Subgridded FDTD on GPU Allows Rapid Design of Implantable and Wearable Technology

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Director of Product Management

About Acceleware

GPU and HPC Programming Experts

- Pioneered GPU software development since 2004

Programmer Training

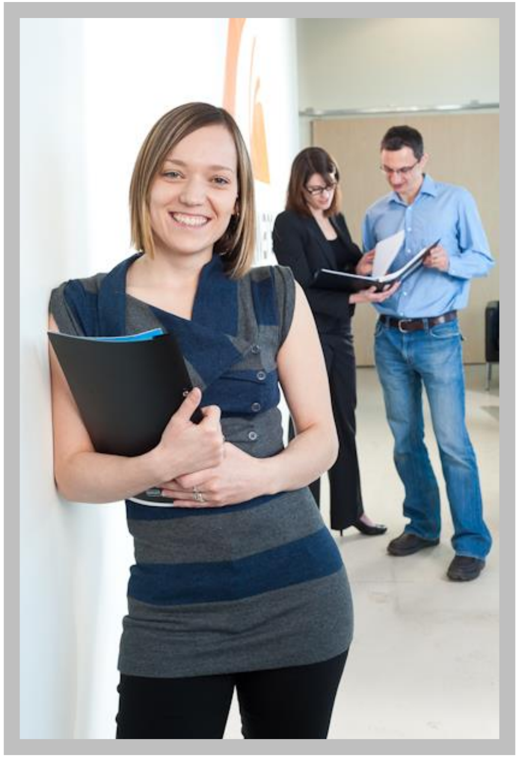
- CUDA and other HPC training classes

Consulting Services

- Projects for Oil & Gas, Medical, Finance, Security and Defence, CAD, Media & Entertainment
- Mentoring, code review and complete project implementation

GPU Accelerated Software

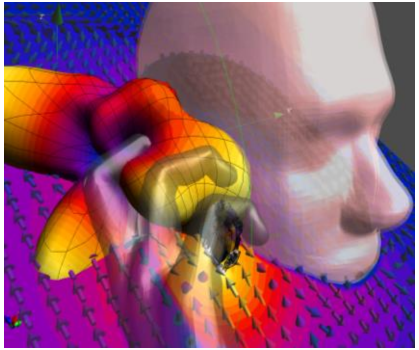
- Seismic imaging & modeling
- Electromagnetics

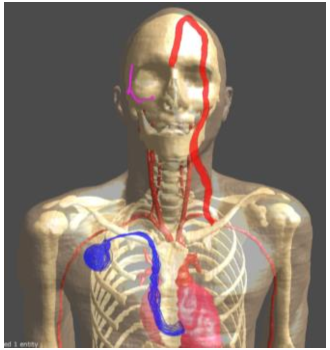


About SPEAG and ZMT Zurich Med Tech AG

SPEAG and ZMT offer hardware and software solutions to engineering applications:

- SEMCAD X
  - Mobile devices, antennas, specific absorption rate (SAR)
  - EMC/EMI interference and emissions
- Sim4Life
  - Life sciences, medical applications, and MRI
  - Human body phantoms





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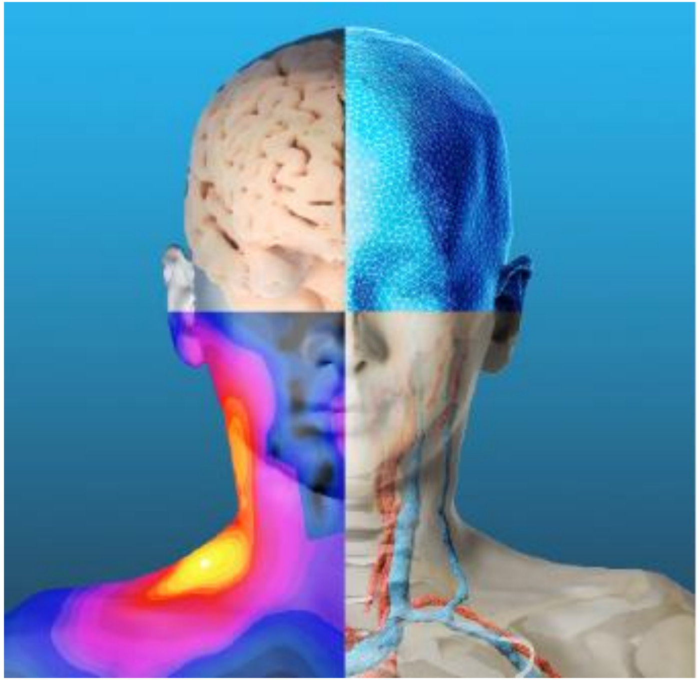
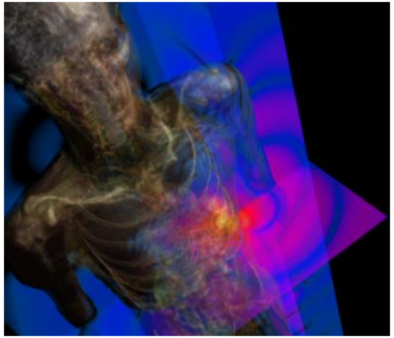
Overview

