RSNA-QIBA COMPARISON OF SHEAR WAVE SPEED ESTIMATION IN VISCOELASTIC PHANTOMS

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Thanks!

- This is an international effort involving many groups
  - Industry
  - Academics
  - Clinicians
  - Government agencies
  - Pharma
  - Over 200 participants

- Special thanks to Mark Palmeri (Duke University) and Jun Chen (Mayo Clinic, Rochester, MN) for many of the slides/plots included here

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Clinical Motivation

- Clinical guidelines
  - EFSUMB Ultrasound Elastography Guidelines
  - JSUM Ultrasound Elastography Practice Guidelines
  - WFUMB Guidelines and Recommendations for Clinical Use of Ultrasound Elastography
  - SRU Elastography Assessment of Liver Fibrosis Consensus Statement
- Guidelines and clinical literature cite differences in SWS for liver fibrosis staging
- Need controlled datasets and imaging environments to characterize and delineate sources of SWS bias and variation

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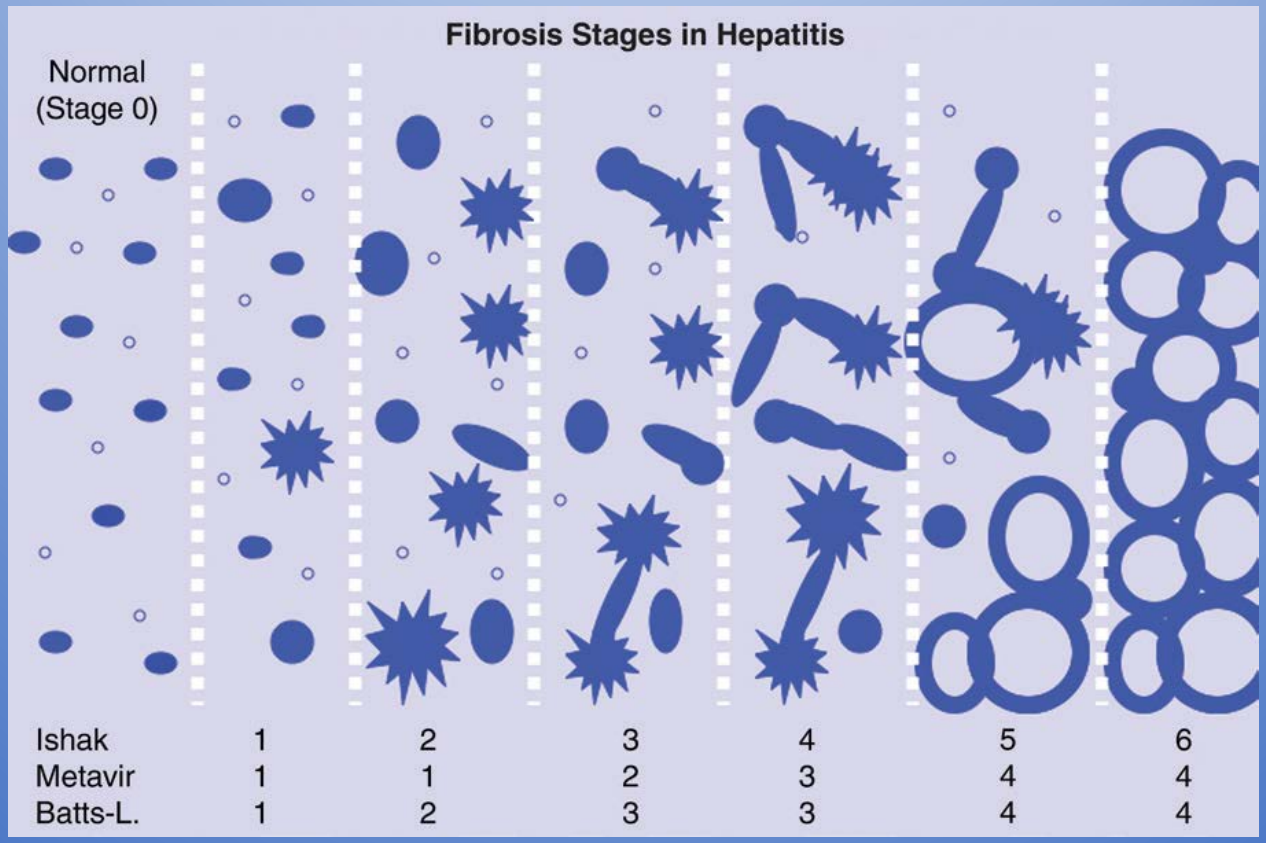
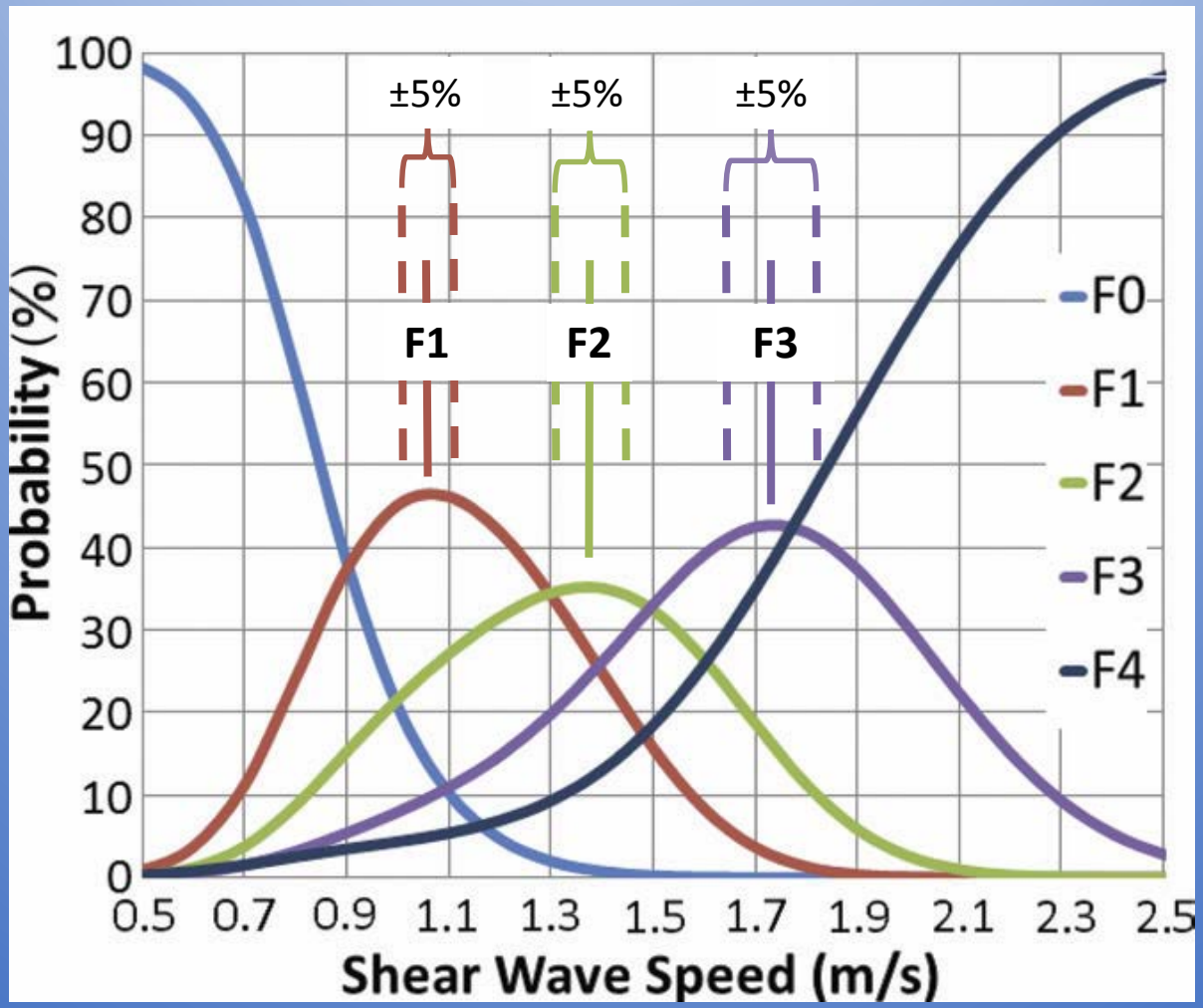
Liver Fibrosis Stages



