PROGRESS PRESENTATION

Echospine: Developing an Ultrasound Assisted Lumbar Puncture Device

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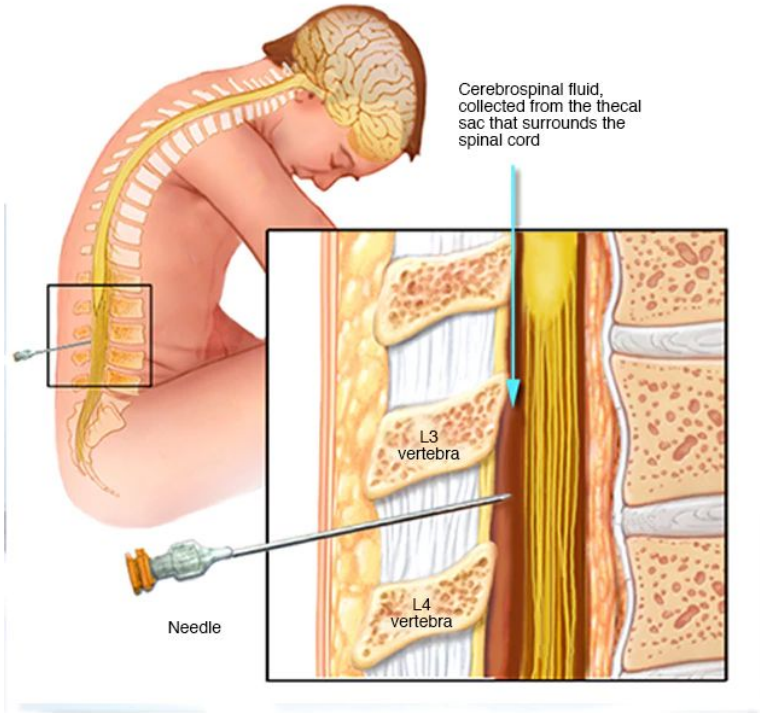
Project Goal Summary

Build a hands-free patch to guide lumbar puncture with ultrasound imaging so the clinician can

- **Find where and what angle to insert the needle**
- **See where the needle is as it goes in**



Progress of project goals

minimum:

- (in progress) mechanical “ultrasound rails” and the needle guide prototype
  - Subtask 1 - (met) Part selection: linear motion and sensing
  - Subtask 2 - (partial) Construct rail system
  - Subtask 3 - (unmet) Combine probe and needle system
- (in progress) An image acquired from the spine phantom with “ultrasound rails”
  - Subtask 1 - (met) Build prototype: 3D-printer + Verasonics
  - Subtask 2 - (unmet) Combine Ultrasound Probe with rail construction

Progress of project goals

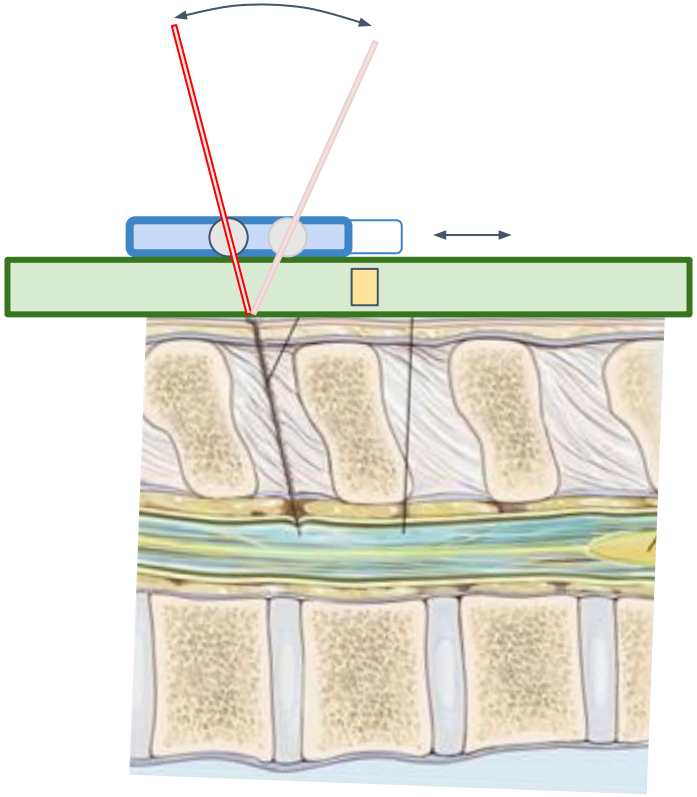
expected:

- (in progress) demo imaging a spine phantom and inserting a needle
  - Subtask 1 - (partial) Develop needle localization algorithm
  - Subtask 2 - (unmet) Image with our hardware prototype

maximum:

- (in progress) design and fabricate a FPGA-based ultrasound transmit+receive electronics
  - Subtask 1 - (met) Architecture + Part selection
  - Subtask 2 - (met) EDA Schematic
  - Subtask 3 - (partial) Software + firmware
  - Subtask 4 - (unmet) EDA Layout
  - Subtask 5 - (unmet) Assembly

Original approach



Original approach

- Move a single element to mimic a linear array to image the spine.
- Why single element? Small, less wires, less electronics, cheap.