1. Subgridding Background
2. GPU Development – Optimizations
3. Performance Results
4. Application Examples
    - RF Powered Contact Lens
    - Wireless Capsule Endoscopy
    - Smart Watch
5. Conclusions



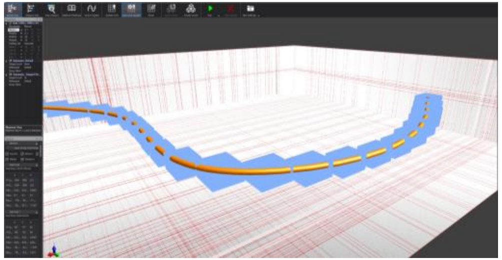
Subgridding – Motivation

- Finite Difference Time Domain (FDTD) is a numerical modeling technique
  - Used to model electromagnetic interactions with simple to complex structures
- FDTD segments large objects into small voxels
  - Increased accuracy often requires voxels comparable in size to the feature



Subgridding – Motivation (Continued)

- Small voxels result in large computational domains
  - Small timesteps
  - Simulations can take minutes to months
- How can we improve the performance?
  - GPUs!
  - Change the voxelization strategy
    - Only use small voxels where there are small features
    - Additional benefit of using larger timestep for most of simulation



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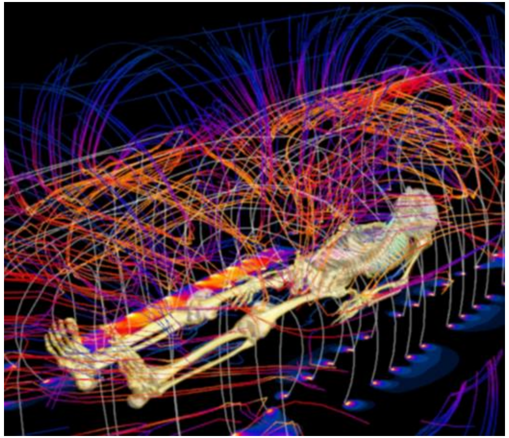
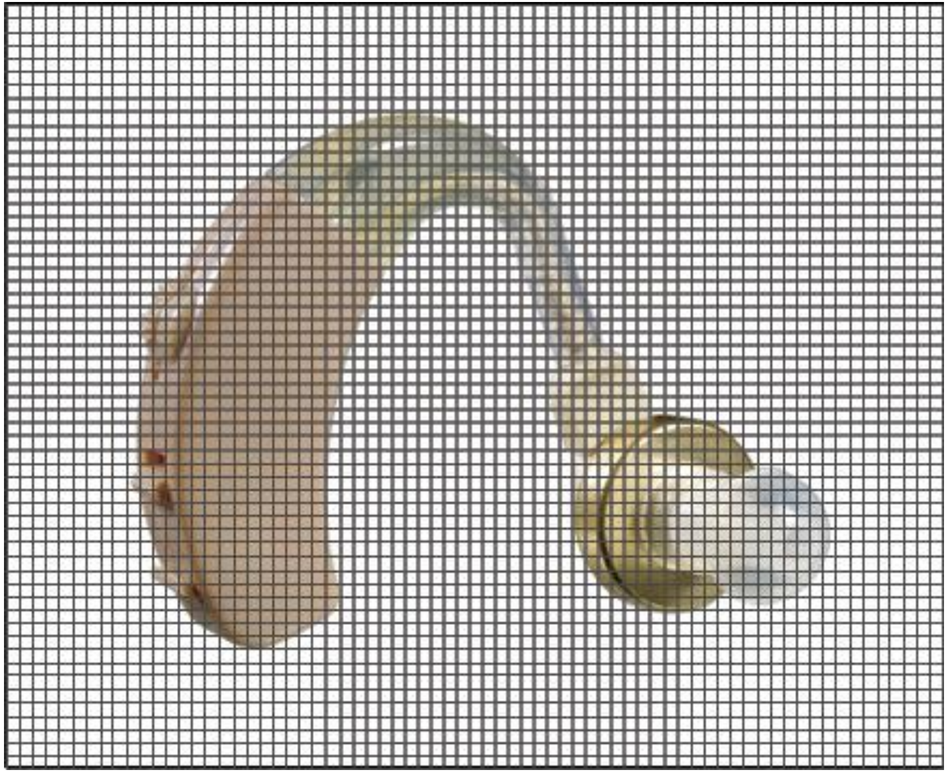
Subgridding – Evolution

