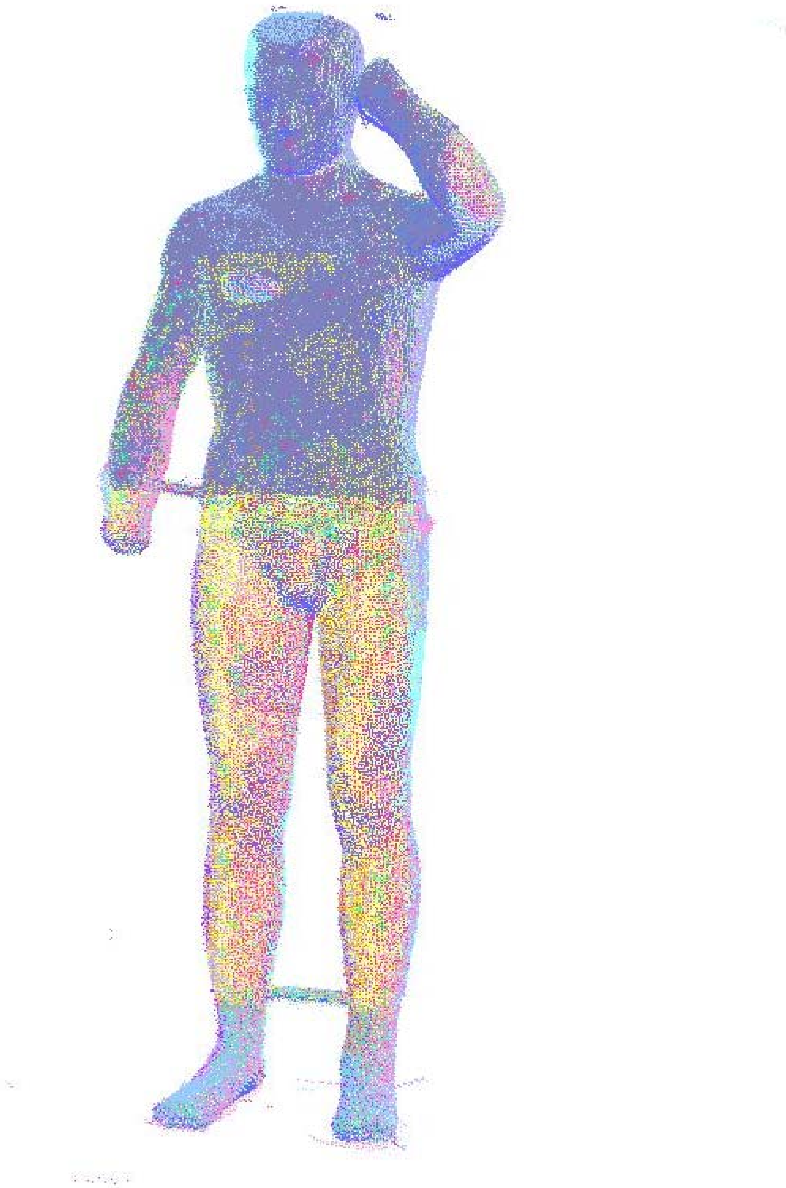

Figure 3. *Point Clouds Aligned From Laser Scanner*

The point clouds from the laser scanner were imported into Innovemetric's Polyworks software to be aligned and further processed. Figure 3 shows the alignment of the scans; each color contains data from a different angle.

Alignment of the point clouds indicated that the scans were aligning together with RMS accuracy of 1-3 mm.

