# MECE Capstone Project

Spring 2023

# “What keeps you up at night?”

RICE UNIVERSITY
News and Media Relations
*Office of Public Affairs*

Menu

RICE NEWS > CURRENT NEWS > 2022

Dec. 16, 2022

POSTED IN: **RICE NEWS** > Current News > 2022

## DesRoches outlines 2023 goals to faculty

***President’s first State of the University highlights values, plans and commitments***

Rice University’s dedication to equity and innovation will be taken to new heights going forward, President Reginald DesRoches said during his inaugural State of the University presentation to faculty Dec. 15.

“We will enhance our research enterprise while remaining committed to undergraduate education, growing improving graduate programs, and maintaining our commitment to diversity, equity and inclusion,” he told the audience gathered in the Glasscock School of Continuing Studies’ Hudspeth Auditorium.

While acknowledging the traditional “RICE” values — responsibility, integrity, community and excellence — DesRoches has added a few. “We have a number of guiding principles, many of which I’ve mentioned throughout the inauguration,” he said. “Have courage, curiosity (and) cultural care, which is so important in everything that we do.”

Reginald DesRoches delivers his State of the University.

After recognizing the university’s new leadership team, DesRoches said Rice remains on solid financial footing with an endowment of $7.81 billion as of June 30 that provides 43% of the yearly budget. Philanthropy over the last

https://news.rice.edu/news/2022/desroches-outlines-2023-goals-faculty

‘The question that gave him pause, however, came from engineering colleague, Behnaam Aazhang, J.S. Abercrombie Professor of Electrical and Computer Engineering and director of the Rice Center for Neuroengineering: “What keeps you up at night?”’

# What possibilities keep me up at night?

- No learning occurs during the capstone project
- Nothing gets done during the capstone project

**Let’s start on the right foot so that learning and progress happen**

# Grading & Assessment - See all deadlines in Canvas

| | | |
|---|---|---|
| Final Presentation | **15%** | |
| Final Report | **15%** | |
| Documentation | **20%** | |
| + SW & HW Documentation | 10% | Based entirely on GitHub repo |
| + Online Project Description | 10% | |
| Meetings | **20%** | |
| + Update Meetings | 10% | The 1 weekly class time where I meet with you |
| + Work Meetings | 10% | The other weekly class times |
| Execution & Development | **30%** | |
| + Abstract | 5% | |
| + Goals Outline | 5% | |
| + Achievement of Goals | 20% | |

# Overall Expectations

- It is your responsibility to check Canvas weekly and see what is due
  - I will not always make announcements about deadlines
  - Everything is already set up in Canvas
- **NO LATE WORK accepted for this class**
  - You know all deadlines in advance, unlike most classes
  - The workplace can be unforgiving when it comes to deadlines
- The project you get assigned is a two-semester (year-long) commitment

# Project Expectations - Slack

- Required to join the Slack workspace
  - You should have received an invite via email
    - Let me know if you did not
  - We'll make channels for each project
    - You must join the channel for the project that you are working on
    - You are expected to check that daily

# Code & Documentation - GitHub (10% of the grade)

- Required to contribute to github repo for respective project
  - I will make repo's for each project
  - You must contribute to both code and documentation
  - Do not use your own github repo, everything must be in the repo I host
- You should make contributions that make it so anyone could read the documentation on the repo and recreate the entire project
- I will grade according to the degree that this reproducibility is possible

# Meetings (20% of the grade)

- All meetings after this first week will be in Ryon B12
- Update meetings (10% of grade)
  - 1 meeting each week for each team
  - Up to 50 minutes
  - During class time
  - Monday I will meet with 1 team, Wed another, and Friday another
  - Every team member is expected to present an individual update
- Work meetings (10% of grade)
  - While I meet with 1 team in Ryon B12, you are expected to also be in B12 meeting with your team to work on your project
    - This is the expectation all days, MWF
  - I will take attendance right at 10am and record it on Canvas
  - If you aren't in Ryon B12 at 10am, you will get a 0 for work meetings that week, no exceptions

# Final Presentation (15% of the final grade)

- Final presentations will happen the final week of classes
  - Please prepare and give a final presentation as a team (if you are working in a team; otherwise individual). I have scheduled or will schedule times and locations with all of you. Please let me know if you have any questions about your final presentation. Please also upload the slides (only 1 member of your team needs to do this). Here is my recommended format:
    - What's the problem? (Why do we care?)
    - What are current solutions? What's the state of the art?
    - What is your proposed solution?
    - What does the performance of your solution look like?
    - What's next?
  - Every member of the team must present at least once during the presentation, however the presentation should be a unified presentation and not a repeat of the 5 suggested steps for each teammate.

# Final Reports (15% of the grade)

- Due the final week of classes
- Create a 5 page final report describing your project. Papers above 5 pages will not be accepted. References can be included in the page count or excluded. By submitting this report, you are consenting to us posting it online. Please let us know if you have any objection to this before submitting. Use the format:
  - Title and authors
  - Abstract (100-150 words)
  - Introduction
  - Methods
  - Results
  - Discussion
  - Acknowledgements
  - References
- See section descriptions here. Here's one of my papers from my PhD, which may also help give an idea of what those sections are about.
- You must write the report in latex using an IEEE style and put the source (including all files, pictures, etc.) in the GitHub project repo. I should be able to recompile the latex report from your source that you include in your repo.
- Submit a PDF version of the report to this assignment here on Canvas. Also have the PDF on the project GitHub repo.
- Must include at least 3 figure/diagrams/pictures in total.