Stars represent periportal fibrosis, lines represent bridging fibrosis, and circles represent nodularity

Barr et al. "Elastography Assessment of Liver Fibrosis: Society of Radiologists in Ultrasound Consensus Conference Statement", Radiology 276(3):845-861, 2015

Meta-analysis: SWS vs. METAVIR Score



Barr et al. "Elastography Assessment of Liver Fibrosis: Society of Radiologists in Ultrasound Consensus Conference Statement", Radiology 276(3):845-861, 2015.

Friedrich-Rust et al. "Performance of acoustic radiation force impulse imaging for the staging of liver fibrosis: a pooled meta-analysis", J Viral Hep 19(2), 2012.

Systems Involved in the Phase II Study

Most were blinded from knowing the results obtained by others prior to their data acquisition

- GE Logiq E9 - C6-1
- Hitachi
- Mindray/Zonare ZS3
- Philips EPIQ - C5-1
- Philips iU22 - C5-1
- Samsung/Medison RS80A
- Siemens S3000 - 6C1
- Siemens S2000 - 6C1
- Siemens SC2000 - 4C1
- Supersonic Imagine Aixplorer - 6C1
- Toshiba Aplio-500 - PVT
- Verasonics
- Duke custom implementation

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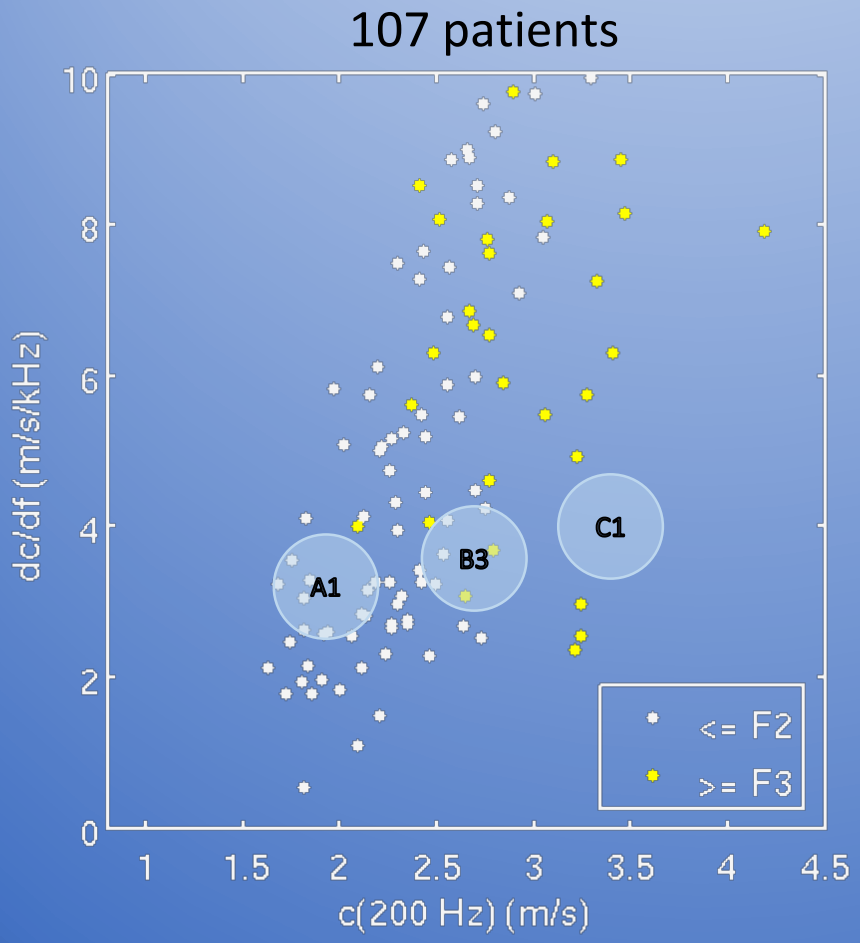
VE Phantoms Chosen to Match Human Liver Data (Healthy-Fibrotic)