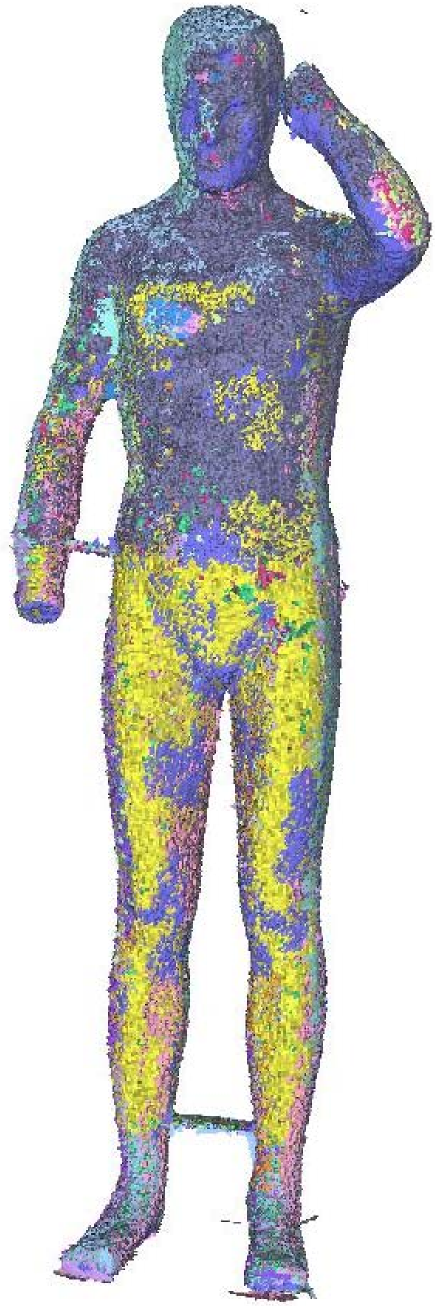

Figure 4. *Aligned, Rendered and Overlapped Point Clouds*

The aligned scans were then processed to remove overlapping regions by selecting the best data from each scan. Figure 4 shows the aligned and merged scans, with reduced overlap.

Next, the IMMerge module of Polyworks generated a triangulation mesh of all the merged scans, resulting in a preliminary raw Polygon model of Phil.

3. Polygon Model Production and Editing

The raw Polygon model, shown in Figure 5, was edited extensively to smooth noise, fill holes, remove degenerate triangles and fix all topology errors. Extensive use of the Polyworks Imedit tools for data smoothing, hole-filling, surface fitting, etc., resulted in considerable improvement to the raw Polygon model.

The resulting 3D Polygon model is watertight and continuous, and free of topology errors. The supporting webs (shown in Figure 5) were removed from the model, to present a more realistic human form.

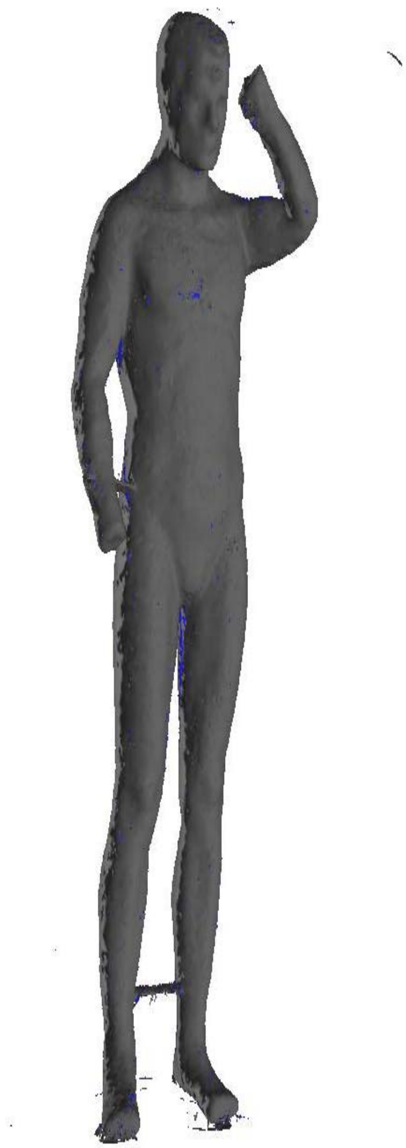

Figure 5. *Raw Polygon Model Before Editing*

Figure 6 shows the resulting final model in wireframe mode.