# Online Project Description (10% of final grade)

- Due on the last day of classes
- As a team please write a 100 word summary of your project that will be used as inspiration for the online description of the project. Be sure to cover the same items as the final presentation:
    1. What's the problem? (Why do we care?)
    2. What are current solutions? What's the state of the art?
    3. What is your proposed solution?
    4. What does the performance of your solution look like?
    5. What's next?

# Abstract (5% of final grade)

- Due 1/20
- In 100-150 words and as a team, write in your own words a draft abstract for your project. The abstract should address:

    1. What's the problem? (Why do we care?)

    2. What are current solutions? What's the state of the art?

    3. What is your proposed solution?

    4. What does the performance of your solution look like? [Use your imagination here to say something like "we achieved 10X the state of the art", even though you don't know yet exactly how your project will go]

# Goals Outline (5% of final grade)

- Due 2/3
- Specify three tasks you plan to execute and complete for the project
- Write a paragraph (3-4 sentences) about each
  - Therefore, submit 3 paragraphs in total
- You can update these tasks later in the achievement of goals assignment, which is due in roughly a month from the goals outline
  - Your final grade for the achievement of goals assignment will be based on your effort and completion of the tasks specified in the achievement of goals submission

# Achievement of goals (20% of final grade)

- Due 3/6
- This is the final version of your goals outline
- Update the three paragraphs you wrote for the goals outline
  - Be more specific and quantitative in this submission
- You must mention a metric of success for each task and how you plan to achieve the task
- Your final grade for this assignment will be based on your effort towards and completion of the tasks specified in this submission

# Project Menu 

- Autodrone: Camera-based autonomous drone
- Cairdio: Digital stethoscope empowered by machine learning
- Athena: RISC-V microcontroller board
- Perfusion: Seeing beneath the skin

# Autodrone: Camera-based autonomous drone

- Check out F22 slides here

# Cairdio: Digital stethoscope empowered by machine learning

- Page: https://www.healthseers.com/cairdio-pcg-ai
- Note to Joe: Show draft explainer video
  - https://mail.google.com/mail/u/0/#search/cairdio/FMfcgzGrbHtTSqfjGxRKGstxjgGrptlg

# Cairdio: Digital stethoscope empowered by machine learning

- Multiple-track PhonoCardioGraphy (PCG) and Artificial Intelligence (AI) to Detect Heart Anomalies
- Heart disease is a leading cause of mortality worldwide but historically goes under-detected. This is primarily due to limitations of the tools, such as Electrocardiogram (ECG), Photoplethysmography (PPG) and blood pressure detectors, currently used by lesser trained medical staff to detect them. Phonocardiography (PCG) is used to detect these issues and there are global efforts to extend the diagnostic ability of PCG by using Artificial Intelligence (AI). PCG relies on microphones, traditionally in the form of stethoscopes, to listen to (“auscultate”) and analyze (“infer”) the sounds of the heart. Stethoscopes are ineffective in the hands of lesser trained staff, and generally require a specialist to know where to place and how to interpret the various sounds.
- A very common approach to PCG data collection consists in recording heart sound from different auscultation locations using a digital stethoscope. The typical four locations are aortic area, pulmonic area, tricuspid area and mitral area, but could be any other location that provides the most audible heart vibration. In situations when more than one recording is collected from a patient, they are collected sequentially, not simultaneously [1].
- Standardized data collection and annotations are essential for artificial intelligence in any diagnostic modality [2]. To accomplish best possible results, we propose an acquisition protocol that records heart sounds from the four most common locations simultaneously.

# Cairdio (2)

- Our current device is a 4-track PCG recorder, named Cairdio, which standardizes the placement of the microphones at locations preferred by cardiologists. Once recorded, the heartbeat tracks are transferred to a mobile app to be interpreted by an AI Convolutional Neural Network (CNN). This interpretation will indicate whether the heartbeats are normal or require further investigation by a trained expert.
- Our intent is to allow the lower trained staff at the front door of the medical system to identify cardiac anomalies that are currently going undetected. For this purpose, we are developing a handheld, easy-to-use device combined with a deep learning based AI app.
- AI reliability has evolved sufficiently to warrant international efforts to capitalize on the combination of PCG and AI to identify abnormal heart sounds. Documented efforts have been proven to classify abnormal heart beats with greater than 85% accuracy [3].

# Cairdio (3)

- A successful outcome for this project will be an improved device that can be used to record and train cardiac AI neural networks. It can then be implemented in medical settings to identify heart abnormalities in people who have not been previously diagnosed, or to track the progress for people who have been. Ultimately we would send the device to cardiac research entities throughout the world to accelerate their own investigative CNN efforts.

