

AustinMan and AustinWoman

High-Fidelity, Anatomical Voxel Models
Developed from the VHP Color Images

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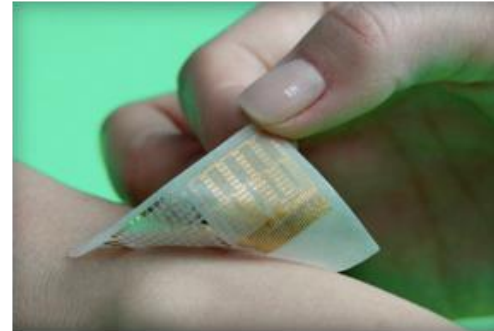
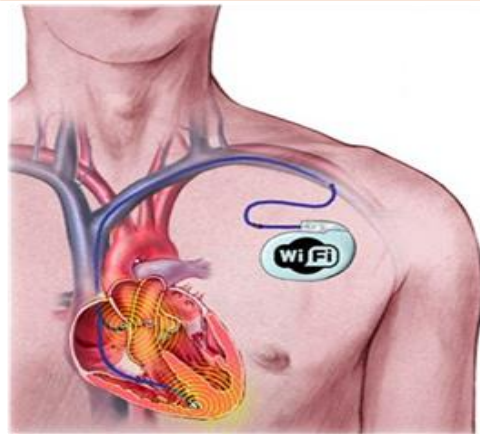
The University of Texas at Austin

Outline

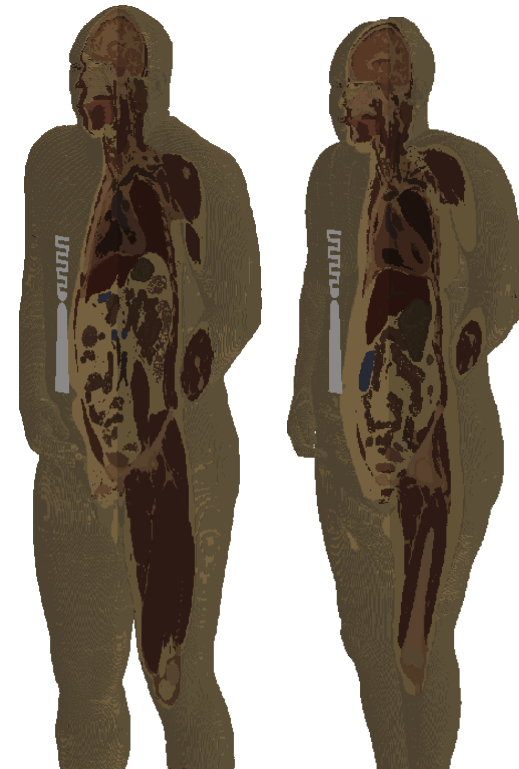
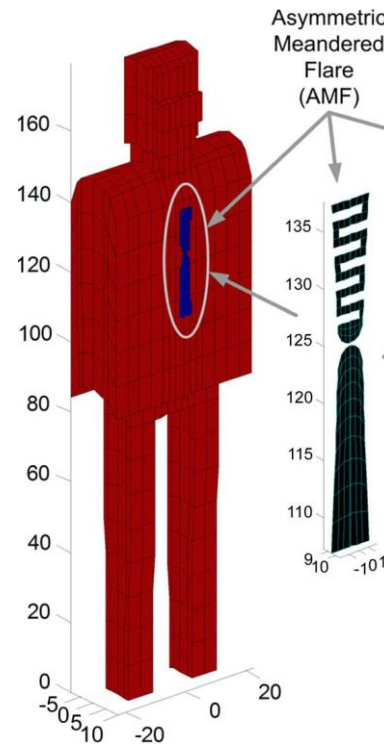
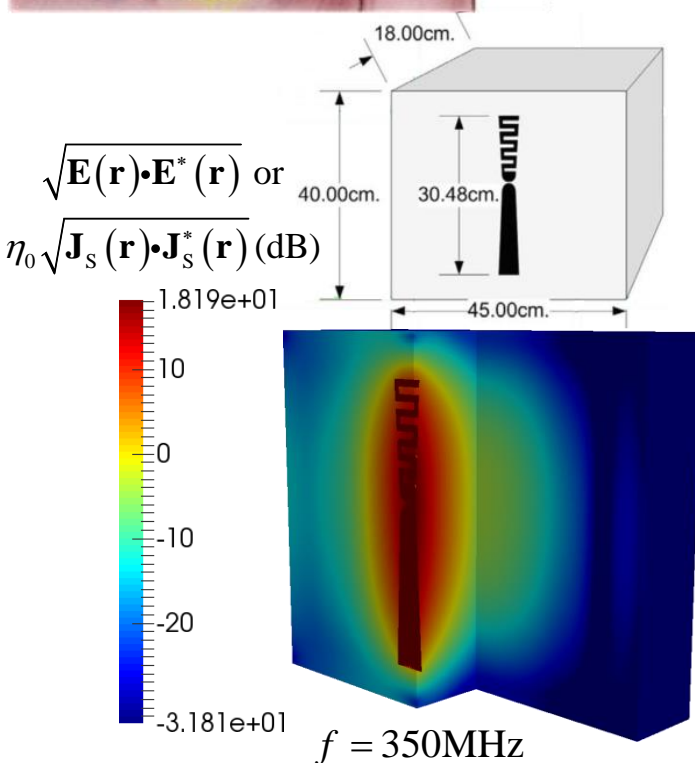
- Why?
- Model Development
 - Initial Objectives
 - Visible Human Project
 - Tissue Identification
 - Updating the Models
- Results
 - Progression
 - Visualization
 - Comparisons
 - Applications
- Conclusions