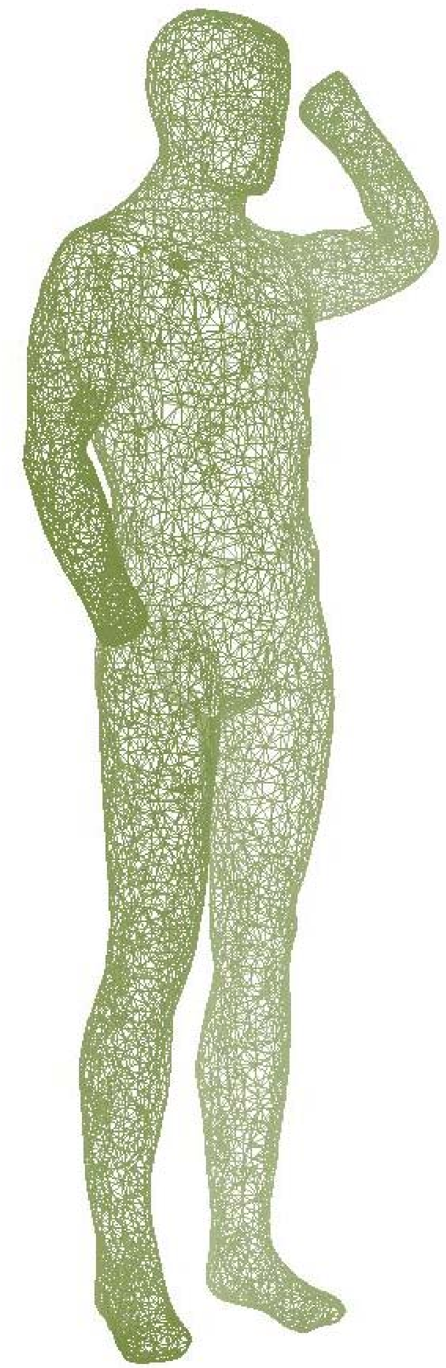

Figure 6. *Triangulated Polygon Mesh of Merged Laser Scans*

Figure 7 shows the data with the Polygon surface rendered on top of the wireframe model, and Figure 8 and Figure 9 show the final rendered model with all smoothing enabled.

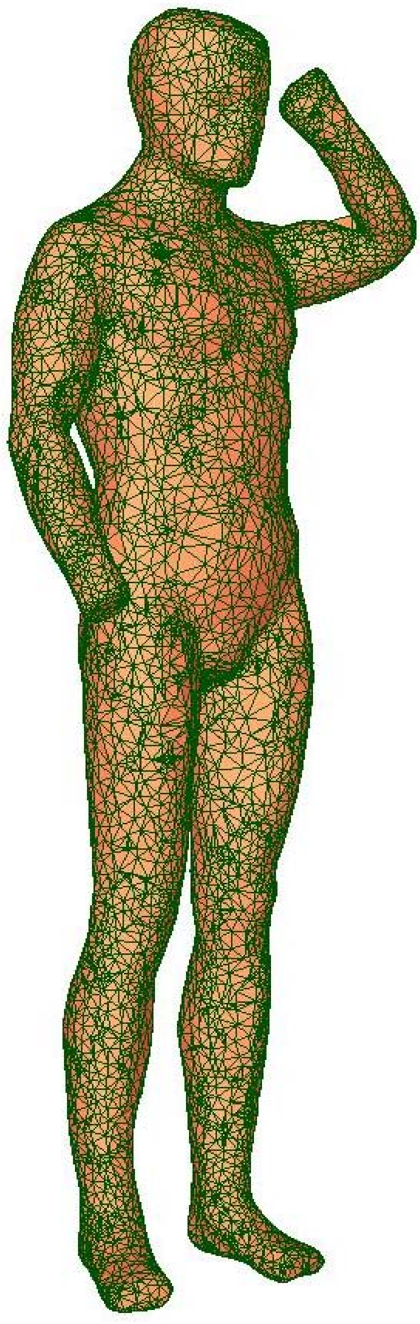

Figure 7. *Polygon Surfaced Mesh*

Figure 8. *Front View of Actual Surface*

Figure 9. *Back View of Actual Surface*

Following the production of the model of the actual surface of the Phantom, layers representing a “simulated shell” were added. As required, offsets of 8 mm were applied to the model to represent a simulated shell or skin.