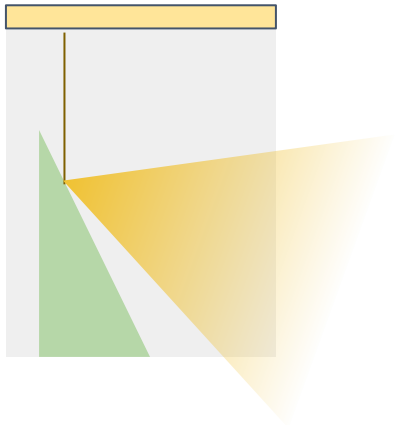
Problems

- The linear array we are trying to mimic is suboptimal for this task (next slide)
- Unfocused element produces bad image. Focused element cannot adapt to varying tissue depth.
- Custom probe fabrication timeline extends past end of semester.

Change in execution

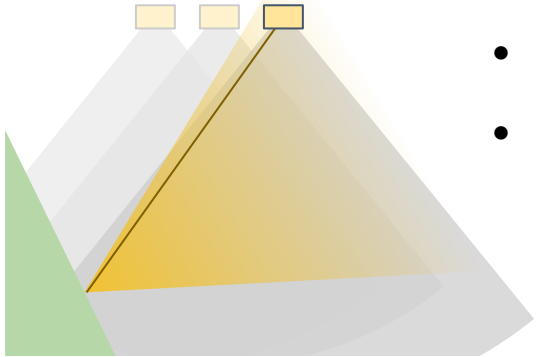
Moving small linear array

Ultrasound energy reflected away



Moving phased array

Energy reflected back to the probe



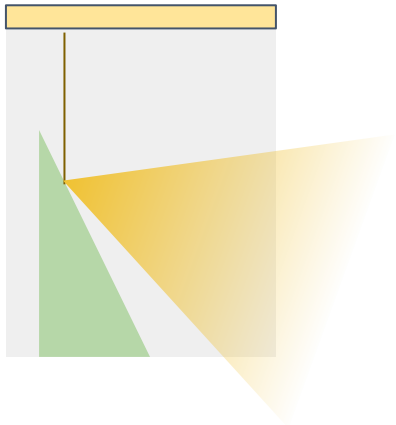
New approach

- **Move a small (~32 elements) aperture to achieve better-than-linear-array image quality.**
- **We compound the image from multiple linear position of the phased array.**
- **The phased array generates redundant insonification angles.**
- **Helps visualising “steep walls” and shadowed areas.**

Change in execution

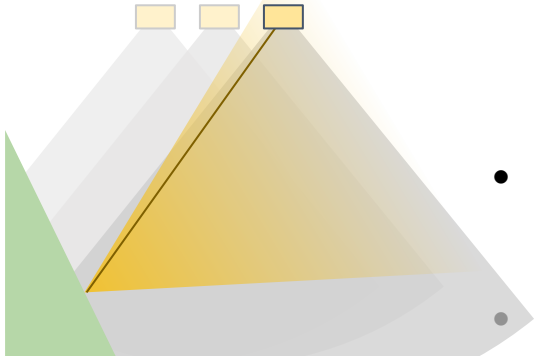
Linear array

Ultrasound energy reflected away



Phased array

Energy reflected back to the probe



From a single element to a small aperture: what about the advantages of single element?

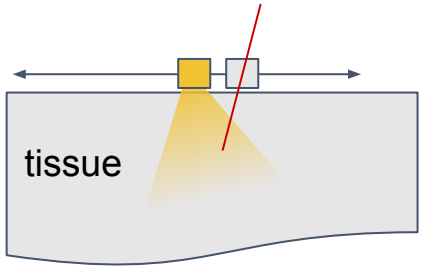
- **Low cost**
  - **Commercial off-the-shelf ultrasound AFEs (analog front end) already have 8/16/32 channels per IC**
  - **Transmit channels can't be multiplexed but are cheap. Receive can be multiplexed (sacrificing frame rate).**
- **Small/Less electronics**
  - **32 wires aren't much larger than 1 wire.**
  - **Small array with integrated electronics in development**

Where do we get the transducer?