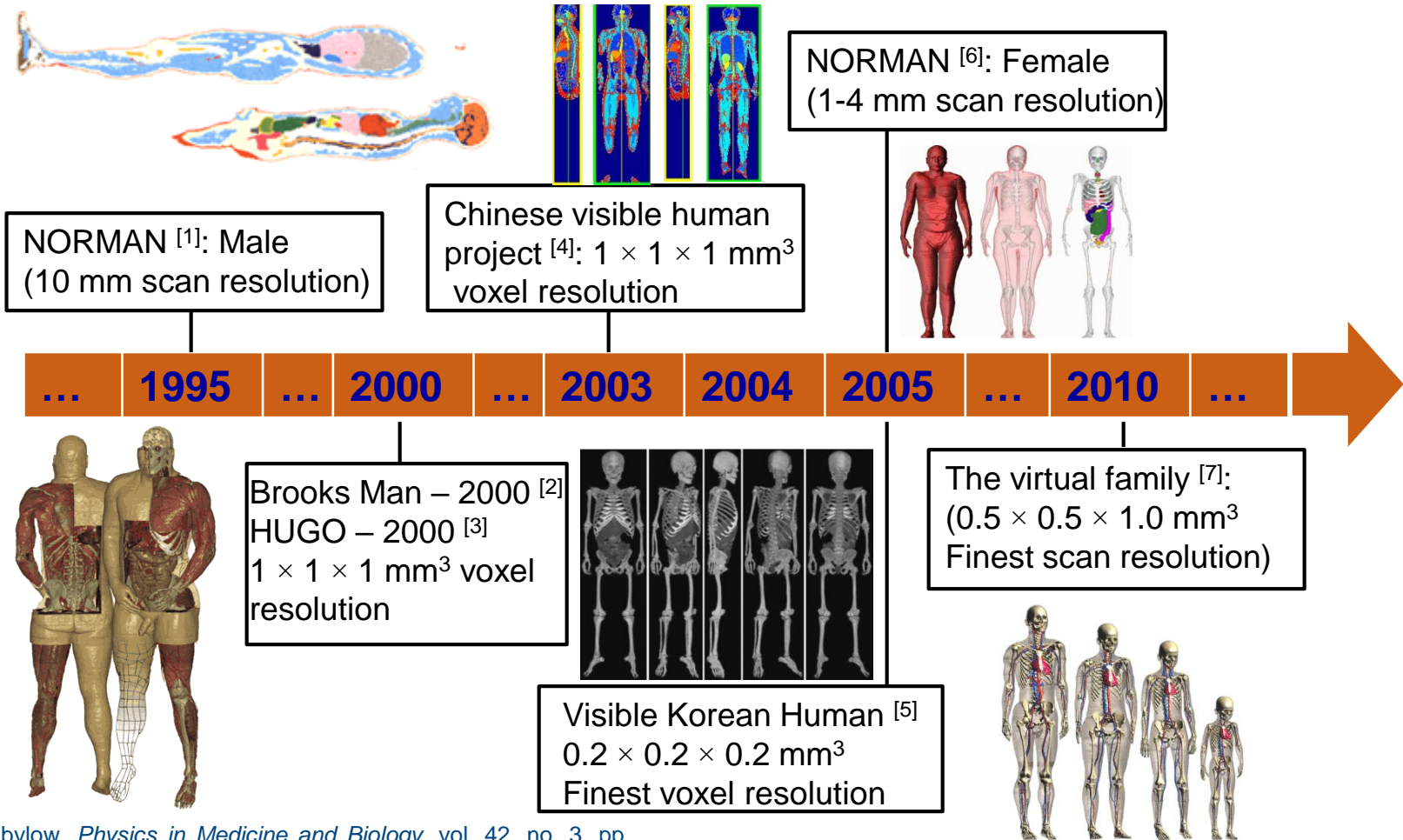
Why?



- [1] D. Psychoudakis and J. L. Volakis, "Conformal asymmetric meandered flare (AMF) antenna for body-worn applications," *IEEE AWPL*, 2009.
- [2] J. W. Massey *et al.*, "Analyzing UHF-band antennas near anatomical human models with a fast integral-equation method," in *Proc. 10th EuCAP*, Apr. 2016.



Electromagnetic Models of Humans



NORMAN [1]: Male
 (10 mm scan resolution)

Chinese visible human
 project [4]: $1 \times 1 \times 1 \text{ mm}^3$
 voxel resolution

NORMAN [6]: Female
 (1-4 mm scan resolution)

Brooks Man – 2000 [2]
 HUGO – 2000 [3]
 $1 \times 1 \times 1 \text{ mm}^3$ voxel
 resolution

Visible Korean Human [5]
 $0.2 \times 0.2 \times 0.2 \text{ mm}^3$
 Finest voxel resolution

The virtual family [7]:
 $(0.5 \times 0.5 \times 1.0 \text{ mm}^3$
 Finest scan resolution)

[1] P. J. Dimbylow, *Physics in Medicine and Biology*, vol. 42, no. 3, pp. 479-490, Mar. 1997.

[2] P. A. Mason et al., in *Radio Frequency Radiation Dosimetry*, Eds. Norwell, MA: Kluwer, 2000, pp. 141-155.

[3] DiPP GmbH, Loerrach, Germany. <http://www.vr-laboratory.com/>

[4] X. Zhang et al., *Anatomical Record. Part B, New Anatomist*, vol. 275, no. 1, pp. 190-195, Dec. 2003.

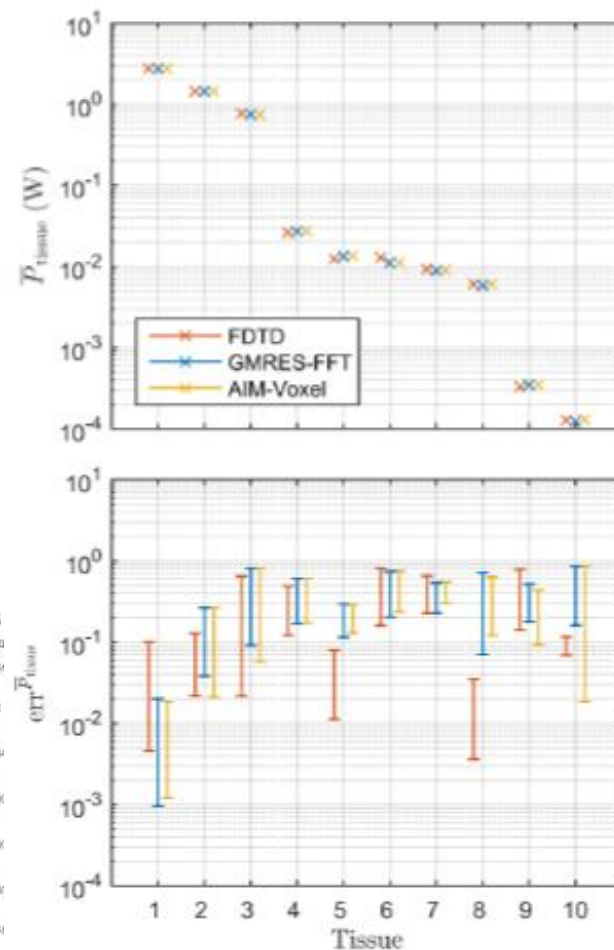
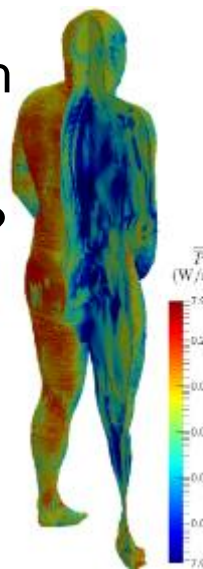
[5] J. S. Park et al., *IEEE Trans. on Med. Imag.*, vol. 24, no. 3, pp. 352-360, Mar. 2005.