To maximize the flexibility of the final product, shells were created with offsets both internally, and externally.

To enable the three shells to be easily imported into the SA’s EM software, each layer was exported as a separate DXF file. Thus, the final model consists of three files -- one containing the actual surface, and two with constant 8-mm mean offsets from this surface – one as an internal simulated shell (Figure 10), and the other as an external simulated shell (Figure 11).

The files for the 2-mm resolution model contain the following number of Polygons: Actual Surface – 7,488 Polygons, Outer Simulated shell Layer – 7,644 Polygons, and Inner Simulated shell Layer – 7,160 Polygons.

Figure 10. *Inner Simulated Shell, Front View of Model Offset Internally by 8 mm*

Figure 11. *Outer Simulated Shell, Front View of Model Offset Externally by 8 mm*

4. Validation of Final Model Accuracy

Although not required in this contract, a validation of the model is presented to show that the resulting 2-mm RMS accuracy requirement was met.

Using Polywork's IMInspect software, the final Polygon model for the actual surface was compared to the original point cloud data from the laser scanner.

The software generates color error maps, shown in Figure 12 to Figure 15 for four views of the model (encompassing the model). Also, a statistical summary is generated in Table 1, demonstrating the 2-mm RMS accuracy. It also shows that the model is unbiased from the scan data. In Table 1, distance units are shown in meters.