- **Use an ATL P7-4 64-element phased array probe for proof-of-concept**
- **We can potentially get an array in the desired form factor from Analog Devices in the future**

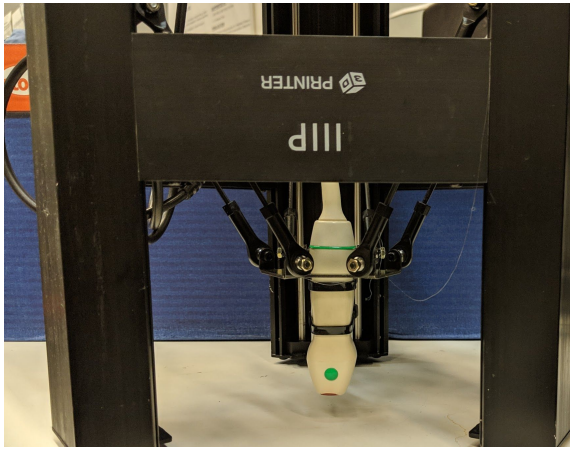
Challenges

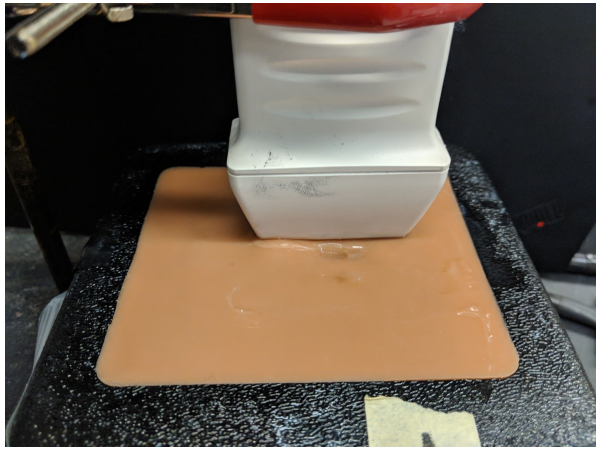
- Can’t see needle out of plane
  - Commercial phased arrays are designed to have excellent elevational focusing. Good for image quality. Bad for seeing out-of-plane targets.
  - Solution 1: Small elev. dimension custom array with less elev. focusing
    - Long wait.
  - Solution 2: Co-plane probe placement
    - Similar to biopsy probe needle guide, but clinician does not hold the probe and probe gets out of the way.



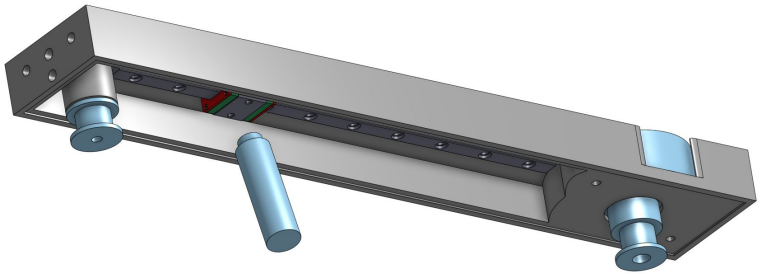
Progress - Probe-on-3d-printer experiment