[6] P. Dimbylow, *Physics in Medicine and Biology*, vol. 50, no. 6, pp. 1047-1070, Mar. 2005.

[7] A. Christ et al., *Physics in Medicine and Biology*, vol. 55, no. 2, pp. N23-38, Jan. 2010.

Why?

- Downsides
 - Time intensive
 - Not anatomy experts
 - Difficult to modify/deform shapes
- Reasons
 - + Open source / reproducible research
 - + Evolving model with versions
 - + What's going on behind the scenes?
 - + Error studies [1]
 - + Free to use
 - + Benchmark [2]:
<http://bit.ly/BioEM-Benchmarks>



[1] J. W. Massey, "A comprehensive comparison of FFT-accelerated integral equation methods vs. FDTD for bioelectromagnetics," M.S. thesis, Dept. ECE, The University of Texas at Austin, Austin, TX, 2015.

[2] J. W. Massey, C. Liu, and A. E. Yilmaz, "Benchmarking to Close the Credibility Gap: A Computational BioEM Benchmark Suite" in *Proc. Int. Symp. EM Theory (EMTS 2016)*, Aug. 2016.

Initial Objective

- High-fidelity, accurate models

- Male and female
- $1 \times 1 \times 1 \text{ mm}^3$ resolution

- Open-source, reproducible models

- Accessible online

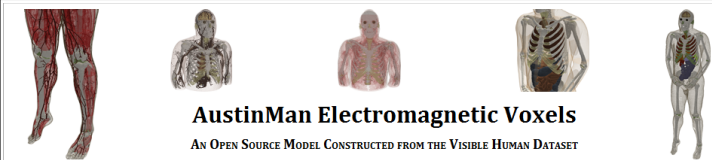
<http://bit.ly/AustinMan>

- Model source and analysis software also available

- Segmented slices and masks
- Boundary and Region Identification Software Kit (BRISKit)

- Documentation of assumptions, errors, and problematic regions
- Evolving model / version control

- Third-party input highly encouraged



AustinMan Electromagnetic Voxels
 AN OPEN SOURCE MODEL CONSTRUCTED FROM THE VISIBLE HUMAN DATASET

Introduction
 Methodology
 Crop Mask
 Segment & Identify
 Coarsen & Extrude
 Homogeneous Model
 Assumptions
 Image Shifts
 Tissue Material
 Assumptions
 Problem Regions
 Electromagnetic
 Material Properties
 Known Errors
 Citing the Model
 Acknowledgements
 Conditions of Use
 Contact
 FAQ
 References
 Download Data
 AustinMan v2.0
 Homogeneous Sphere

Last Update: 2/21/2012
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INTRODUCTION

AustinMan is a voxel model of the human body that is being developed for electromagnetic simulations from the National Library of Medicine's Visible Human Project data set [1]. The model is available to the public at <http://web2.corral.tacc.utexas.edu/AustinManEMVoxels> under these [conditions of use](#). The authors have chosen an "open source" model that is easily accessible and verifiable. The authors encourage users to improve the model and submit new versions to this website for distribution. The model is freely available for research, teaching, or other non-commercial uses.

This website describes the methodology used to develop the AustinMan model. A more detailed description of the methodology and visualizations of AustinMan v1.1 can be found in [Creating AustinMan: An Electromagnetic Voxel Model of the Visible Human](#) [2].

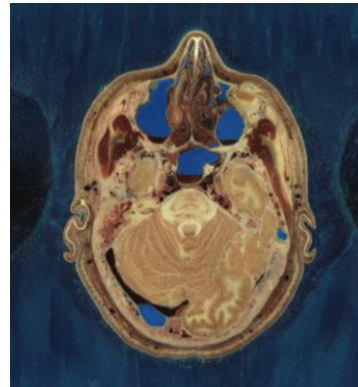
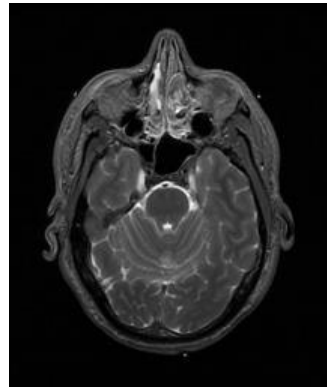
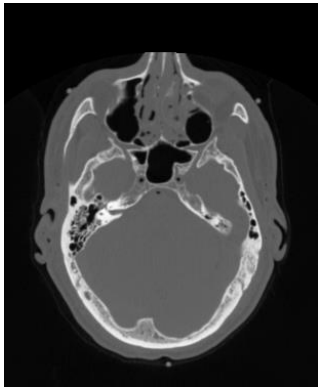
VERSIONS

2/21/2012 Website documentation has been updated for AustinMan v2.0.
 2/15/2012 [AustinMan v2.0](#). Whole body model. Includes all 1878 slices. Only the even slices (i.e. every 2 mm) were manually corrected for slices 1426 - 2000, 2250 - 2360, and 2756 - 2878. Updates to the



Visible Human Project

- Visible Human male and female – 1994-96 [1]
 - CT, MRI, and color cross-sectional images
 - $\frac{1}{3} \times \frac{1}{3} \times 1 \text{ mm}^3$ and $\frac{1}{3} \times \frac{1}{3} \times \frac{1}{3} \text{ mm}^3$ resolutions



- Brooks AFB 2000 [2] & HUGO 2000 [3]
 - $1 \times 1 \times 1 \text{ mm}^3$ voxel resolution
- Male anatomy atlas available
- Dataset creation well documented
- Problems with dataset well established

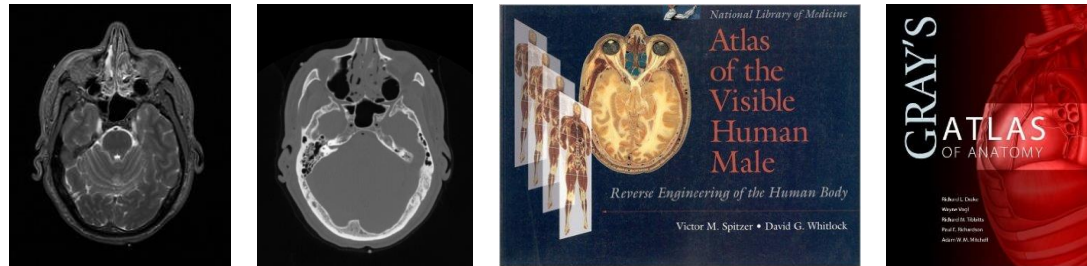
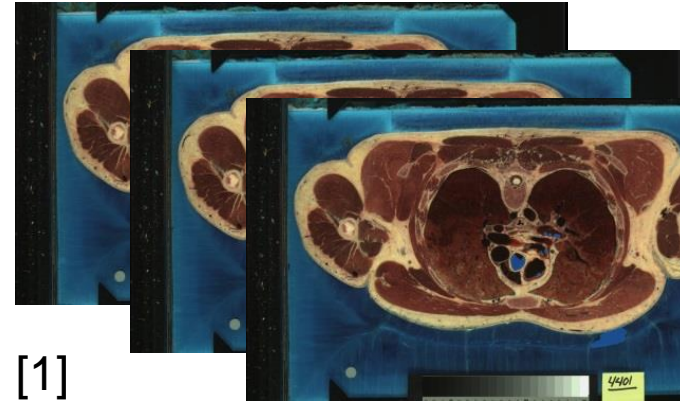
[1] V. M. Spitzer et al., *J. of the Amer. Medical Informatics Assoc.: JAMIA*, vol. 3, no. 2, pp. 118-130, 1996.