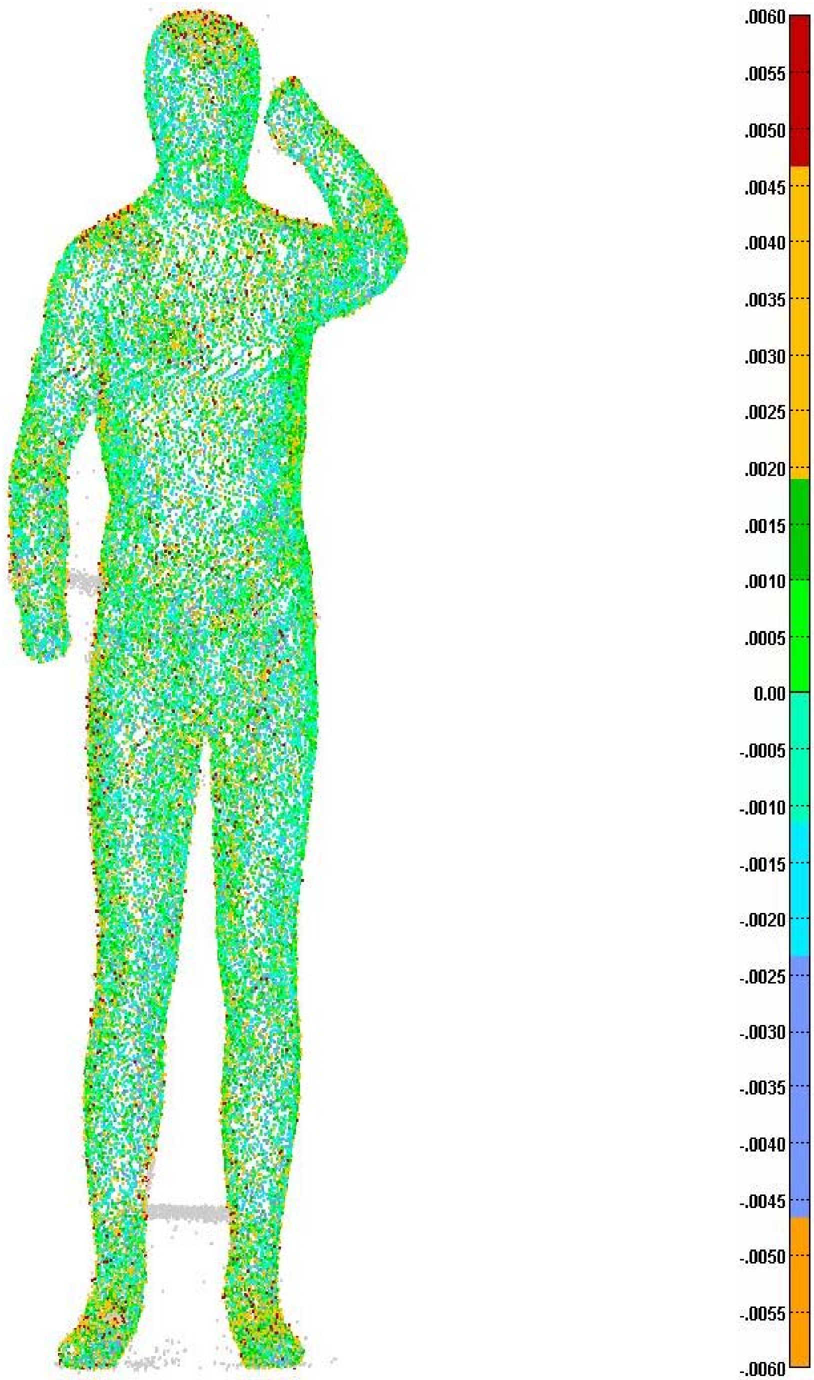

Figure 12. *Error Map of Final Model Compared to Point Clouds, Front View*

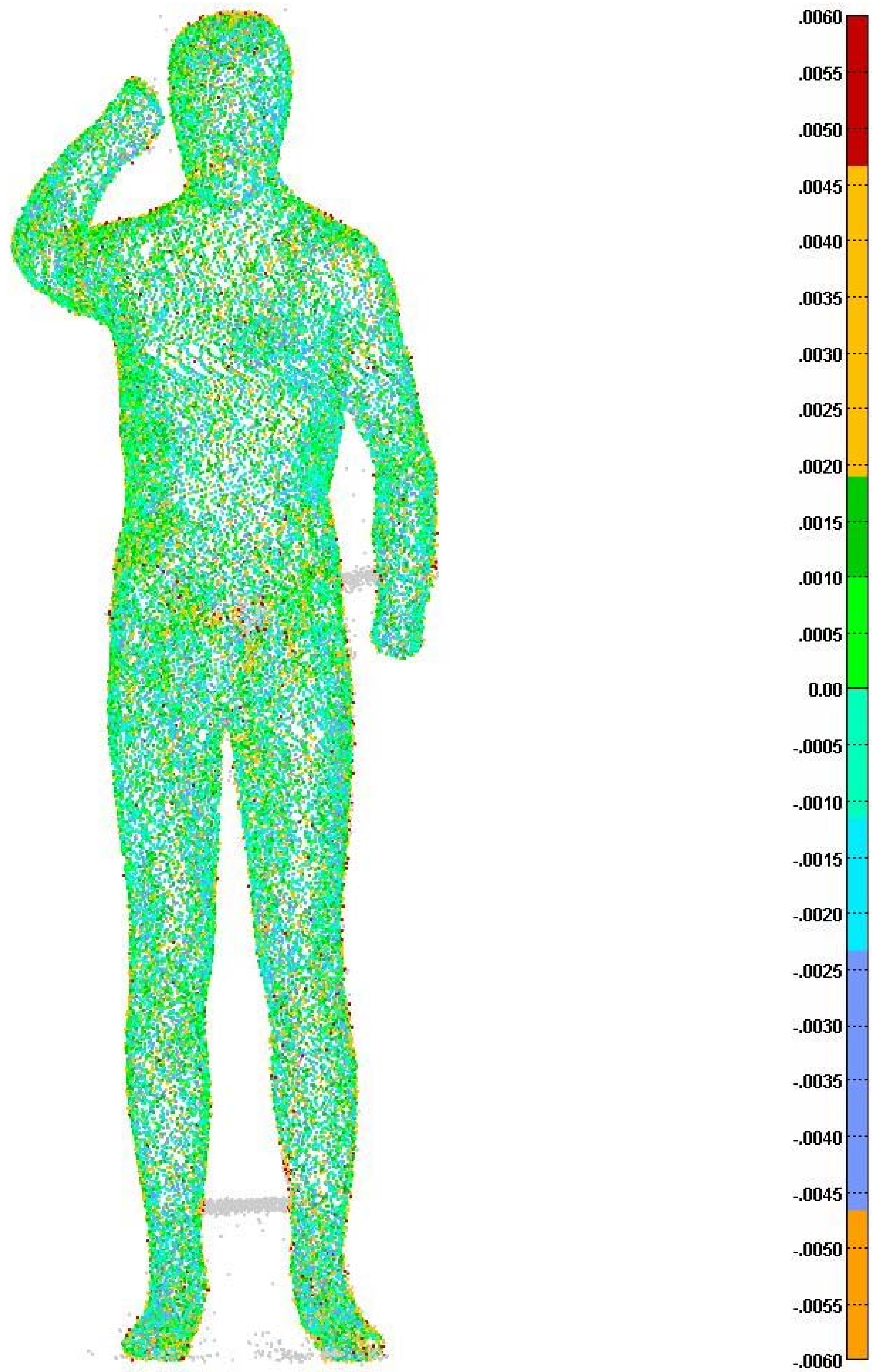

Figure 13. *Error Map of Final Model Compared to Point Clouds, Back View*

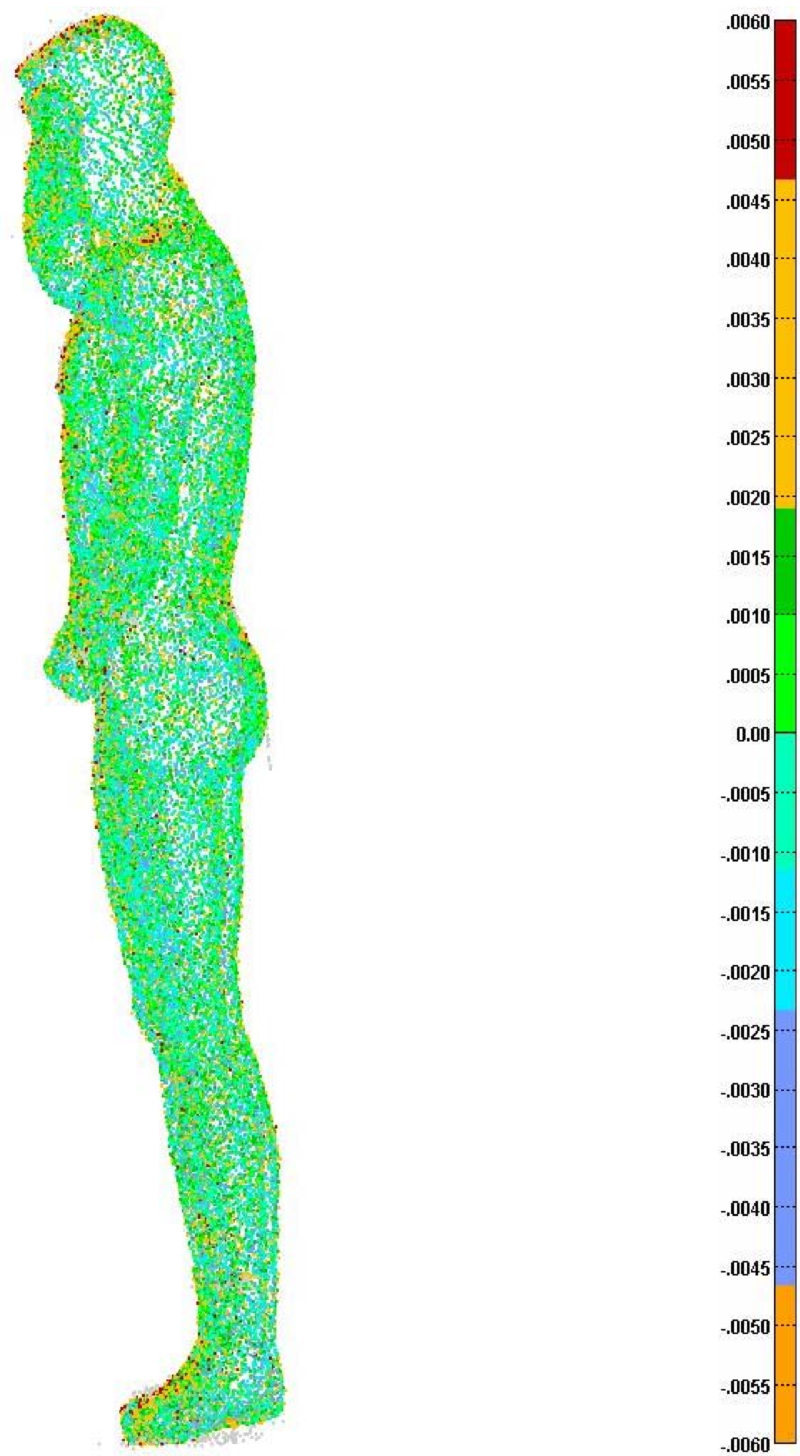

Figure 14. *Error Map of Final Model Compared to Point Clouds, Side View*

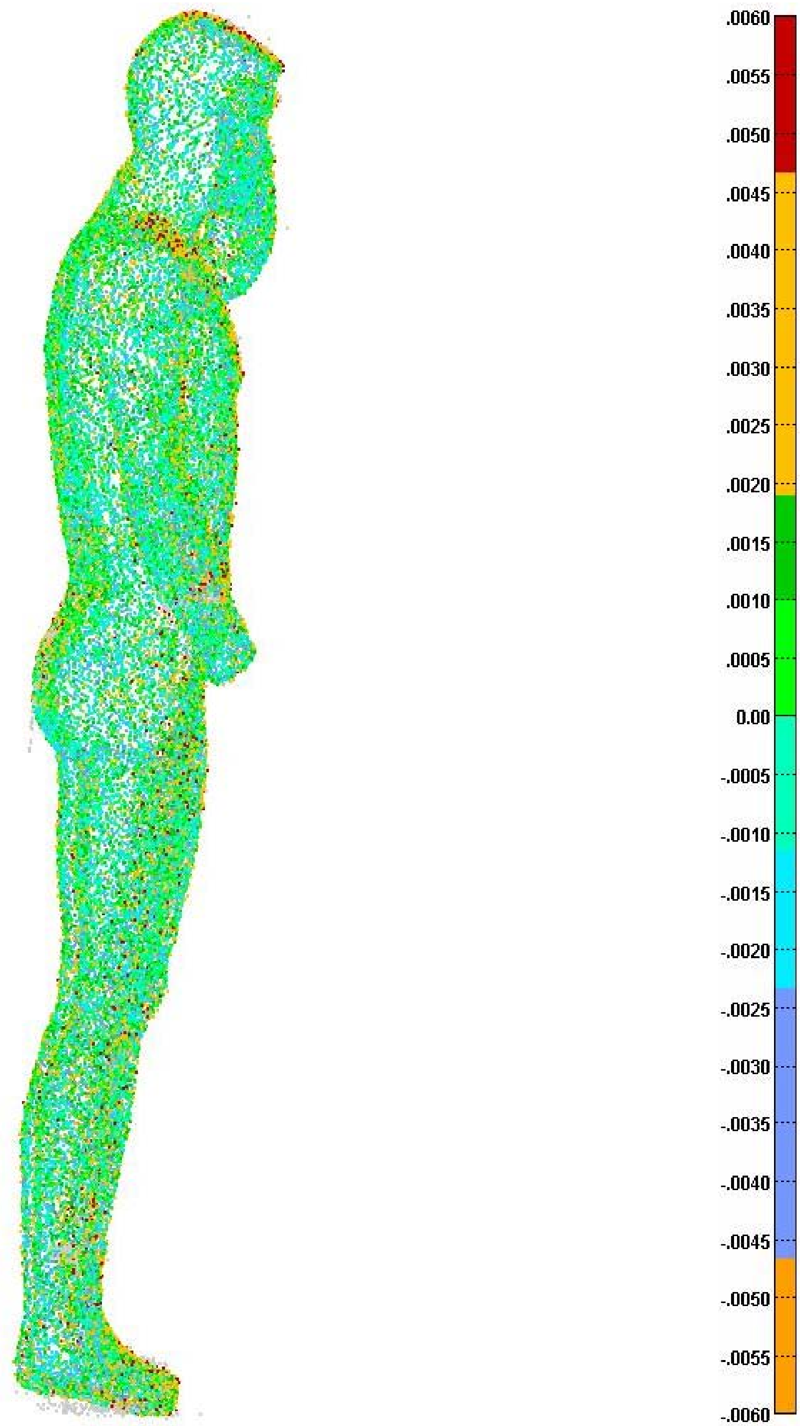

Figure 15. *Error Map of Final Model Compared to Point Clouds, Side View*

Table 1. *Validation Inspection Report*

Report Type	Data To Reference Results
Cmp Object(s)	big_cloud_raw.asc
Ref	outer_simulated shell.pol
Cmp Dist	0.006000
Cmp Angle	45.000000
HiTol +	0.004000
LoTol +	0.002000
LoTol -	-0.002000
HiTol -	-0.004000
Err Dir	Shortest Distance
Offset	
#Points	815299
Mean	-0.000024
StdDev	0.002005
RMS Error	0.002006
MaxErr +	0.006000
MaxErr -	-0.006000
Max Error	0.006000
Min Error	-0.006000
Profile of a surface	0.012000
Pts within +/-(1 * StdDev)	567921 (69.658003%)
Pts within +/-(2 * StdDev)	771197 (94.590696%)
Pts within +/-(3 * StdDev)	815259 (99.995094%)