# Cairdio (4)

Overall Goals:

1) Our goal is to refine the hardware device for accuracy and robustness for use in AI. The design challenges are to create a device that is:

- Lightweight and handheld
- Collects undistorted sounds of the body (20-400hz)
- Is easily charged and maintains that charge for a reasonable time
- Communicates to a mobile app via wireless technology (likely Bluetooth)
- Adapts to different body shapes and sizes
- Provides recordings that are easily used for training AI neural networks
  - Rejects outside noise contamination
  - Records clear snips of 5-10 seconds of heart sounds
  - Records from 4 preferred locations simultaneously

# Cairdio (5)

**Some suggested resources and reference information:**

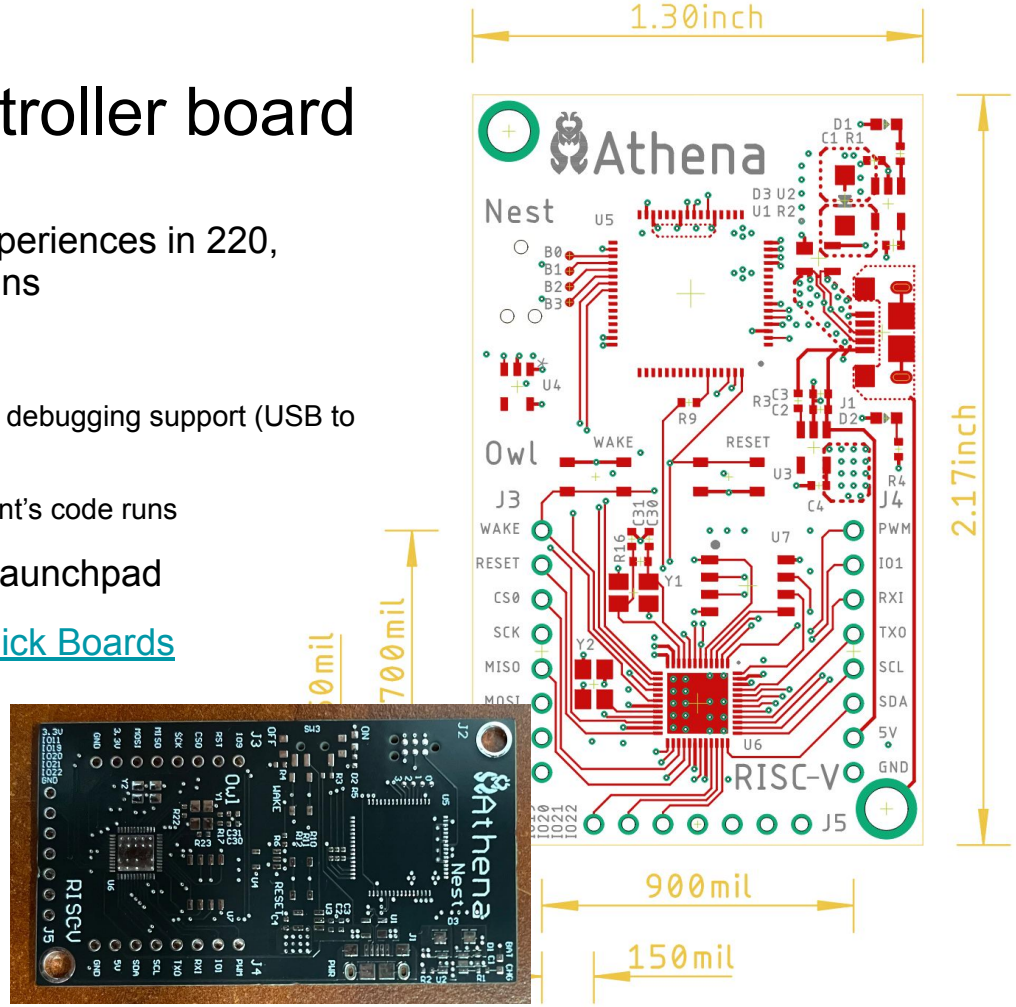
[1] Liu, Chengyu et al. “An open access database for the evaluation of heart sound algorithms.” Physiological measurement vol. 37,12 (2016): 2181-2213. doi:10.1088/0967-3334/37/12/2181

[2] Diaz, Oliver, et al. "Data preparation for artificial intelligence in medical imaging: A comprehensive guide to open-access platforms and tools." Physica medica 83 (2021): 25-37.

[3] Classification of Normal/Abnormal Heart Sound Recordings: the PhysioNet/Computing in Cardiology Challenge 2016
Gari D. Clifford, Chengyu Liu, Benjamin Moody, David Springer, Ikaro Silva, Qiao Li, Roger G. Mark