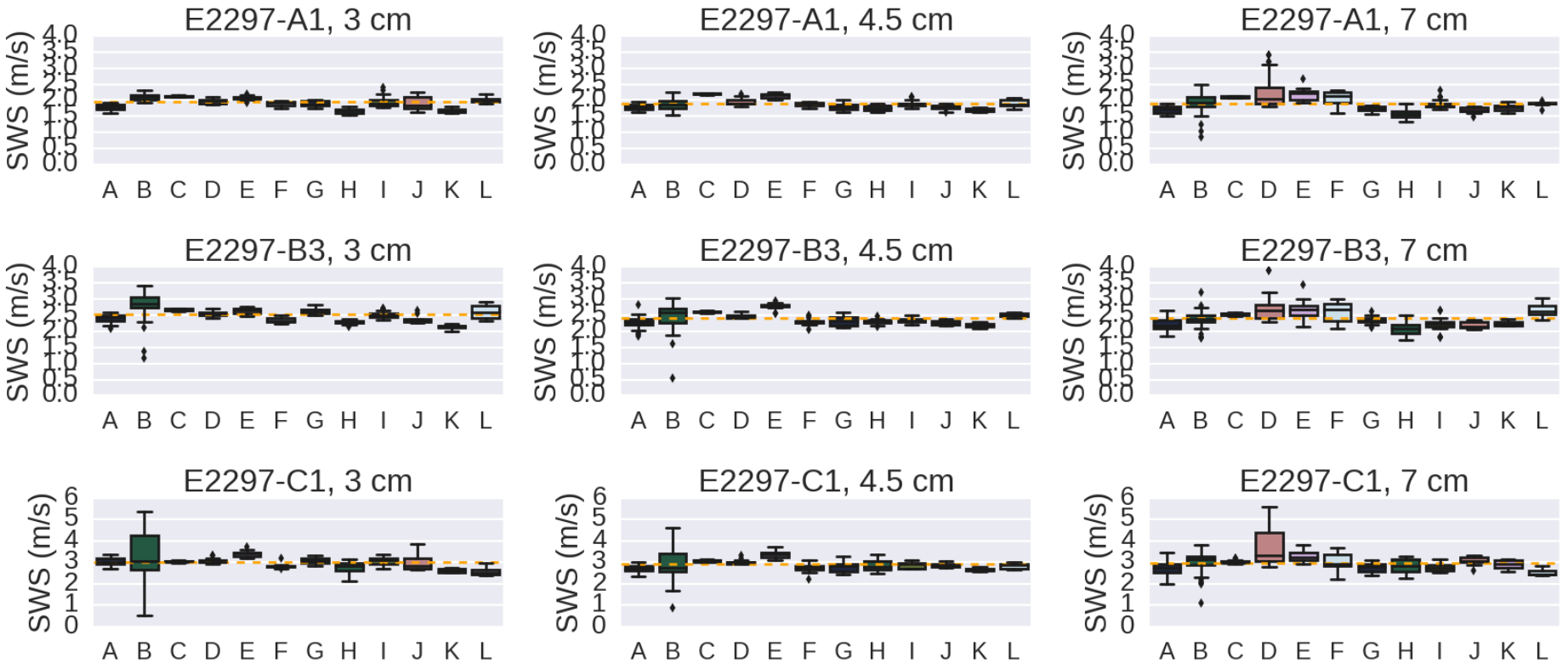
Three phantoms from CIRS
-- A1
-- B3
-- C1
(oil-in-polyacrylamide dispersions)

Increasing stiffness and dispersion

Demonstrates a need for more dispersive phantom materials

Nightingale *et al.*, "Derivation and analysis of viscoelastic properties in human liver: impact of frequency on fibrosis and steatosis staging", *IEEE UFFC, 62(1), 2015.*