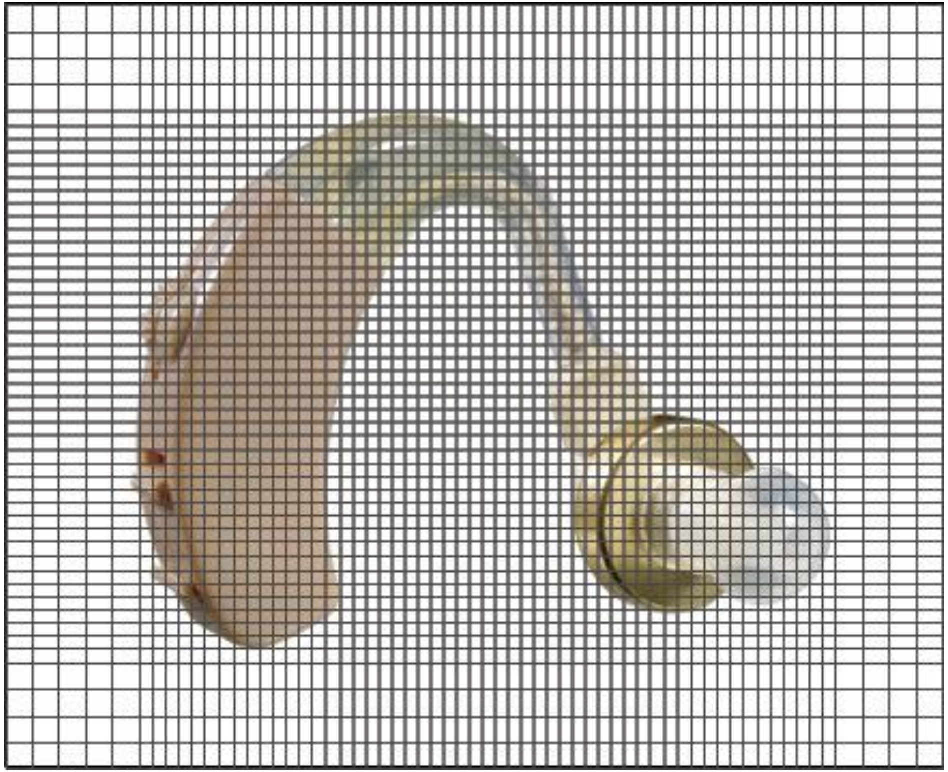
- Reducing the number of cells has been an area of active research
- Gridding evolution
  - Uniform – easy
  - Graded – easy
  - Local subgridding – hard
  - Connected subgrids – hard