[2] P. A. Mason et al., in *Radio Frequency Radiation Dosimetry*, Eds. Norwell, MA: Kluwer, 2000, pp. 141-155.

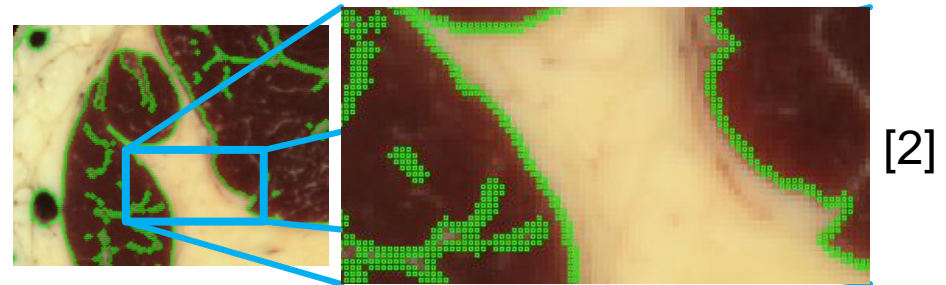
[3] DiPP GmbH, "HUGO - The Professional Anatomical Data Set," Loerrach, Germany. <http://www.vr-laboratory.com/>

Methodology: Creating

- Based on color cross-sectional images
- Assistance



- Tissue identification
 - Approximately 1 billion pixels
 - Time intensive
 - Validation
 - Assumptions carefully documented



- Extruded pixels → voxels (volumetric pixels)

- Staircased boundary

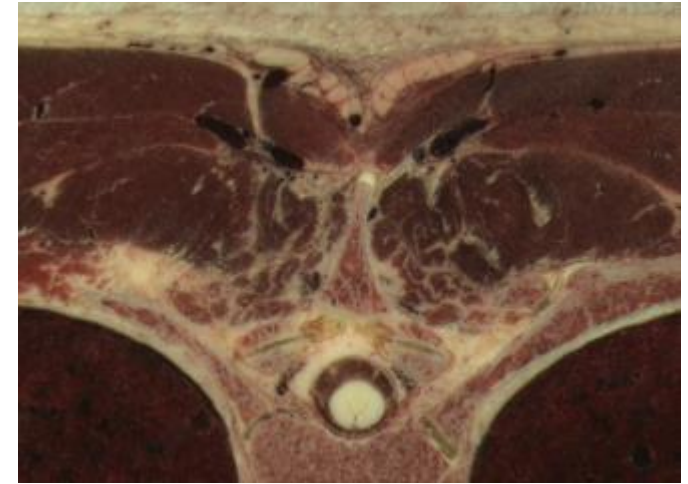


[1] V. M. Spitzer et al., J. of the Amer. Medical Informatics Assoc.: JAMIA, vol. 3, no. 2, pp. 118-130, 1996.

[2] J. Massey et al., in Proc. 34th Annual Conf. Bioelectromag. Soc., June 2012. <http://bit.ly/AustinMan>

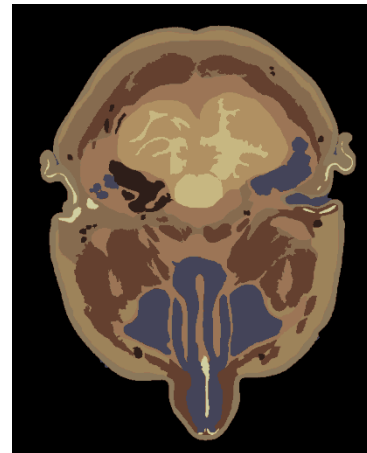
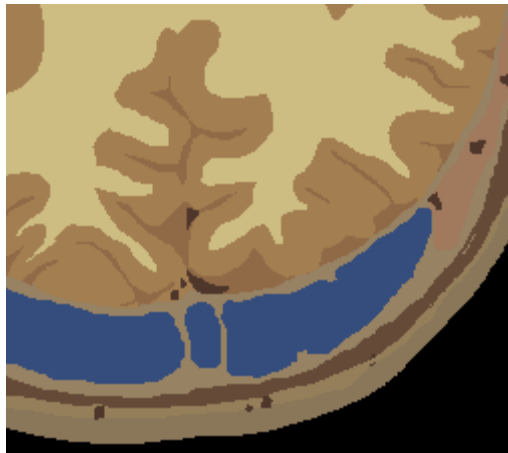
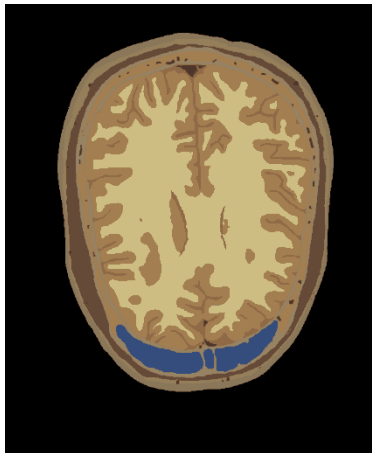
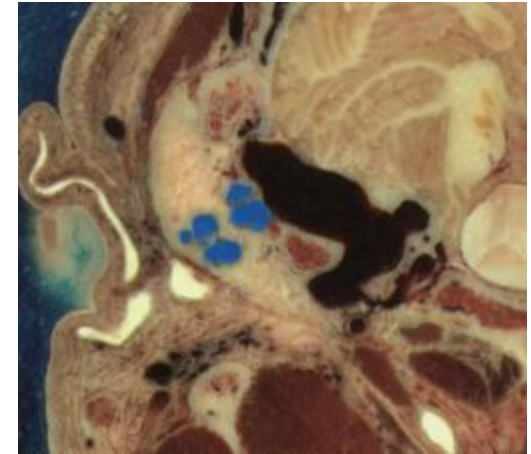
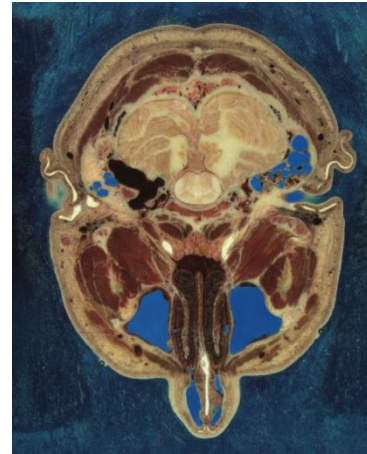
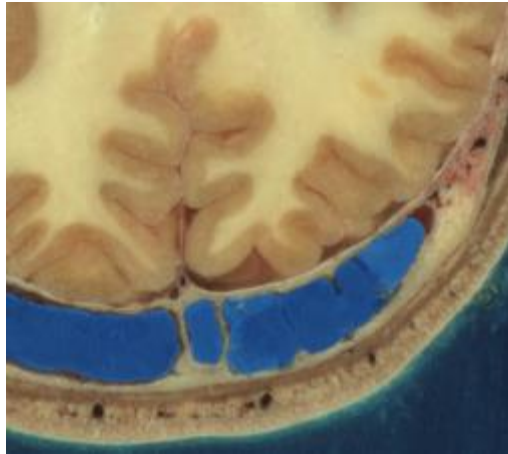
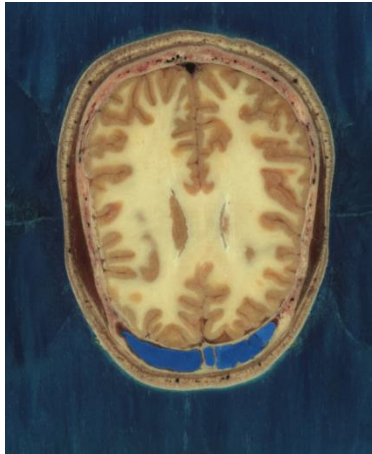
AustinMan Segmented Images