Phase II Results



3 Phantoms (A1, B3, C1), 3 depths (3.0, 4.5, and 7.0cm), and 11 systems

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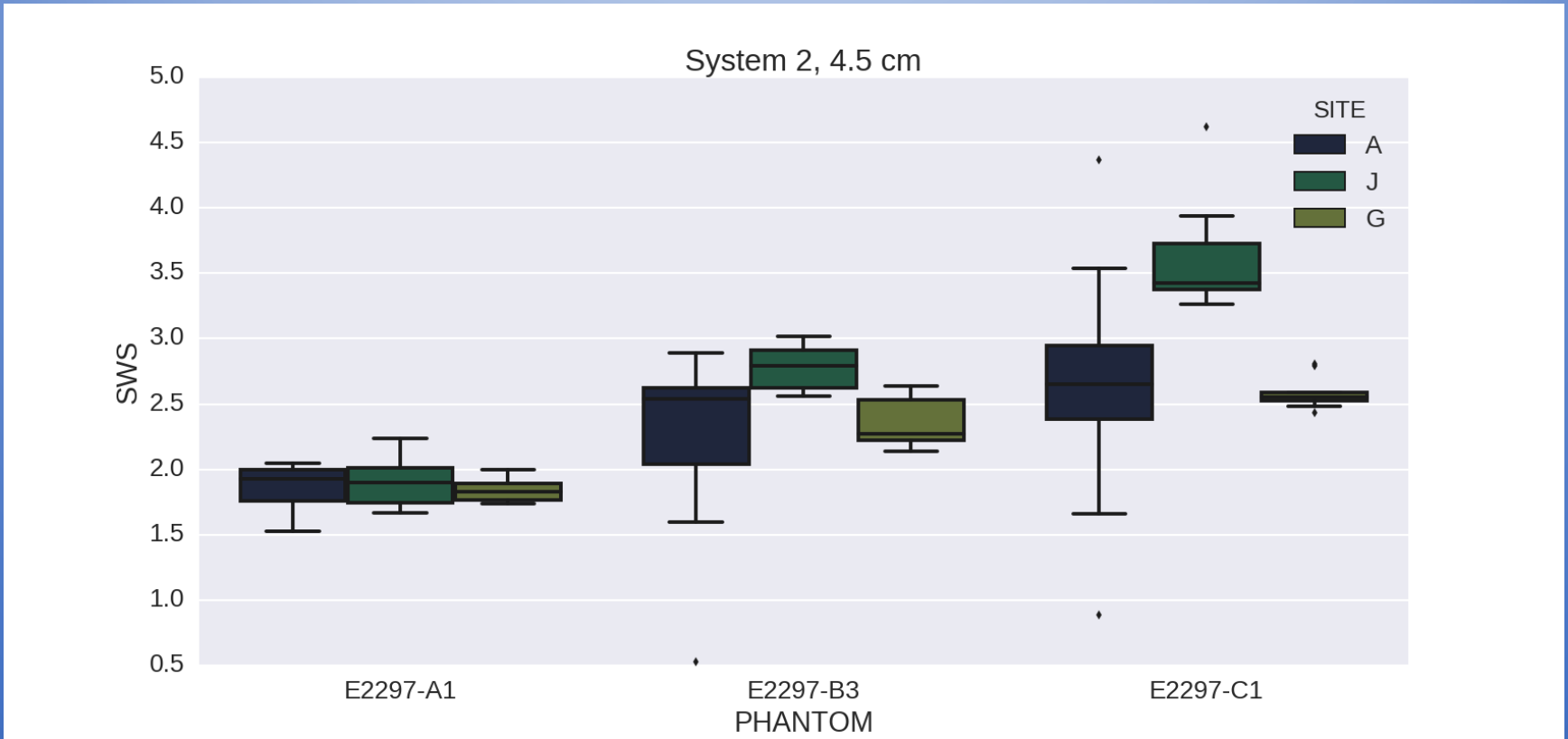
Phase II Results



Reproducibility

3 Phantoms (A1, B3, C1), 1 depth, and 1 system at 3 sites

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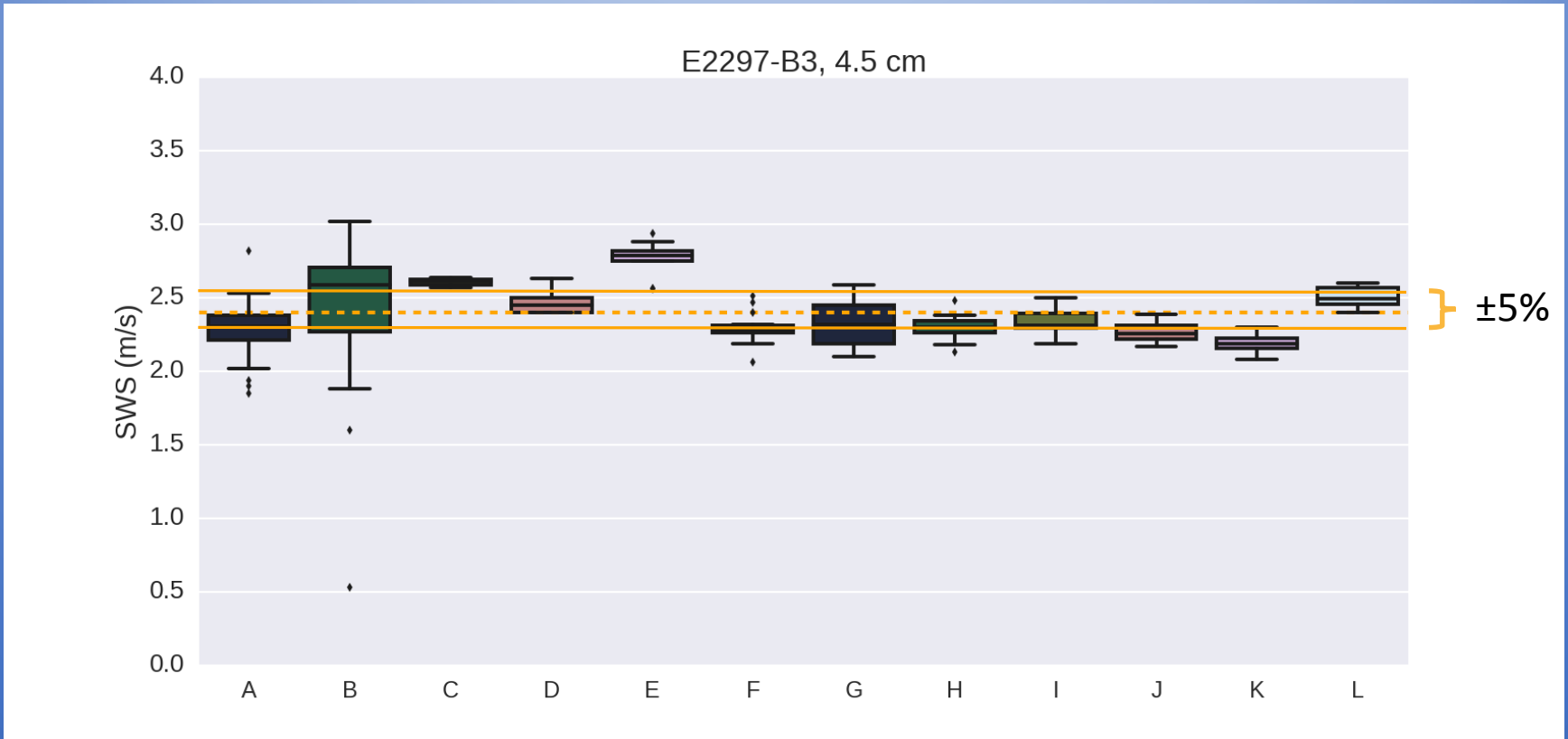
Phase II Results