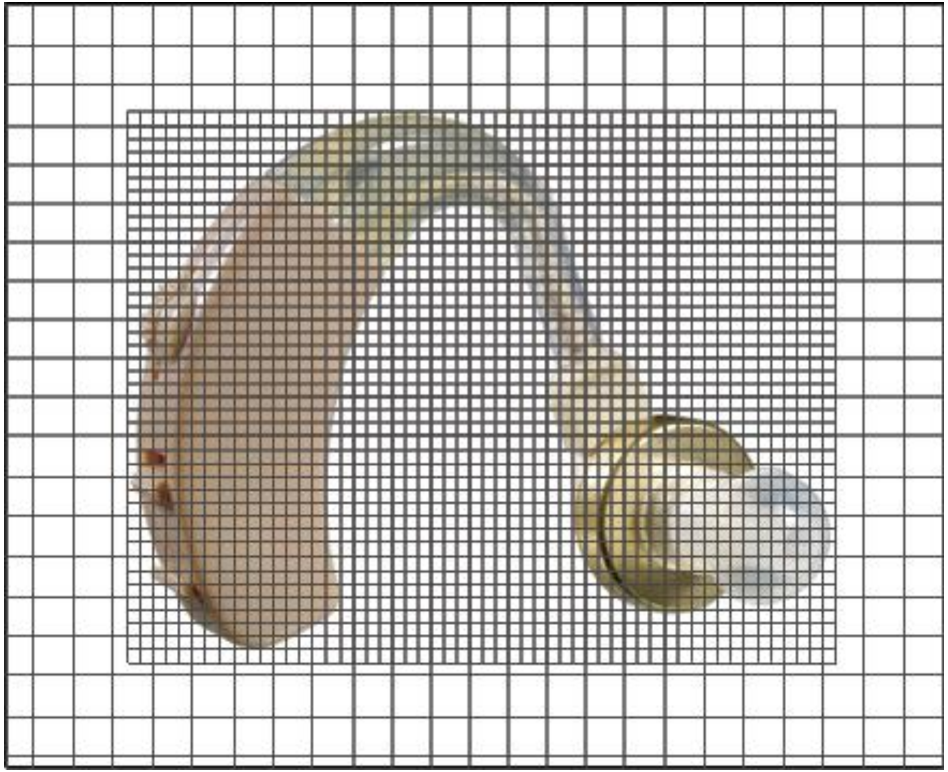
Uniform Grid



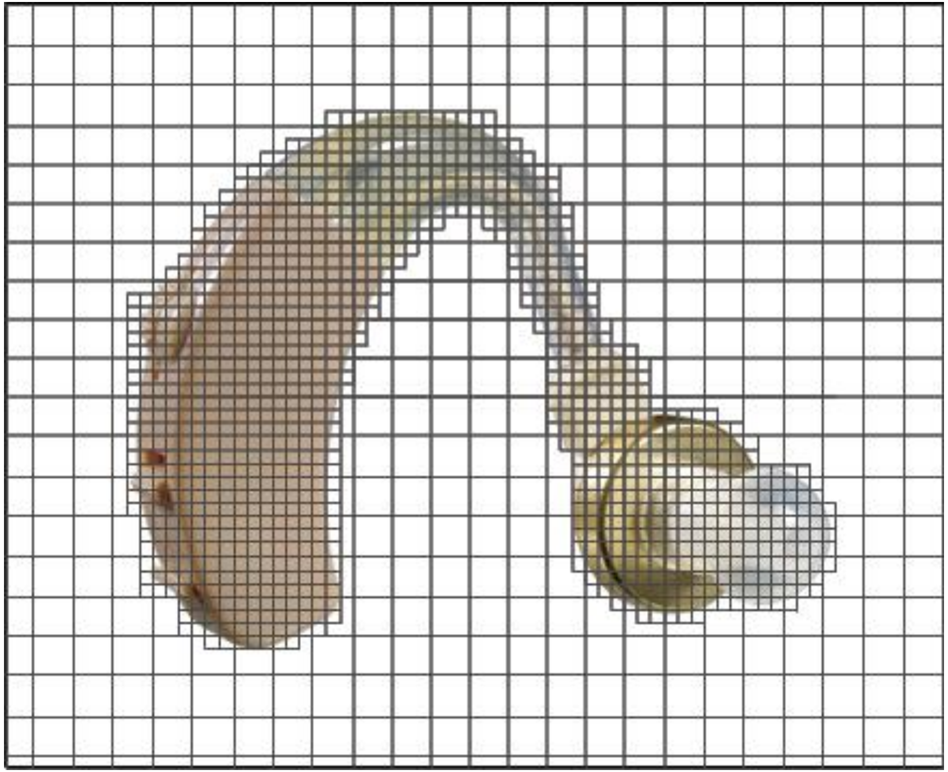
Graded Mesh



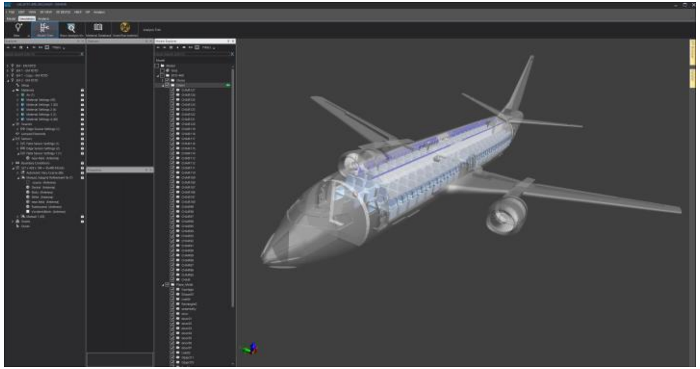
Subgridded Mesh

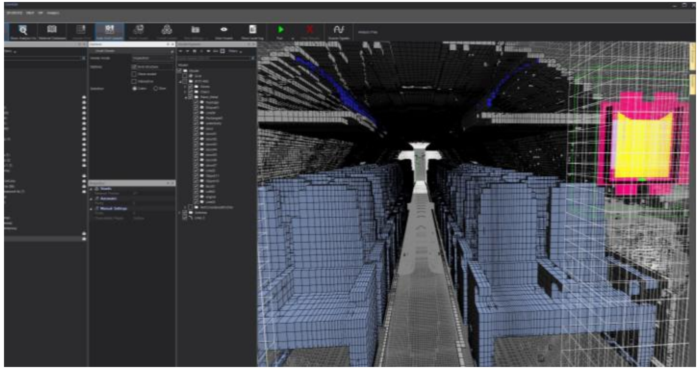


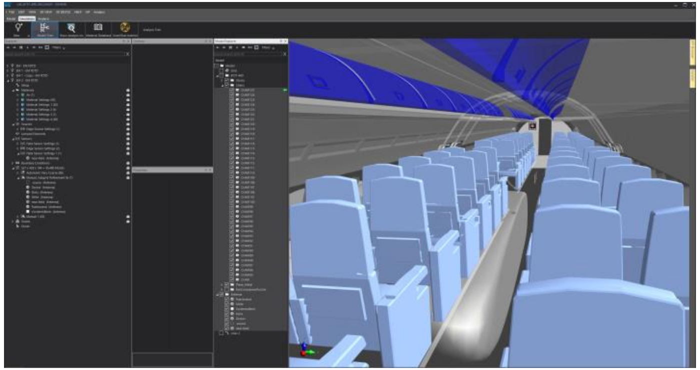
Connected Subgridded Mesh

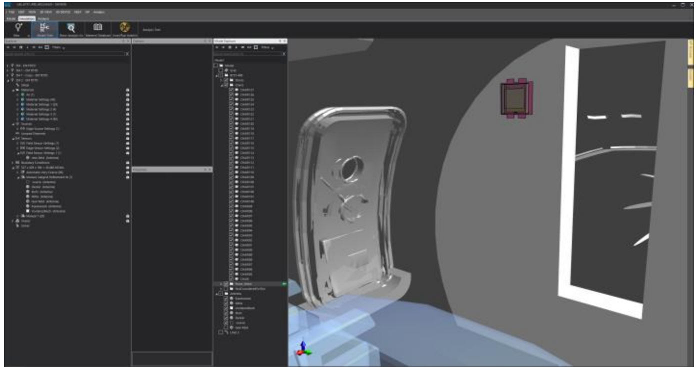


Antenna in Boeing 737-400









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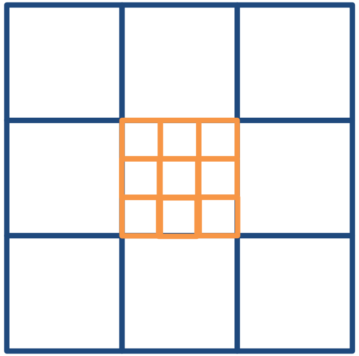
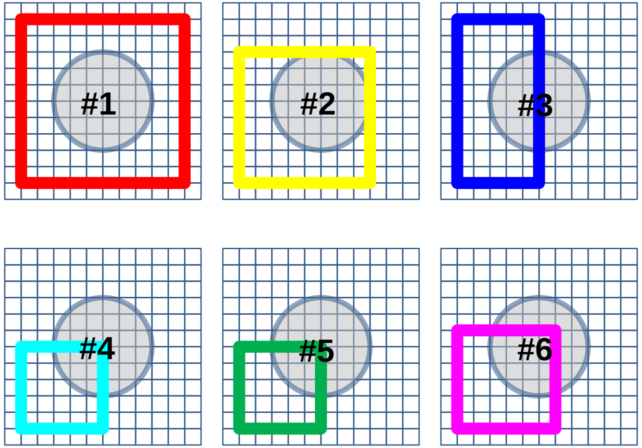
Subgridding – Algorithm

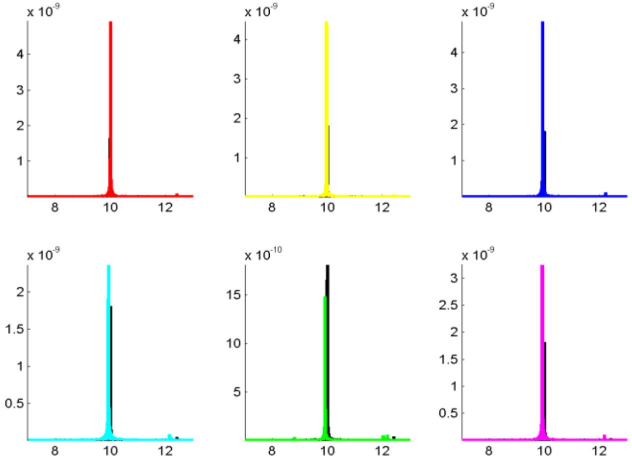
- Each spatial dimension is divided by 3
  - 27 additional cells per subgridded cell
- 3 timestep iterations per subgridded region