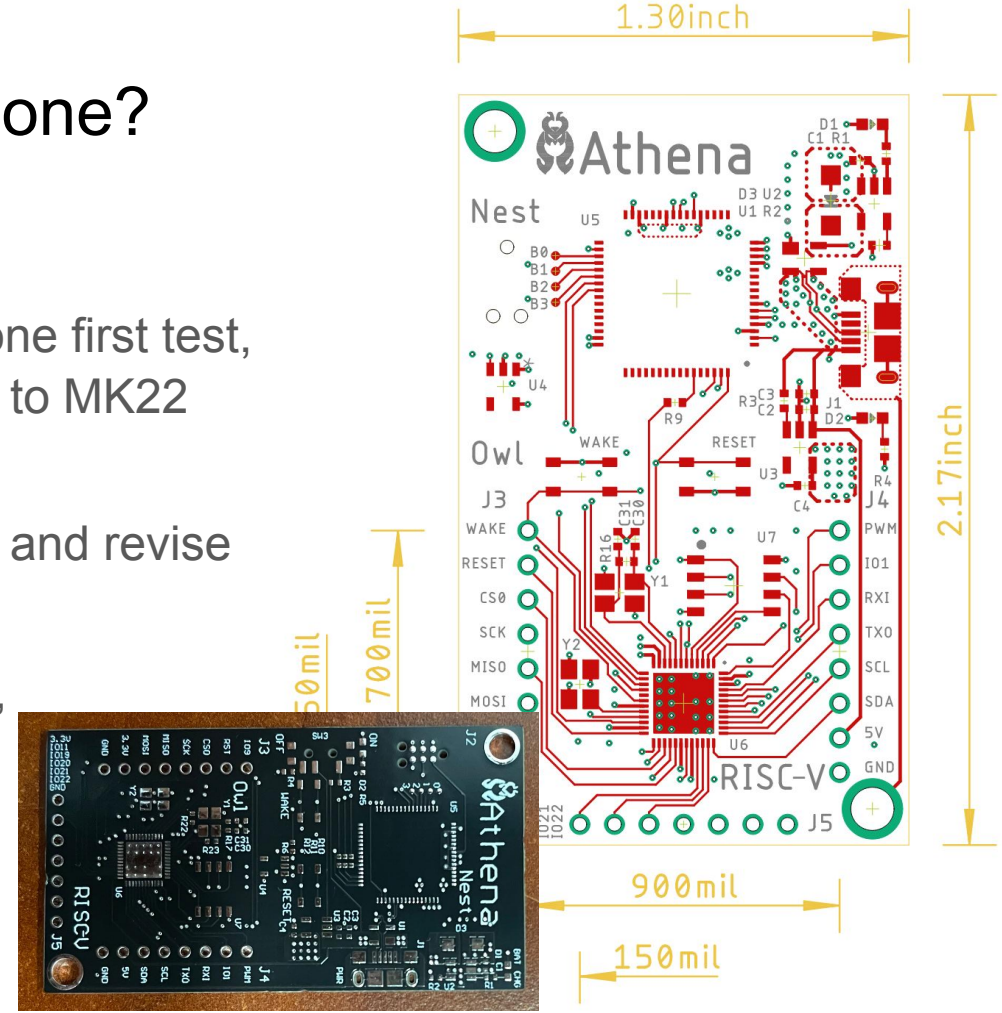
# Athena: RISC-V microcontroller board

- Novel design based on Rice students' experiences in 220, Junior design, and senior capstone designs
- "Two processor" design
  - – Nest: an ARM processor providing onboard debugging support (USB to JTAG)
  - – Owl: SiFive RISC-V processor where student's code runs
- Less than half the size of an Arduino or Launchpad
- Support for extension Wings based on Click Boards
- Great support from SiFive and Segger
- Will be used in ELEC 220, and more!



# Athena: What's left to be done?

- A lot
- Haven't assembled it, haven't done first test, haven't flashed Segger software to MK22 debugger (J-Link)
- Need to see how version 1 goes and revise design from there
- Software/hardware, PCB design, embedded systems



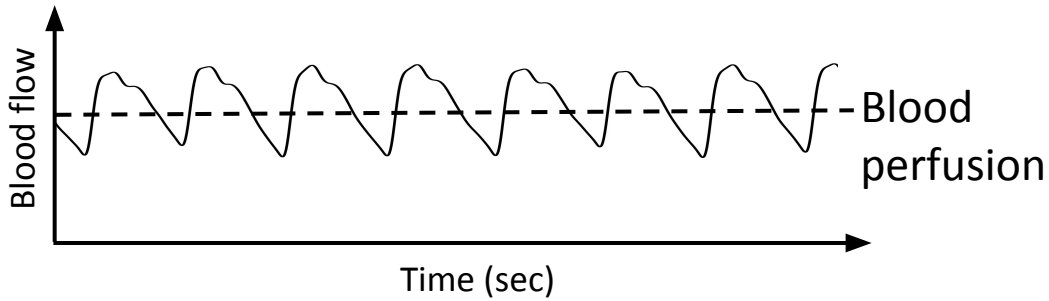
# Perfusion: Seeing beneath the skin

- PulseCam
  - Note to Joe: Show folks slides here
- Speckle contrast for blood flow

- The following slides are from Rice ECE PhD student Kendra Khodabandehloo

# Blood perfusion

- Blood flow is pulsatile, synchronous with the cardiac cycle.