Bias? Comparison with a 'consensus mean'

1 Phantom, 1 depth, and 11 systems

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Phantom Material Properties

- What is ground truth?
- What are the viscoelastic properties of these materials?
- What is the (shear wave) frequency dependence of those properties?

- ***How can we determine estimate bias lacking ground truth?***

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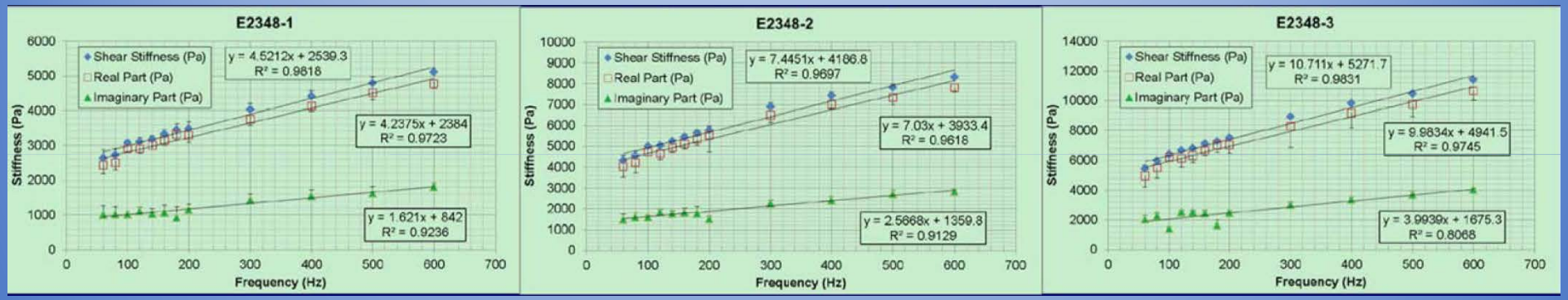
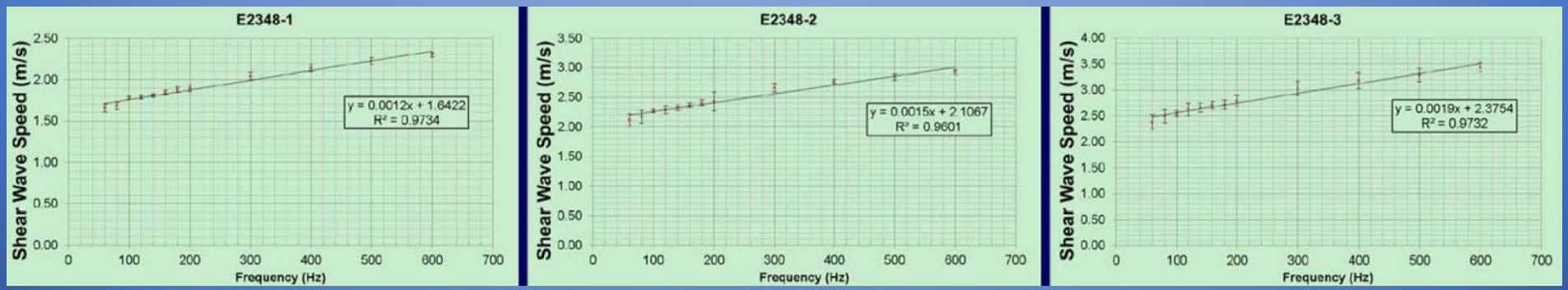
Use MRE Estimates as a Reference