- Fields are interpolated between subgridded and regular regions at each coarse timestep
- Nested subgrids supported
  - Also scaled by a factor of 3



Subgridding Algorithm – Challenges

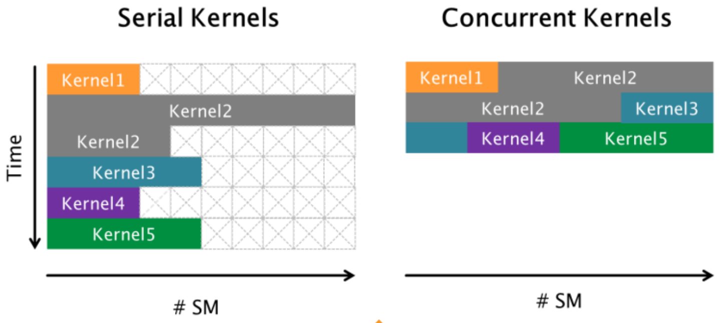
- Stability
  - Many subgridding algorithms result in late time instabilities – energy increases in the system
- Acceleware tests use reflective boundaries – 1 million timesteps





GPU Optimizations

- Migration from CUDA 5.0 to CUDA 7.5
  - Removal of older architectures
- Addition of streams
  - Allows for concurrent kernel execution to do the interpolation exchange on faces
- Other Optimizations – did not improve performance
  - Streams for boundary conditions
  - Prefer L1 cache over shared memory