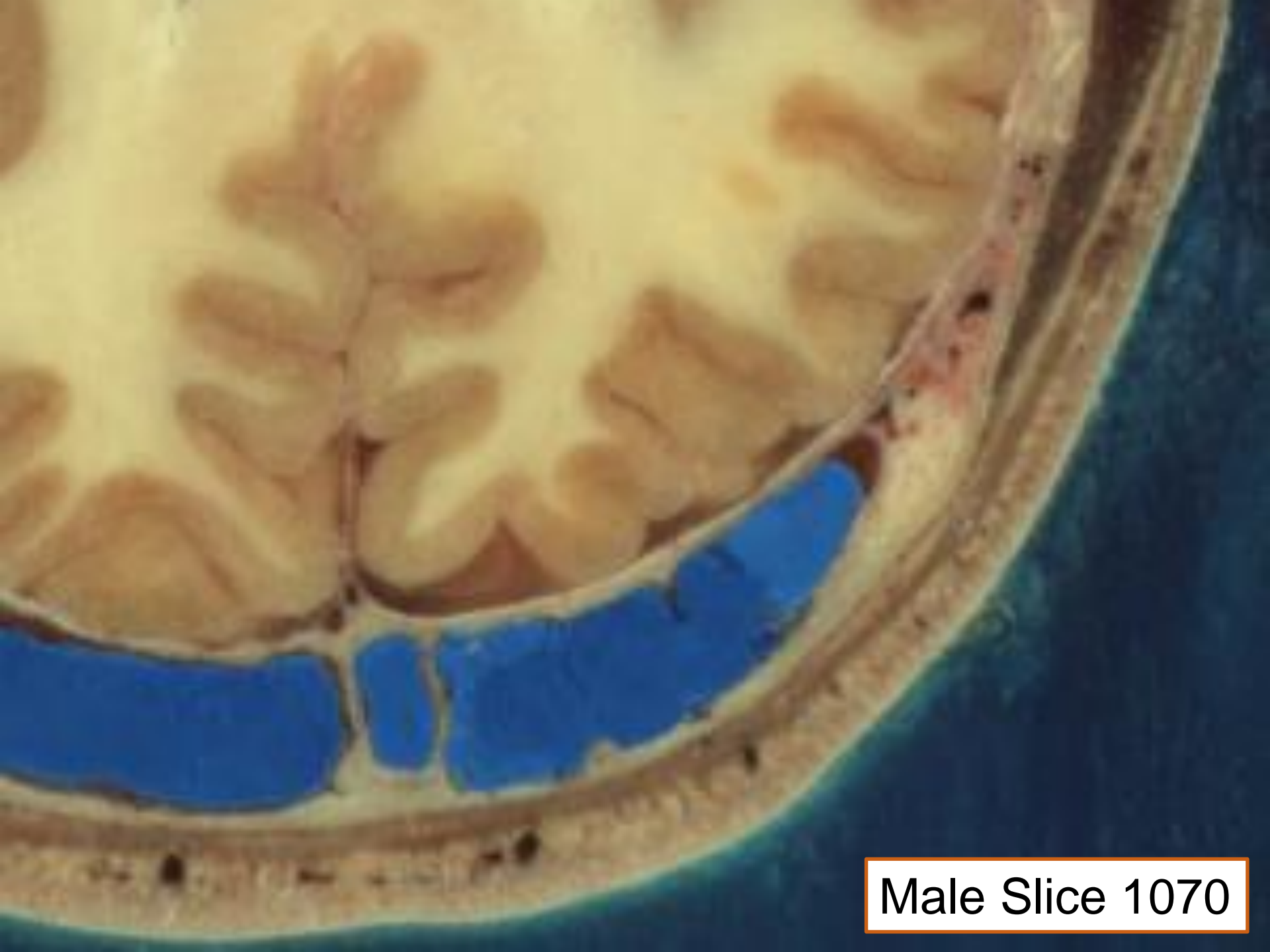
- Sub-millimeter pixel resolution (1/3 mm)