MRE complex modulus estimates



MRE estimates converted to equivalent SWS



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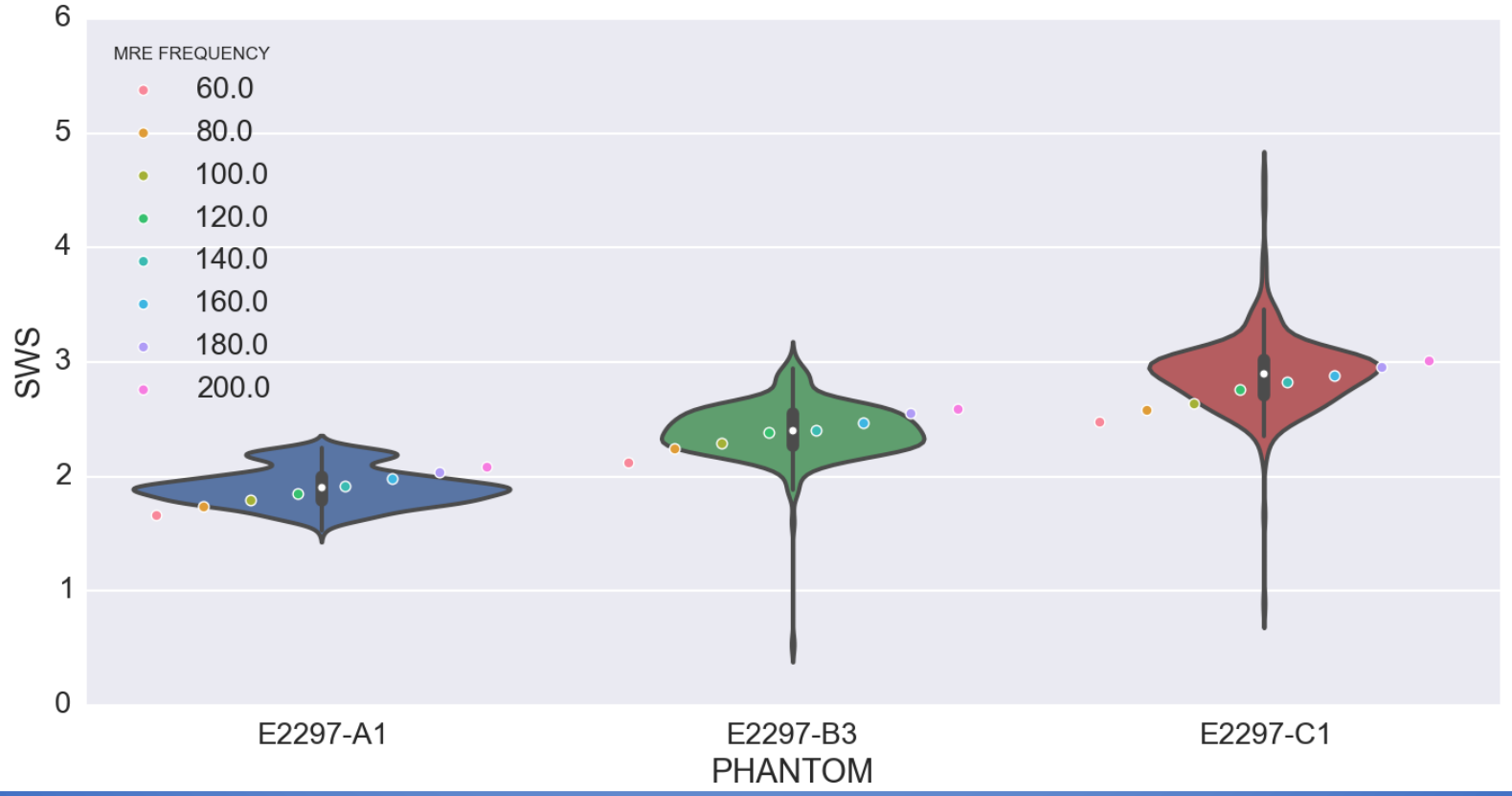
Compare SWS to MRE Estimates



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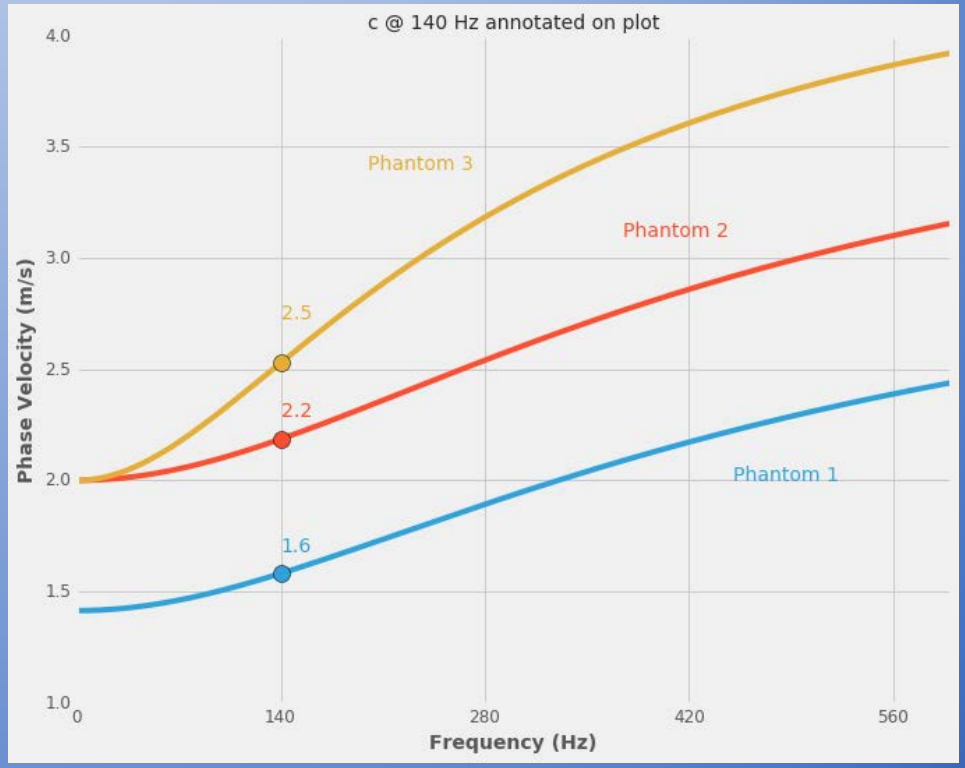
Digital Phantom Study Parameters