Pts within +/-(4 * StdDev)	815299 (100.000000%)

Pts within +/-(5 * StdDev)	815299 (100.000000%)
Pts within +/-(6 * StdDev)	815299 (100.000000%)
#Pts Out of HiTol	44588 (5.468914%)
#Pts Out of LoTol	248453 (30.473851%)

5. Final Deliverables and Conclusion

Prior to completion of the project, several simple test files were sent to the SA to test importing of the model into the EM modelling package. Tested formats consisted of DXF and STL formats, which are supported by Innovmetric's Polyworks. Also, tests were made using an SAT format from a format conversion program.

Based on these test files, the SA requested delivery of the final model in DXF format, and these are the models supplied on the CD contained in this package. To maximize the application of the Phantom model, a series of polygon models were created at various resolutions, including 2 mm, 3 mm, 5 mm, and 10 mm accuracy.

To facilitate import into the SA's EM modelling software, three files were produced for each of four requested resolutions: one for the actual surface, one for the outer shell (or skin), and one for the inner shell (or skin). Each shell is offset by 8 mm from the actual scanned surface.

Array is pleased to supply the models requested, and laser scanning and processing of the data was completed to the required accuracy. We recommend this technique for producing and importing 3D graphics models to the SA's EM software.

List of acronyms and abbreviations

3D	Three-Dimensional
Array	Array Systems Computing Inc.
CAD	Computer Aided Design
DRDC	Defence Research and Development Canada
EM	Electro-Magnetic
MB	Megabyte
mm	millimetre
REW	Radar Electronic Warfare
SA	Scientific Authority
SOW	Statement of Work

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

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   Array Systems Computing Inc.
   1120 Finch Avenue West, 7th Floor
   Toronto, Ontario, Canada, M3J 3H7

2. SECURITY CLASSIFICATION (overall security classification of the document, including special warning terms if applicable)

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3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C or U) in parentheses after the title.)

   Final Report: Development of a 3D Polygonal CAD Model for DRDC Ottawa Human Phantom (Phil)

4. AUTHORS (Last name, first name, middle initial)

   Obidowski, Ray, M

5. DATE OF PUBLICATION (month and year of publication of document)

   December, 2004

6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.)

   34

6b. NO. OF REFS (total cited in document)

   0

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

   Final

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

   Defence Research and Development Canada - Ottawa
   Bldg 29, 3701 Carling Avenue
   Ottawa, Ontario, K1A 0Z4

9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant)

   Project

9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)

   W7714-043015/A

10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)

10b. OTHER DOCUMENT NOS. (Any other numbers which may be assigned this document either by the originator or by the sponsor)

   DRDC Ottawa CR 2005 - 170
   ASC_3DPCM_003

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