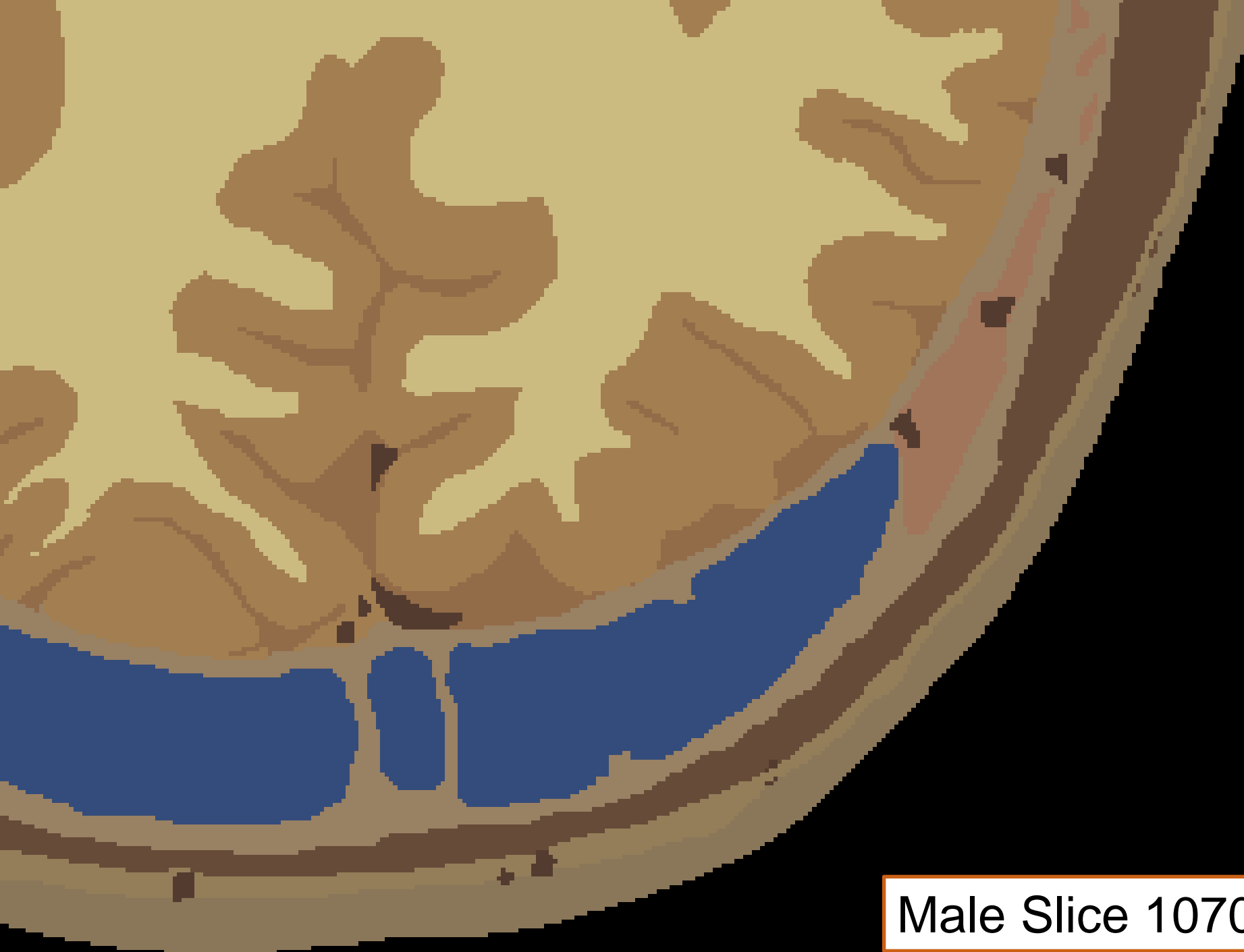
AustinMan Segmented Images

- Sub-millimeter pixel resolution (1/3 mm)





Male Slice 1070

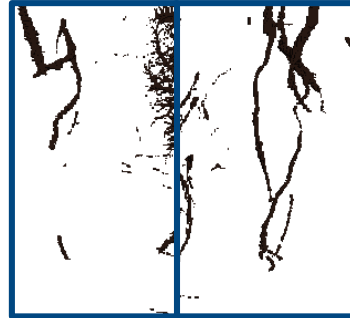


Male Slice 1070

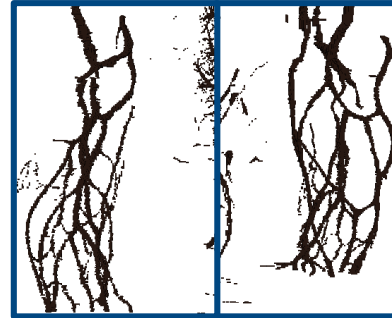
Methodology: Updating

- 3-D visualization
- Targeted updates
- Weekly review meetings
- Documentation

AustinWoman v2.1



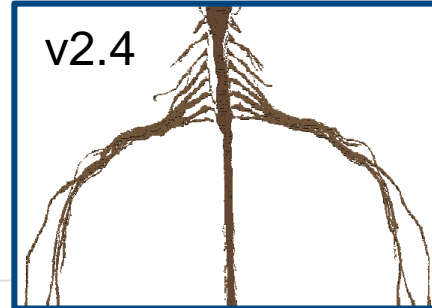
v2.3



v2.3



v2.4



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- Introduction
- Methodology
 - Crop
 - Mask
 - Segment & Identify
 - Coarsen & Extrude
- Homogeneous Model
- Assumptions
 - Image Shifts
 - Tissue Material
 - Assumptions
 - Problem Regions
 - Electromagnetic
 - Material Properties
- Known Errors
- Citing the Model