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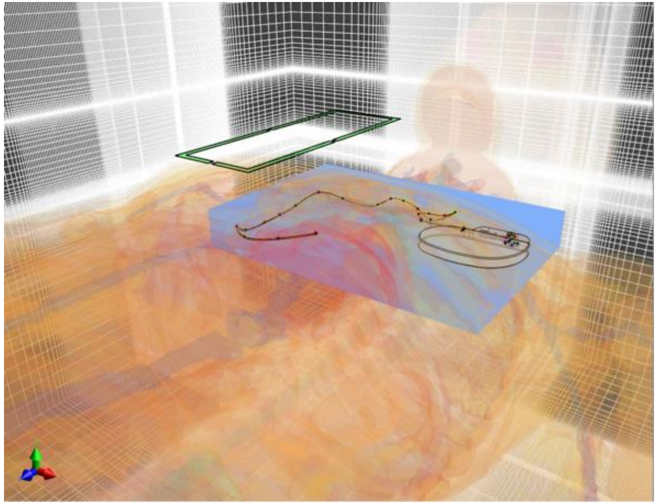
Optimization Results

- Simulation size – 64MCells
- Throughput is measured in MCells/s
  - Higher is better!

Optimization	M2090	K40	M60
Baseline CUDA 5.0	278	337	N/A
CUDA 7.5	365	445	827
Streams	384	537	886

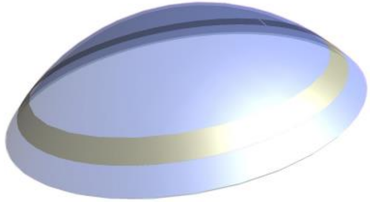
Performance Results – Pacemaker

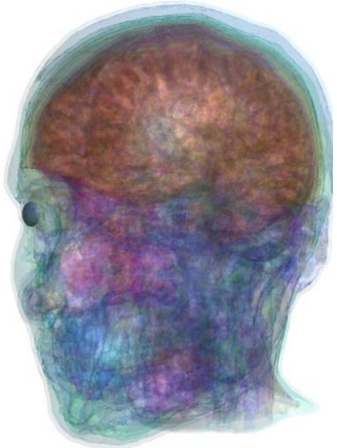
	Size (MCells)	Run Time (h)
Regular	200 MCells	14.0
Subgridding	9 MCells (53 MCells Subgridding)	1.58



Case Study – RF Powered Contact Lens

- Monitors user's health
- Enhanced display functionality
- Design considerations include:
  - Safety – Material Construction
  - Communications
  - Power
- Simulated using a head model in Sim4Life





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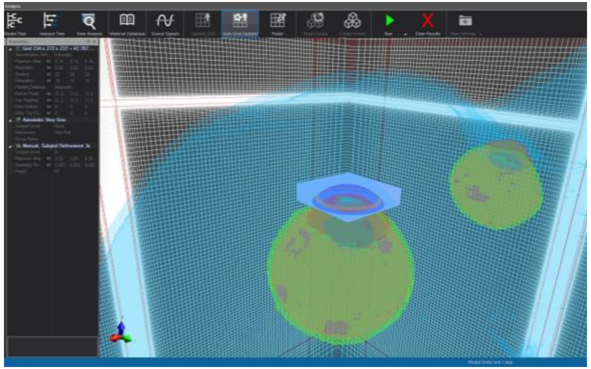
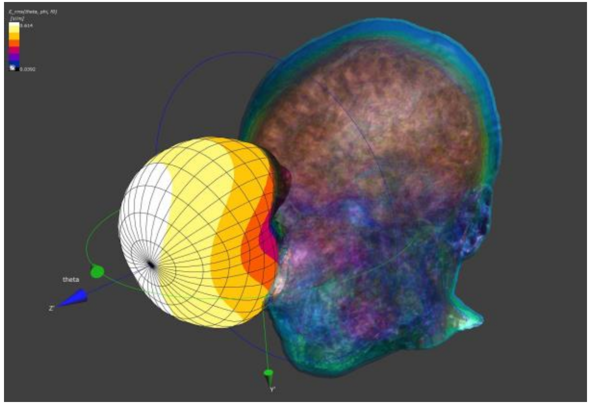
Case Study – RF Powered Contact Lens

- Subgridding applied around lens (1:3)
- Simulations performed with a Tesla K40



	Size (MCells)	Run Time
Regular	8800	139 days
Subgridded	15 – Main 29 – Subgridded	9.5 hours