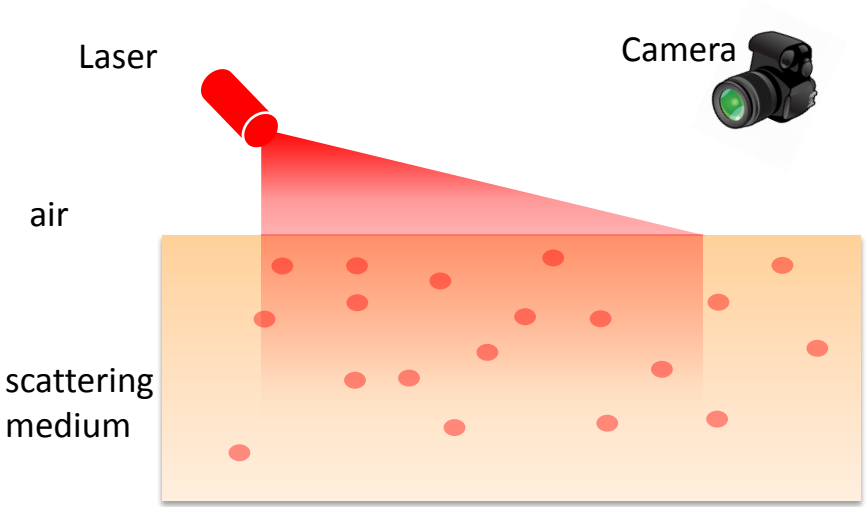

Average blood perfusion

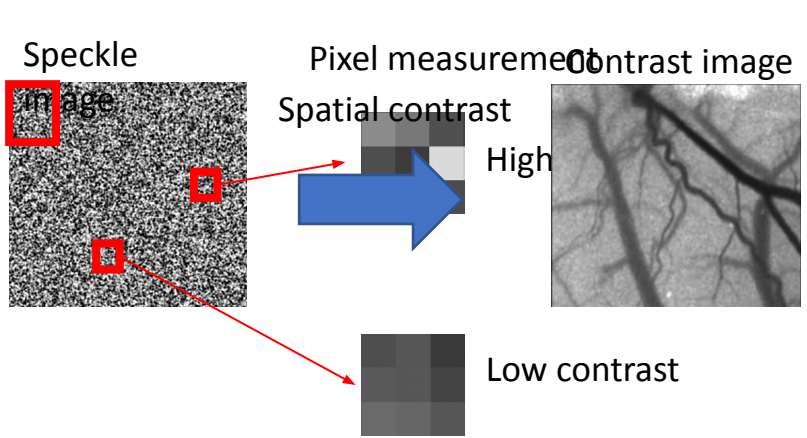

- Temporal variation: functional changes
- Spatial variation

Monitoring of hemodynamic changes induced in the healthy breast through inspired gas stimuli with MR-guided diffuse optical imaging

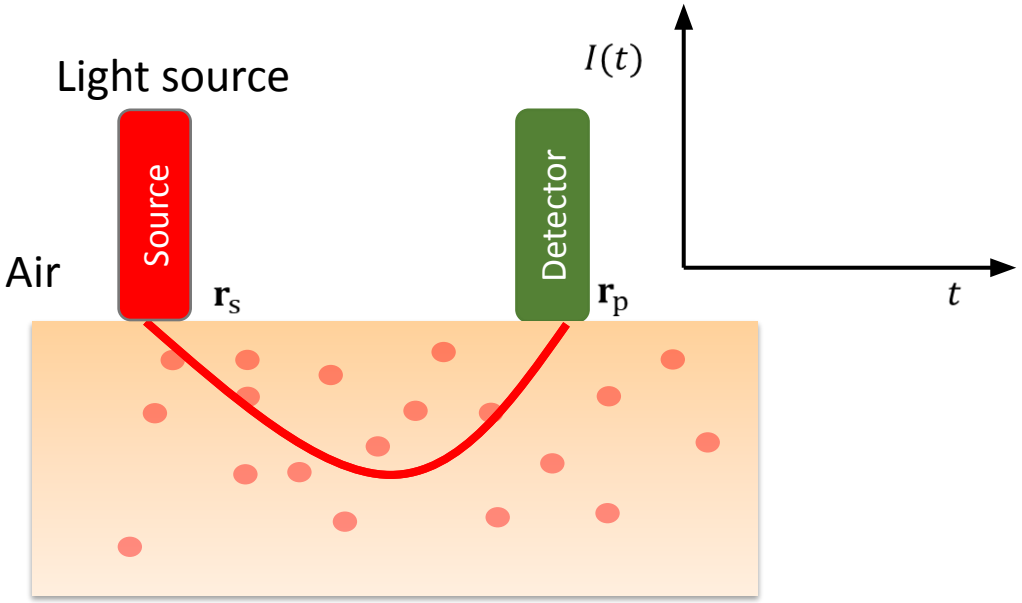
# Laser speckle contrast imaging

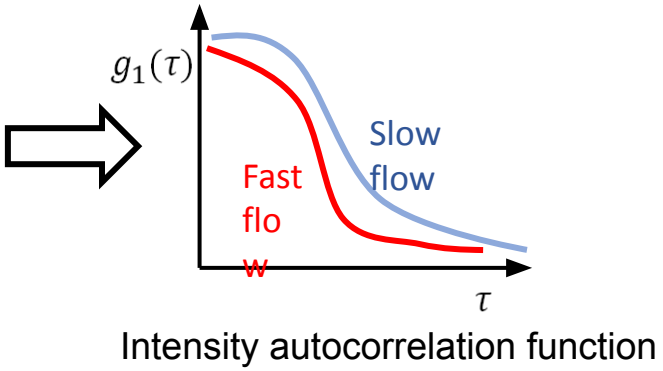
- Dynamic scattering particles introduce a blur in the speckle image
- The blur, measured by the contrast measures the speed of dynamic particles in the medium