- **Curvilinear Probe Parameters**
  - Radius of curvature: 60 mm
  - Element Height: 14 mm
  - Element Pitch: 0.477 mm (0.007 mm kerf)
  - Center Freq: 3.0 MHz
  - Frac. Bandwidth: 100%
  - Elevation Focus: 50 mm
- **ARF Excitation Parameters**
  - Frequency: 3.0 MHz
  - F/# = 2, 3.5
  - 500, 1000 cycles
  - Focal Depths: 30, 50, 70 mm (F/2 for all configurations)
- **Acoustic Material Properties**
  - Attenuation: 0.45 dB/cm/MHz
  - Linear
- **Elastic Material Properties**
  - Poisson's ratio: 0.495
  - Shear modulus: [1.0, 2.0, 5.0, 10.0] kPa
- **Viscoelastic Material Properties**
  - Match Phase II phantoms
  - Fewer focal configurations

VE Digital Phantoms

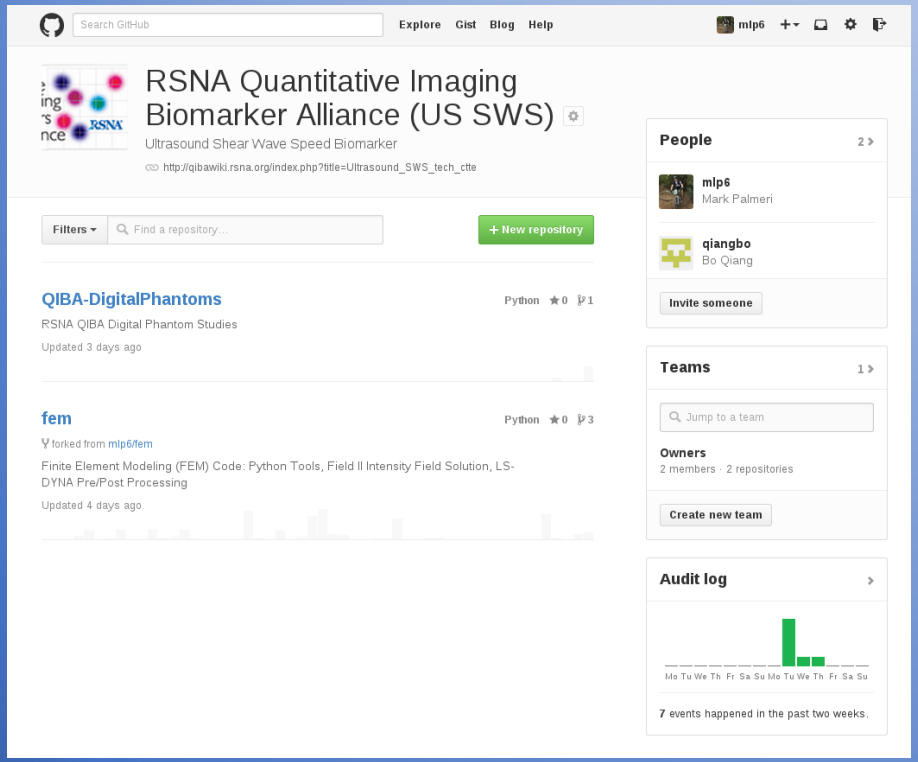
$$G(t) = G_\infty + (G_o - G_\infty)e^{-\beta t}$$

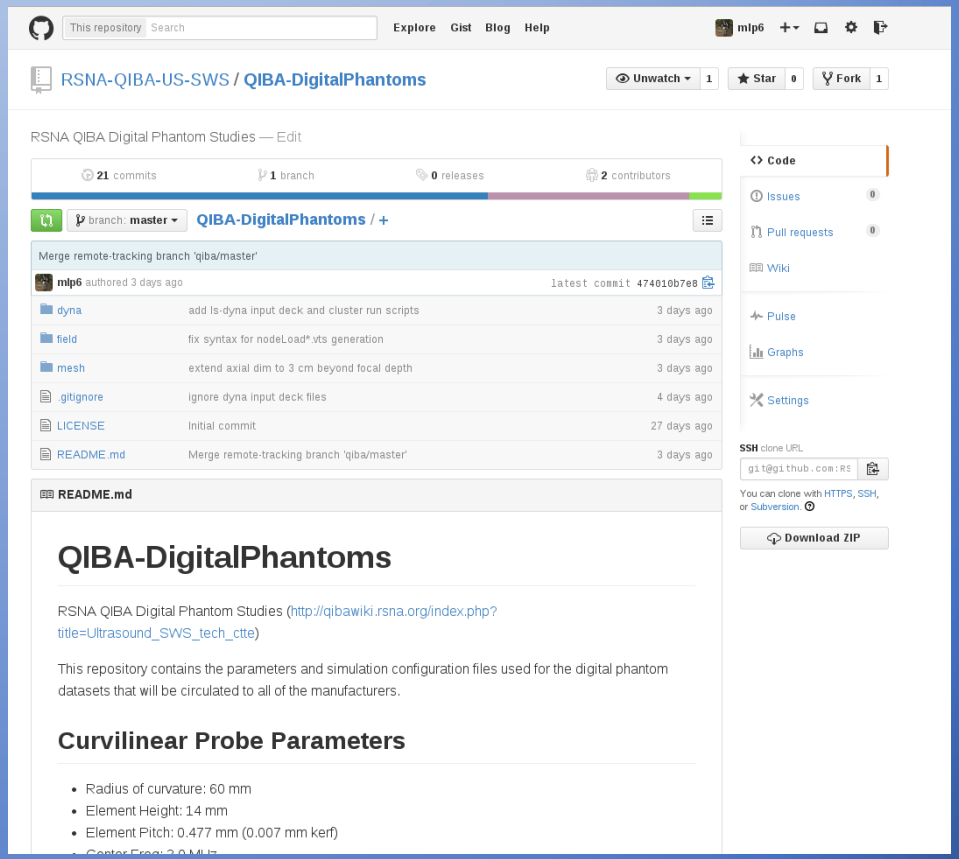
	Go (kPa)	G∞ (kPa)	B (s-1)
Phantom 1	10	2	6667
Phantom 2	15	4	5500
Phantom 3	20	4	4000