- Moves probe translational 3-DOF ✅
- Acquires B-mode frames with Verasonics 🕑





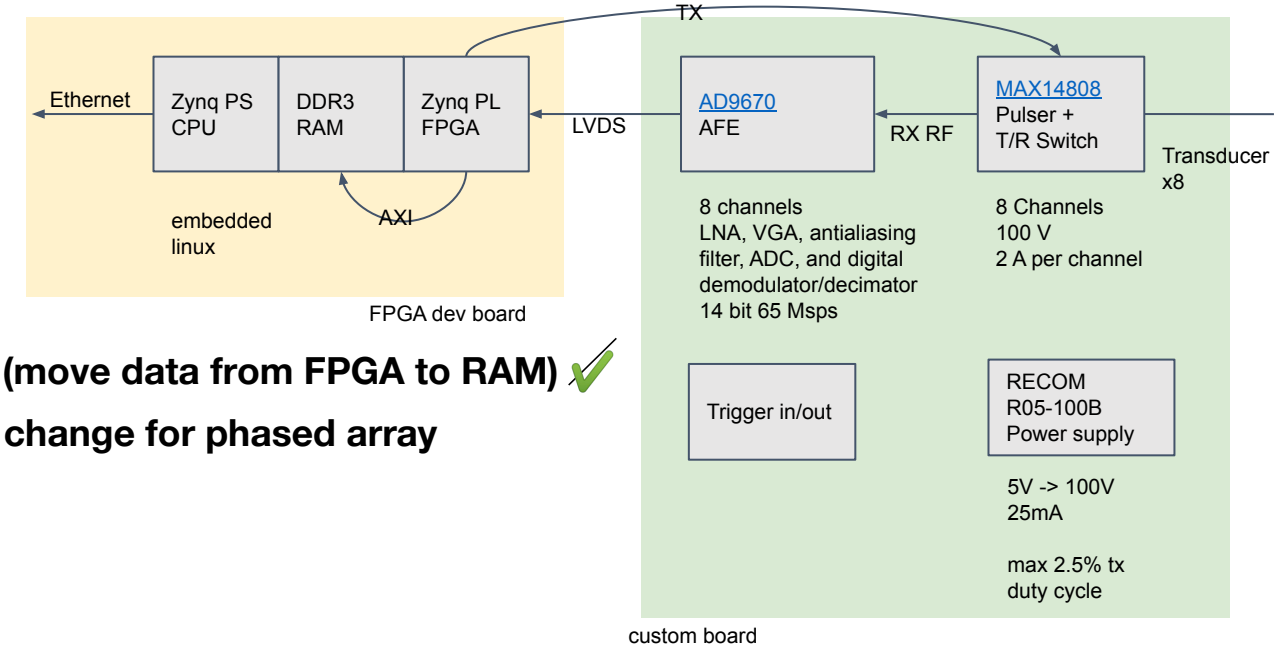
Progress - Imaging rails



We don’t hold a single element anymore.

Needs redesign to hold a P7-4 probe and add a carriage for co-plane needle guide. 🕒

Progress - custom tx/rx board



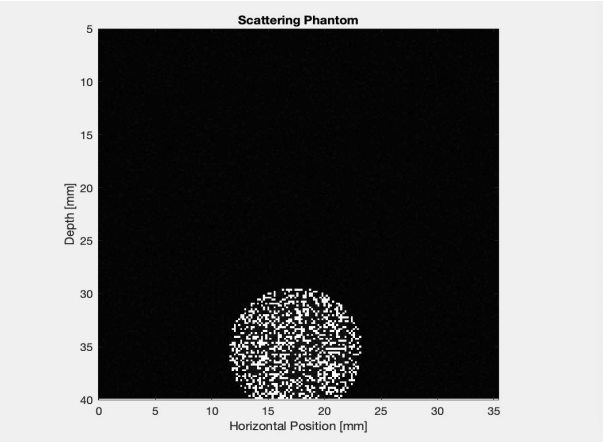
AXI DMA firmware/software (move data from FPGA to RAM) ✅

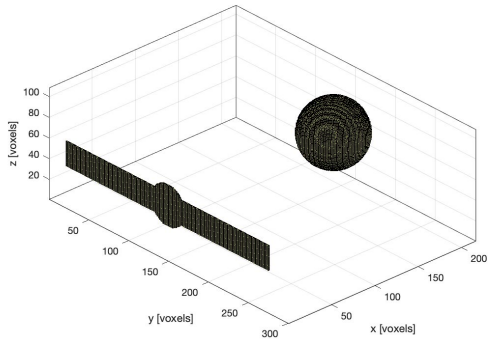
EDA Schematic 🕒 **… needs change for phased array**