# Signal model for single detector speckle contrast



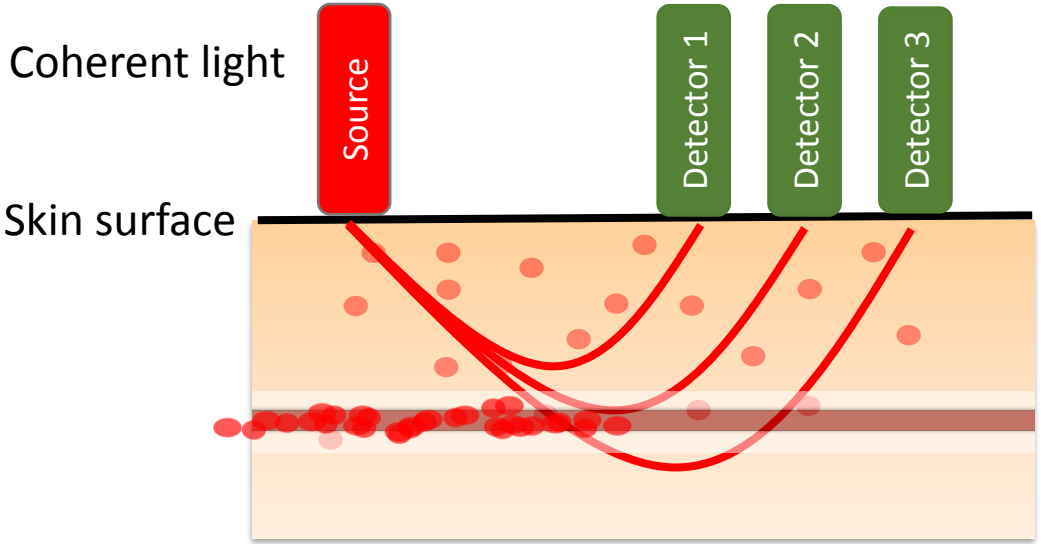

Intensity autocorrelation function

$$\kappa^2(\mathbf{r},T) = \frac{2\beta}{T}\int_0^T |g_1(\mathbf{r},\tau)|^2\left(1-\frac{\tau}{T}\right)d\tau$$

Camera exposure time

# Dependence on detector location

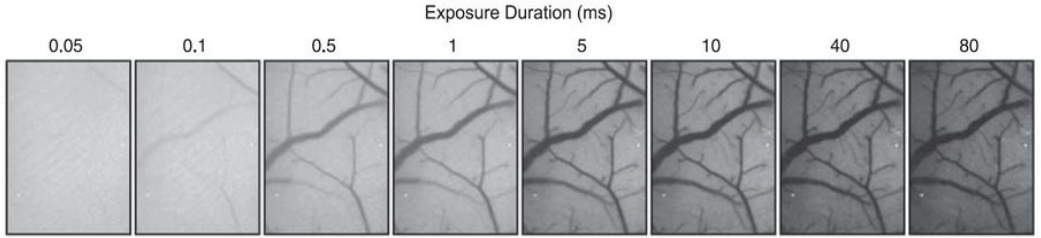
$$\kappa^2(\mathbf{r},T) = \frac{2\beta}{T}\int_0^T |g_1(\mathbf{r},\tau)|^2\left(1-\frac{\tau}{T}\right)d\tau$$




Different detectors at variable distance receives light probing different paths inside tissue

# Effect of exposure time on spatial blood perfusion changes

- Various camera exposure times are sensitive to different flow speeds
- Optimal exposure time should be chosen to differentiate between static tissue scatterers and blood vessels of interest



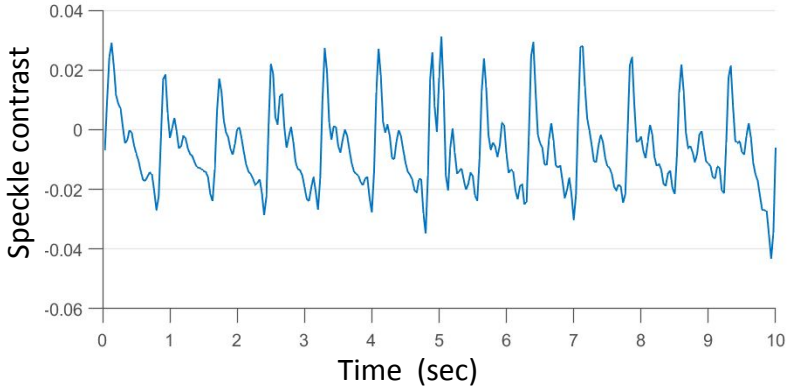

Kazmi SMS, Parthasarthy AB, Song NE, Jones TA, Dunn AK. Chronic Imaging of Cortical Blood Flow using Multi-Exposure Speckle Imaging. *Journal of Cerebral Blood Flow & Metabolism*. 2013;33(6):798-808. doi:10.1038/jcbfm.2013.57

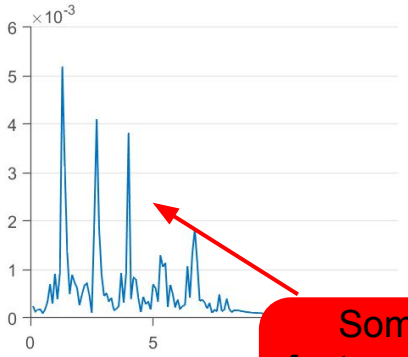
# Effect of exposure time on temporal waveform