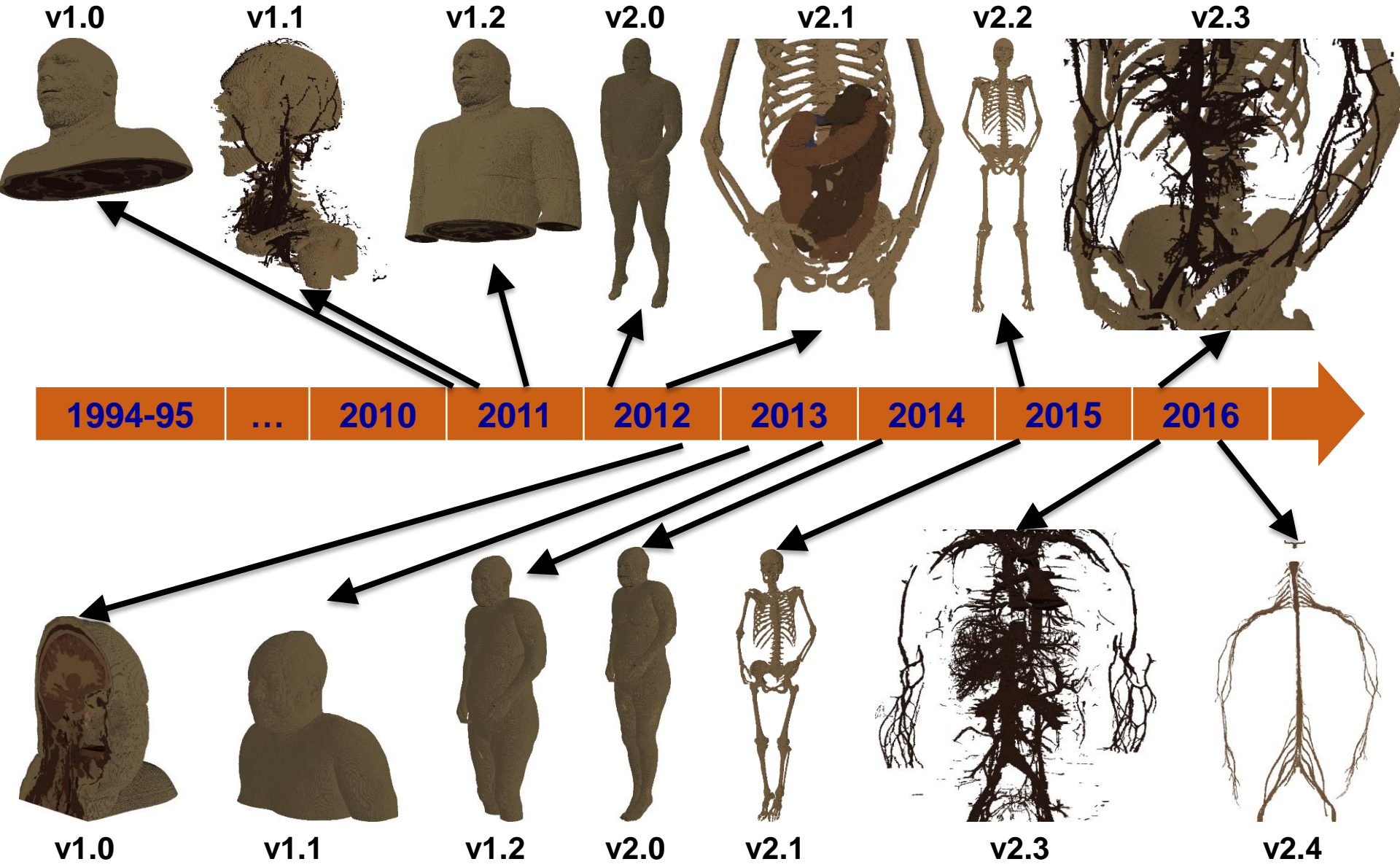
Last Update: 5/11/2016
 Jackson W. Massey¹, Cemil S. Geyik¹, Jungwook Choi², Hyun-Jae Lee³, Natcha Techachainiran¹, Che-Lun Hsu¹, Robin Q. Nguyen³, Trevor Latson¹, Madison Ball⁴, and Ali E. Yilmaz¹
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INTRODUCTION

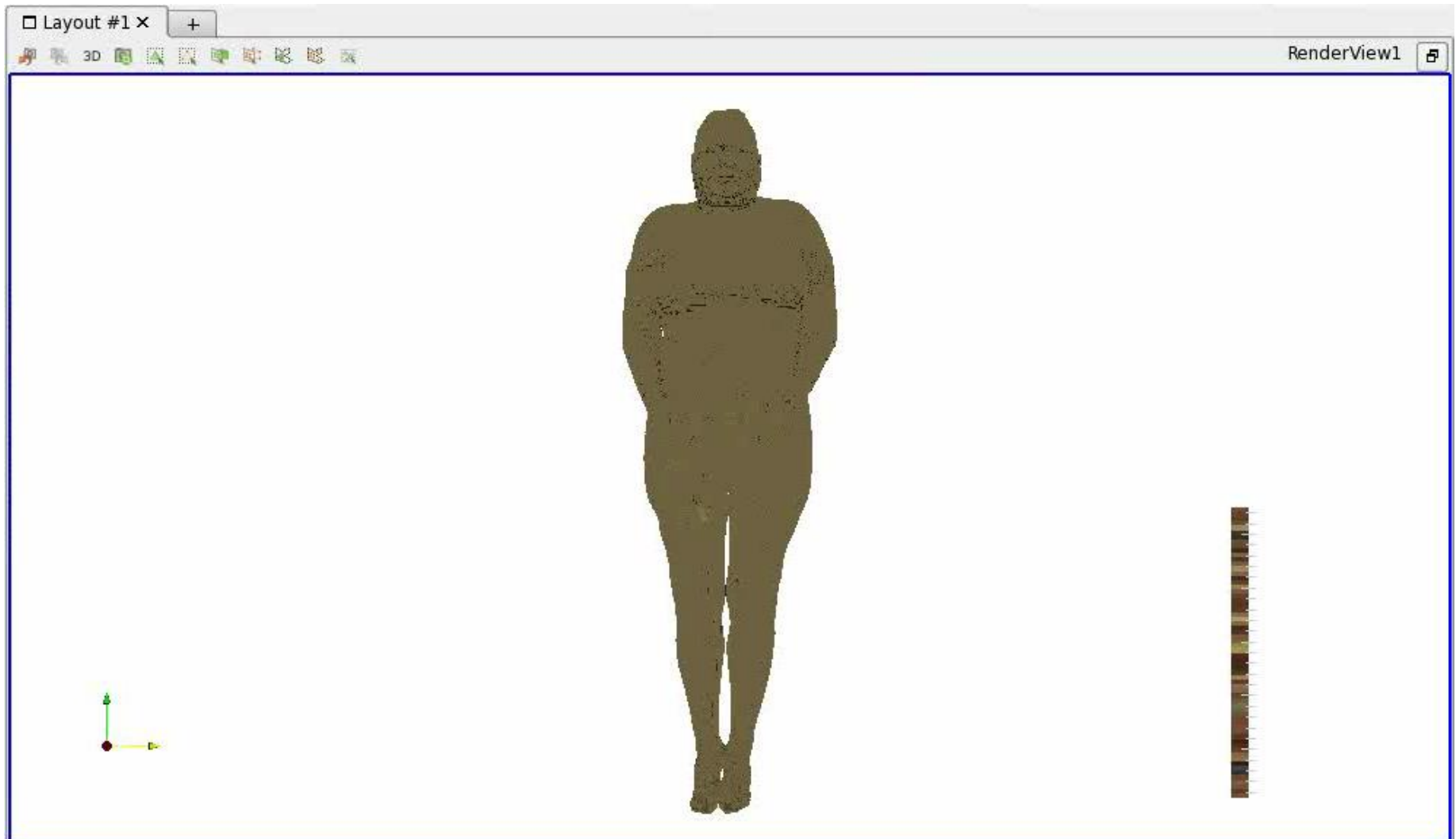
AustinMan is a voxel model of the human body that is being developed for electromagnetic simulations from the