Simulation Setup Code Hosted on GitHub

https://github.com/RSNA-QIBA-US-SWS

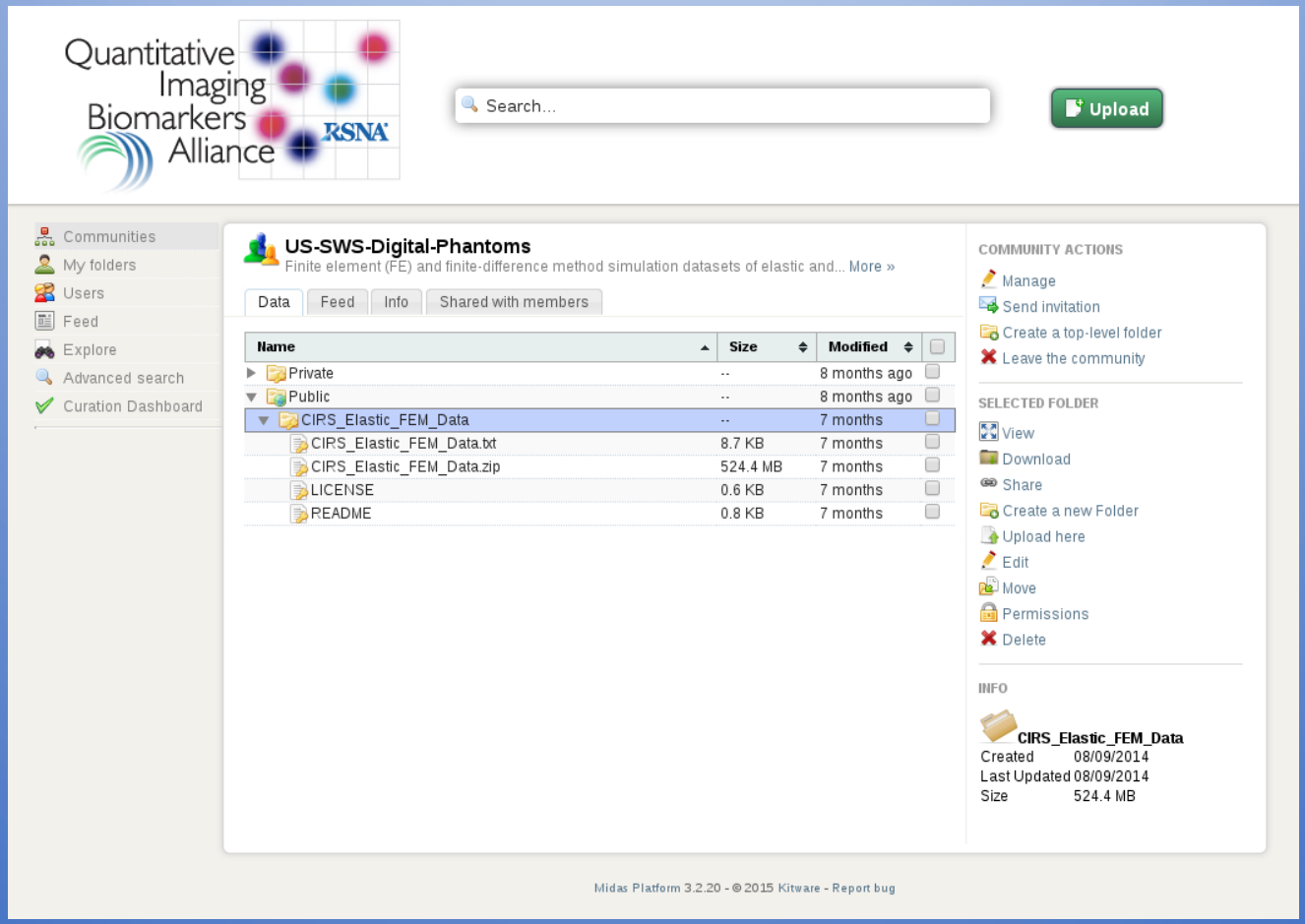




Quantitative Imaging Data Warehouse (QIDW)

http://qidw.rsna.org

(US SWS Digital Phantoms)



Conclusions

- Most commercial ultrasound systems agree quite well with a ‘consensus mean’ SWS in uniform phantoms
  - Some outliers (systems), but that can be corrected
- Calibration against MRE at ultrasound SWS-relevant frequency (e.g., 140 Hz for liver) provides a consensus ‘target SWS’ for a particular phantom
- Simulated data provides a basis for determining sources of bias in SWS estimation for each individual implementation
- Highly possible to minimize bias and reduce variance to about ±5% among systems in uniform media
- Better phantom materials and calibration methods are needed