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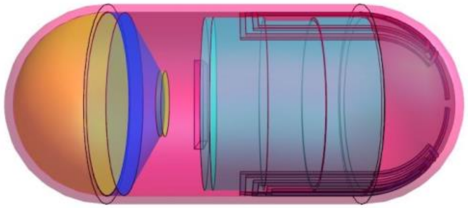
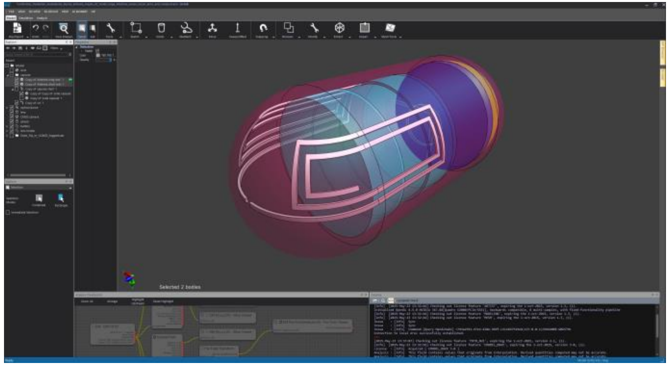
Case Study – Wireless Capsule Endoscopy

- Bio-telemetry
- Ingestible capsule
- Design considerations include:
  - Safety
  - Communications
  - Antenna Design
- Capsule includes:
  - CMOS camera, battery, antenna
- Simulated using a full body model in Sim4Life

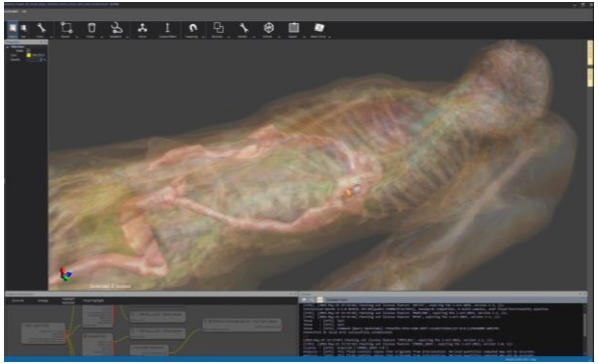


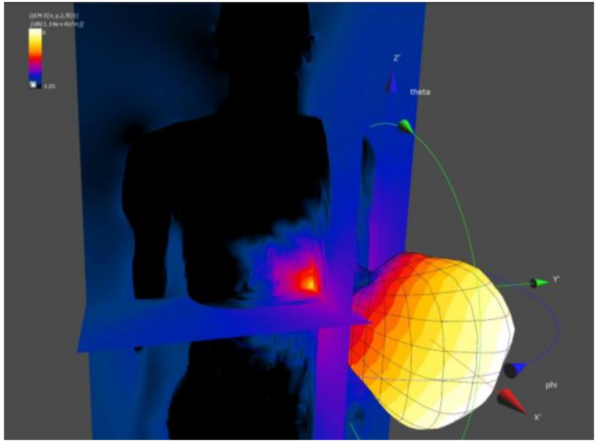


Case Study – Wireless Capsule Endoscopy

- Subgridding applied around capsule (1:9)
- Simulations performed with a Tesla K40

	Size (MCells)	Run Time
Regular	1230	3 days
Subgridded	90 – Main 18 – Subgridded	1.1 hours





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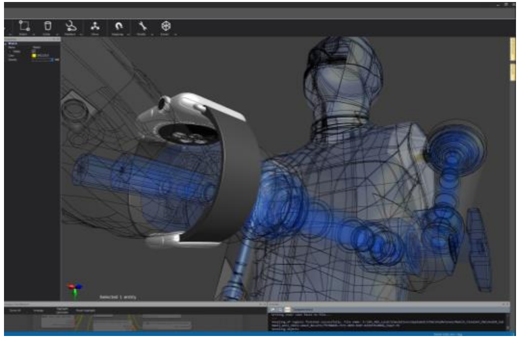
Case Study – Smart Watch

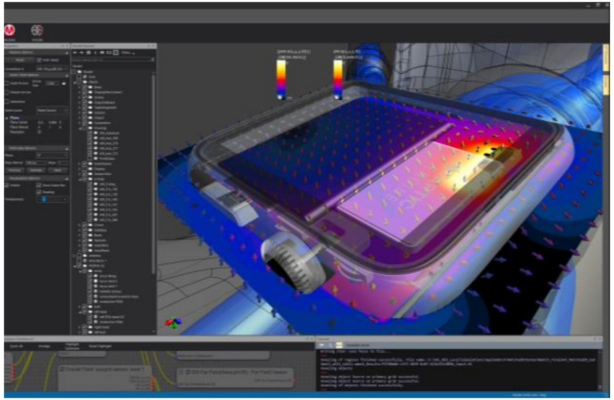
- Mobile communications
- On body consumer devices
- Design considerations include:
  - Safety
  - Communications
  - Antenna Design
- Simulated using a full body model in Sim4Life