Time domain

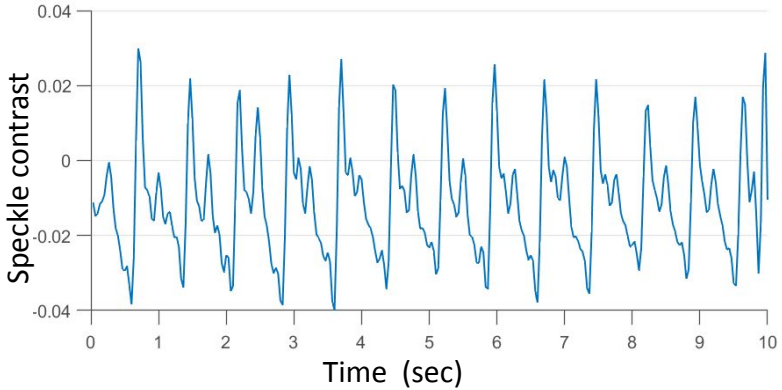
Frequency domain

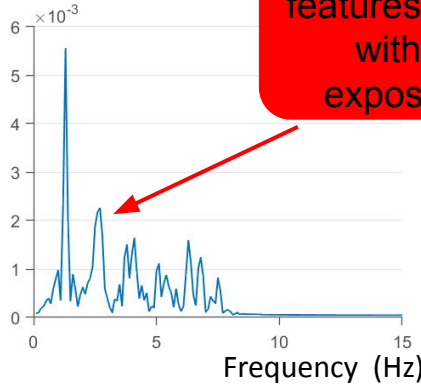
Exposure time = 0.5 ms



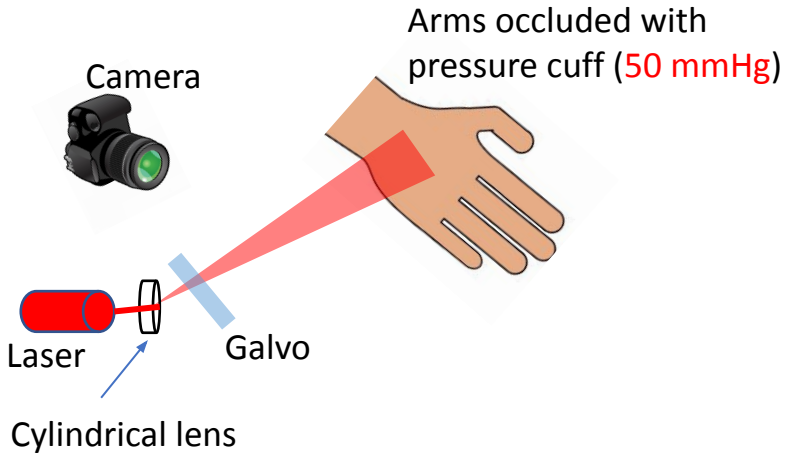

Exposure time = 1.5 ms

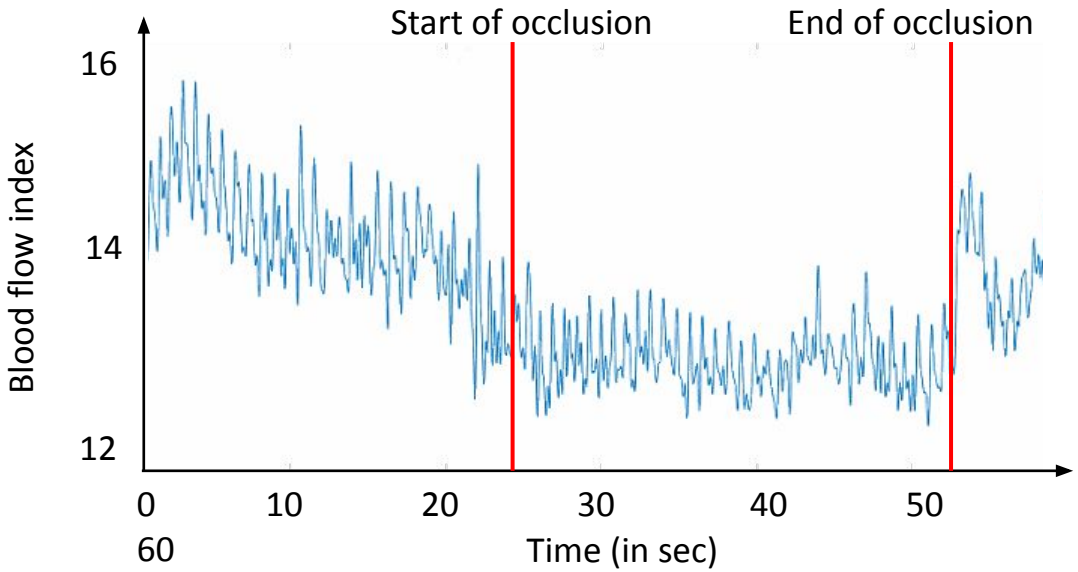


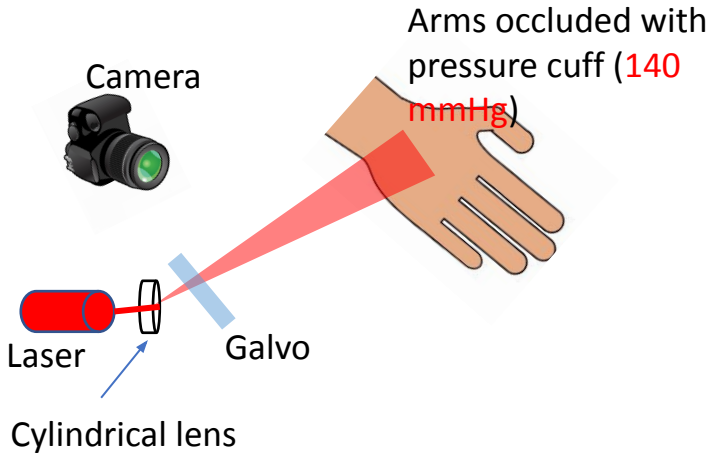

Some signal features disappear with larger exposure time

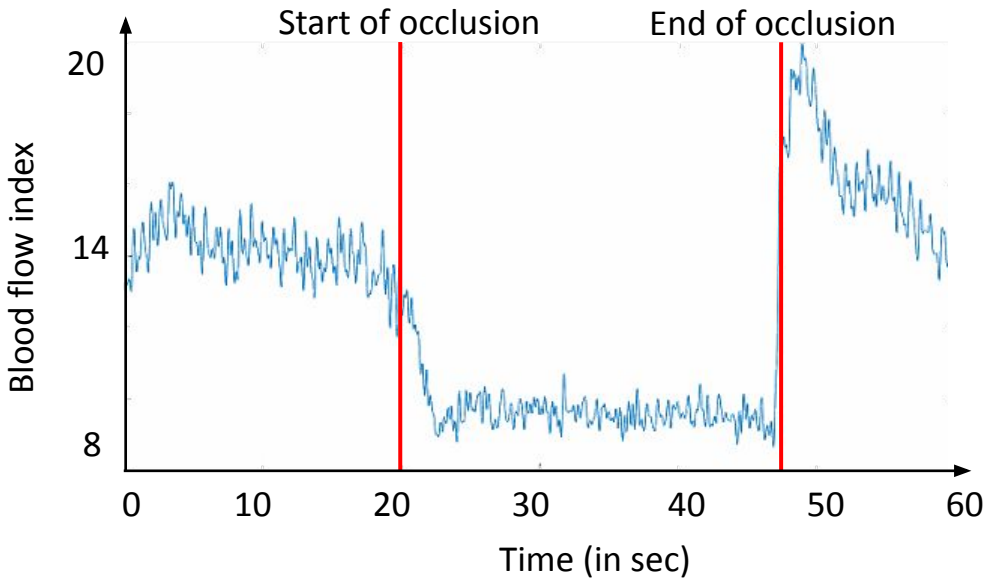
# Arm experiment: partial occlusion experiment



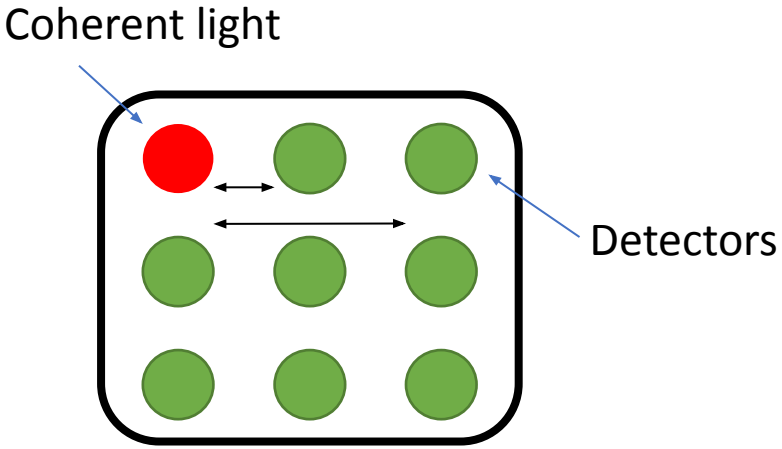



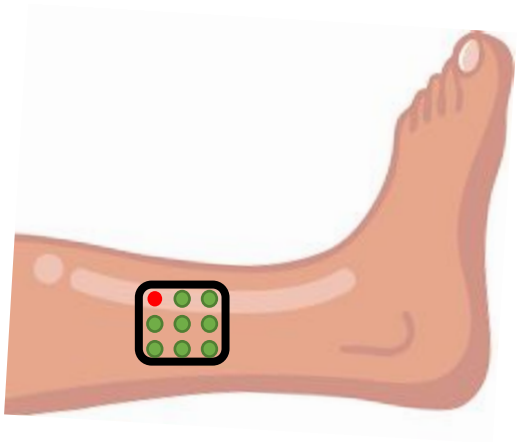
# Arm experiment: total occlusion experiment



# Proposed prototype and experiment



Proposed sensor:

- A coherent light source
- Detectors located at various distances from the source
- Detectors operating at multiple exposure time for best sensitivity

Study aim:
To evaluate sensitivity of speckle contrast variation to changes in blood flow due to occlusion

# The Next Step

- **Indicate your project preferences via the Capstone Project Interest Survey on Canvas**
  - Due the end of Tuesday 1/10
- Otherwise you will be randomly assigned to a project 🎲
- Project assignments will be sent out the next morning Wed 1/11 before we meet at 10am for our class time
- We will discuss how to begin the projects
- No meeting on Friday 1/13
- Teams will be assigned meeting days that will start the week of Monday 1/16
  - But remember, you should always be in Ryon B12 MWF at 10am no matter what