EDA Layout 🕒

Assembly 🕒

Progress - K-Wave Simulation



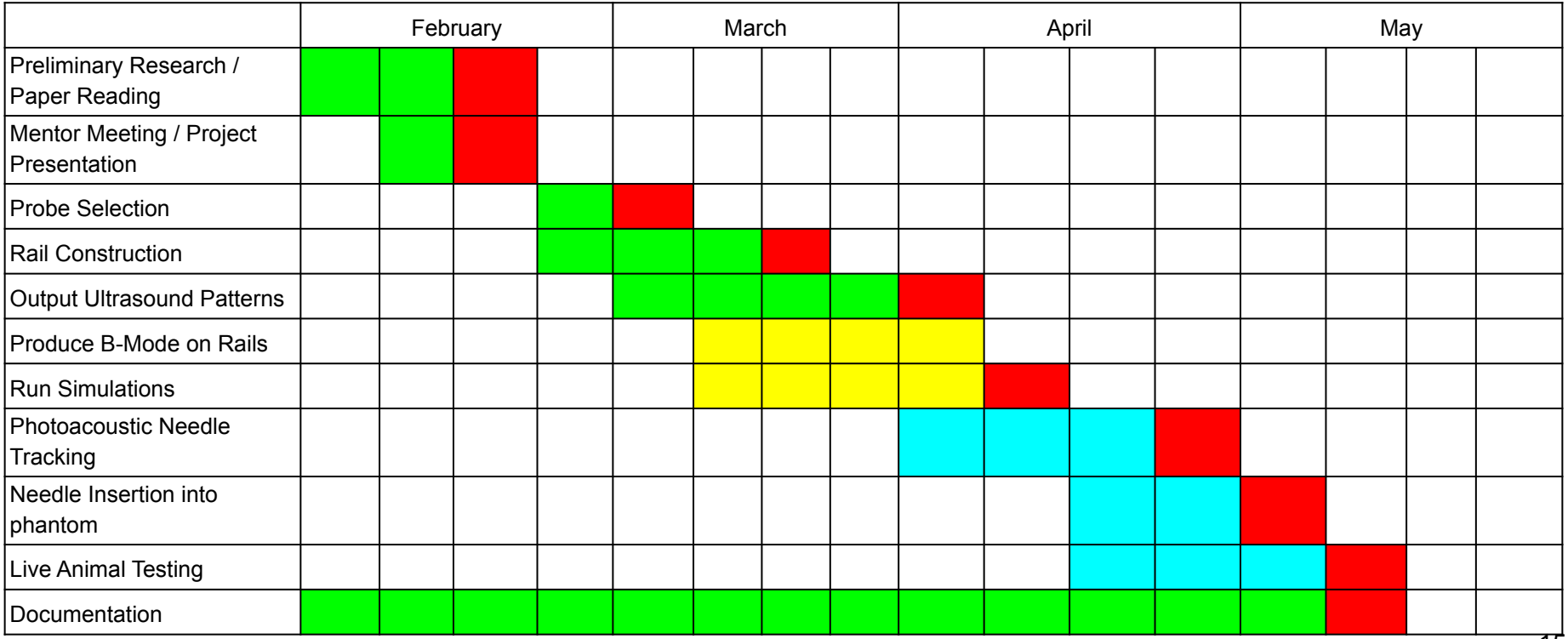


Construct 2D Simulation → Construct 3D Simulation → Apply to actual spine model

Updated Dependencies

Level of Deliverable Affected	Dependency	Proposed Solution	Important Dates	Alternatives	Status
Minimum	Parts for linear motion	Construct with components from vendors	Need by 3/29/2019	Adapt existing tools from the lab space	Resolved
Minimum	Ultrasound Transducers	Provision by MUSiiC lab	Need by 2/21/2019	Purchase through external company	Resolved
Minimum	Verasonics	Provision by MUSiiC lab	Need by 2/21/2019	Develop internally	Resolved
Maximum	Needle and tip element	Purchase components	Need by 2/21/2019	Use probe tool for insertion	Resolved
Maximum	Needle position tracking using ultrasound methods	Purchase components	Need by 4/25/2019	Develop photoacoustic method	Resolved
Maximum (cancelled)	Animal Protocol Approval		Need by 4/25/2019	Continue work with phantom	Resolved

Old Schedule



New Schedule

	April				May			
Run Simulations								
Probe Selection								
Learn Verasonics								
Moving phased array experiment								
Prototype for needle+phased array								
Photoacoustic Needle Tracking								
Needle Insertion into phantom								
Documentation								

Updated project goals

minimum:

- **image+code+doc - A pair of B-mode image comparing image quality of linear scan and our new phased array synthetic aperture scan on a spine phantom**

expected:

- **video+code+doc - A video showing inserting a needle into tissue phantom (no bones) while maintaining its visibility all time.**
- **code+doc - Adaptive compounding algorithm that maximizes information from vertebrae**

maximum:

- **video - A video showing needle insertion in spine phantom with hands-free ultrasound guidance**
- **code+doc - Acoustic needle localization simulation**
- **image - Deep tissue photoacoustic imaging**

Updated Milestones

Compare image quality of linear scan and our new phased array synthetic aperture scan on a spine phantom	→ April 22, 2019
Run the simulation code on the CAD of the spine phantom in K-Wave	→ April 20, 2019
Acoustic needle localization	→ April 25, 2019
Deep tissue imaging with photoacoustics	→ April 27, 2019
Assemble a co-plane needle/probe rail device	→ May 1, 2019

Questions?