11 authors (so far)
 2 groups:
 1) Developers
 2) Reviewers

Model Development History

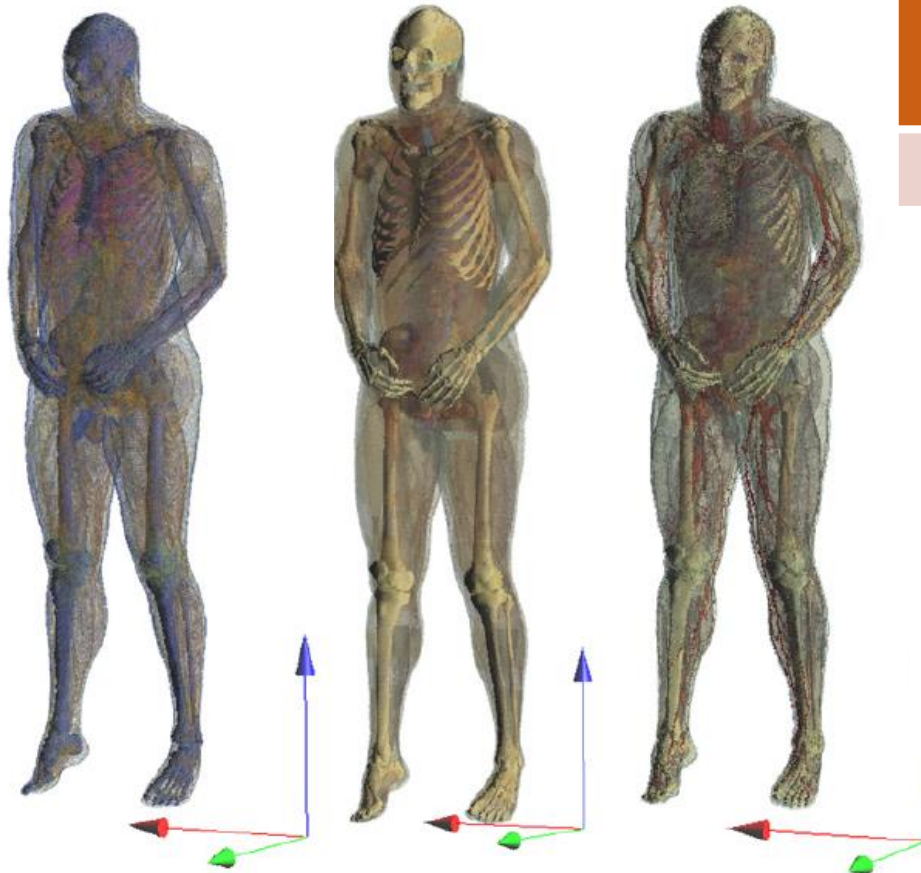


AustinWoman v2.4

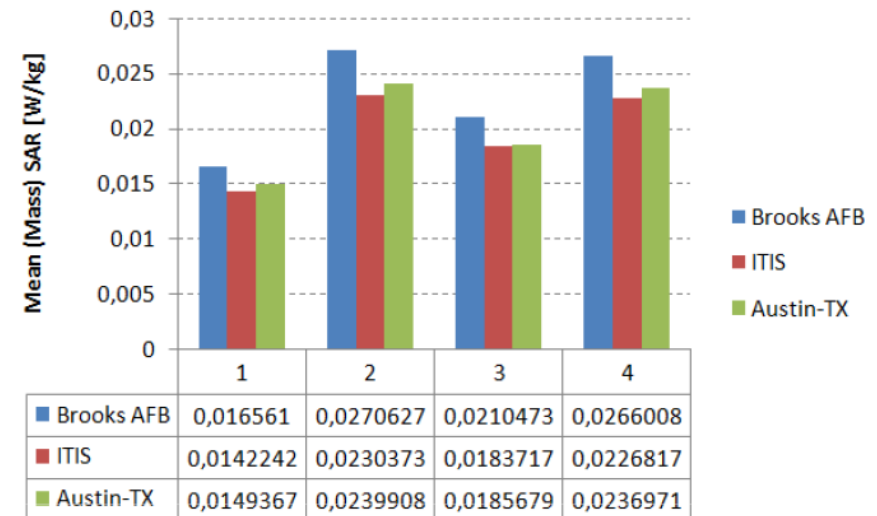


Comparisons

- Brooks AFB, IT'IS VHP Male, AustinMan v2.3 [1]



Brooks AFB	IT'IS VHP Male	AustinMan v2.3
105.42 kg	112.05 kg	112.23 kg



(1.) side exposure, TM_t90_p0, H-field perpendicular to the body axis
(3.) side exposure, TE_t90_p0, E-field perpendicular to the body axis
(2.) frontal exposure, TM_t90_p270, H-field perpendicular to the body axis
(4.) frontal exposure, TE_t90_p270, E-field perpendicular to the body axis

[1] R. Überbacher and S. Cecil, "Influence of anatomical segmentation accuracy for whole body SAR computations evaluated on three different voxel-models based on the Visible Human Project (VHP) data set," in *Proc. BioEM 2016*, Ghent, Belgium, June 2016.

Conclusions

$$|\mathbf{E}(\mathbf{r}, t)| \text{ or } \eta_0 |\mathbf{J}_s(\mathbf{r}, t)| \text{ (dB)}$$



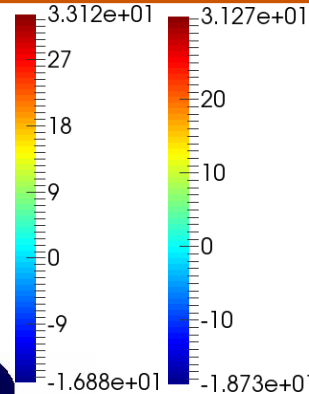
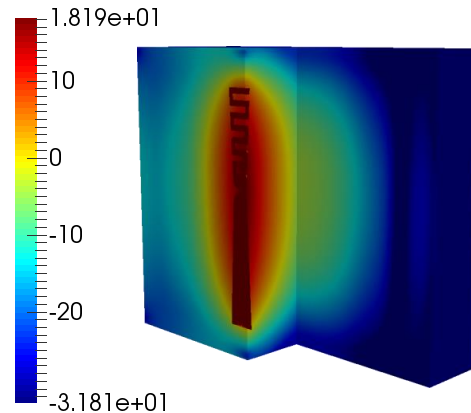
High-resolution, high-fidelity models
 Open, reproducible process
 Assist in identifying modeling errors
 Evolving models
 Available for download
<http://bit.ly/AustinMan>
 Ongoing work

- New versions v2.4 released today
- Comparisons with NEVA-EM

$f = 350\text{MHz}$

$$\sqrt{\mathbf{E}(\mathbf{r}) \cdot \mathbf{E}^*(\mathbf{r})} \text{ or}$$

$$\eta_0 \sqrt{\mathbf{J}_s(\mathbf{r}) \cdot \mathbf{J}_s^*(\mathbf{r})} \text{ (dB)}$$



[1] J. W. Massey *et al.*, "Analyzing UHF-band antennas near anatomical human models with a fast integral-equation method," in *Proc. 10th EuCAP*, Apr. 2016.