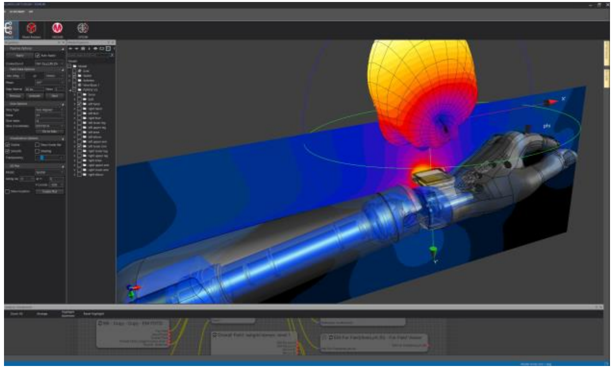


Case Study – Smart Watch

- Subgridding applied around watch (1:9)
- Simulations performed with a Tesla K40

	Size (MCells)	Run Time
Regular	1100	7 days
Subgridded	101 – Main 10 – Subgridded	3.9 hours





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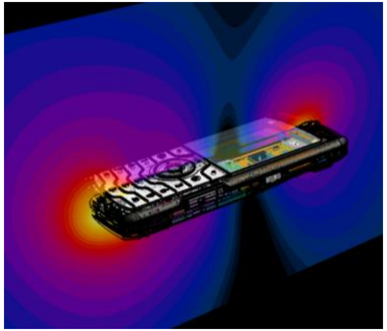
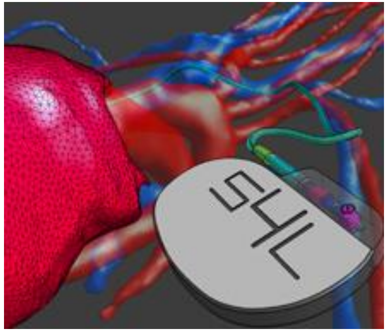
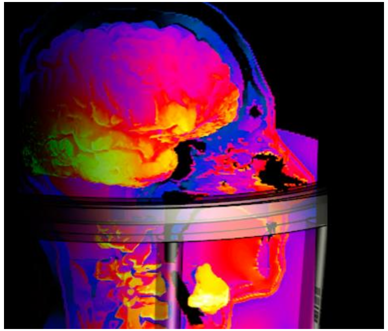
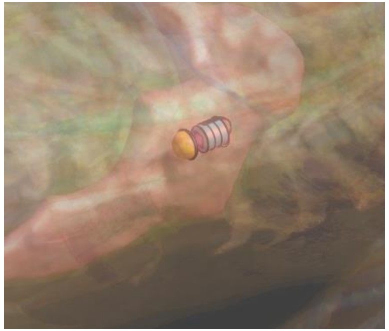
Conclusions

- Subgridding and GPUs can substantially reduce simulation times
  - Particularly useful when simulating small features in large environments
- Large range of applications for subgridding technology including life sciences

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Acknowledgements

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  - Development: Fei Zheng, Saad Rahim, Dan Cyca

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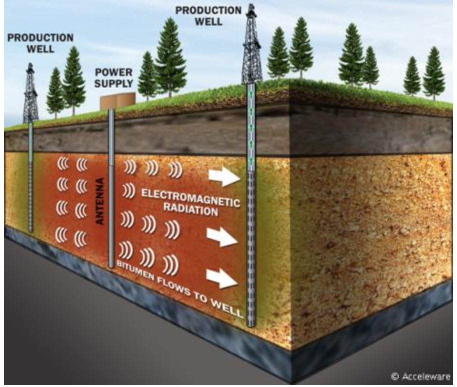
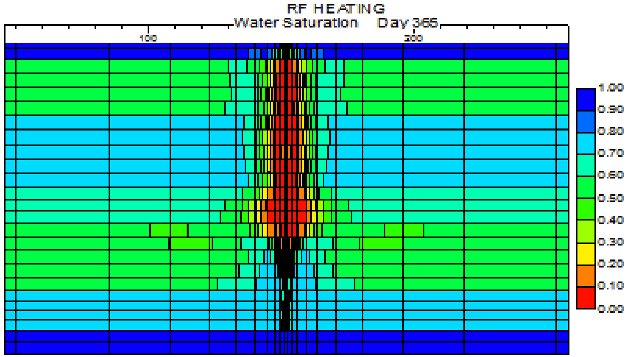
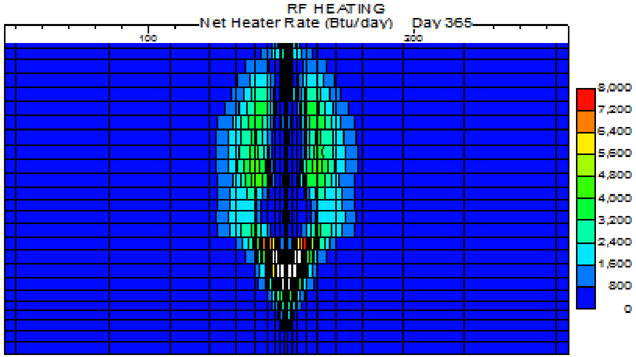
Future Application – RF Heating

- RF antenna used to heat reservoirs
- Benefit of less water, power consumption
- EM Simulation and reservoir simulation
- Subgridding around antenna







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Future Application – RF Heating

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Questions?

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