

# Research in ECE

Rutgers Undergraduate Research week

Prof. Anand Sarwate, Rutgers ECE, September 2023

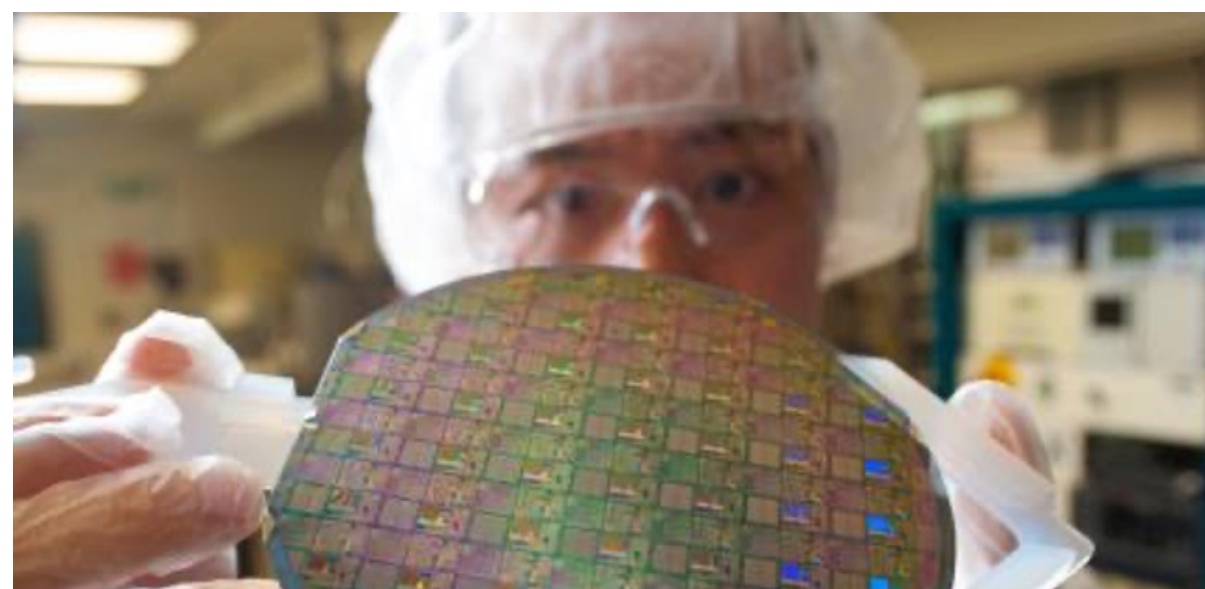
**What is ECE?**

# Any technology that uses computers or electronics



- Energy systems to support carbon emissions reduction
- Controls and communications systems for smarter robots in surgery
- Medical instrumentation and image processing for disease diagnostics
- IT and security for information and data safety on the Internet and online transactions
- Faster processors for advanced TV and gaming
- Nanotechnologies for the study of microorganisms
- Computer circuits supporting faster networks and processors for smartphones and other devices

# Major research areas at Rutgers ECE

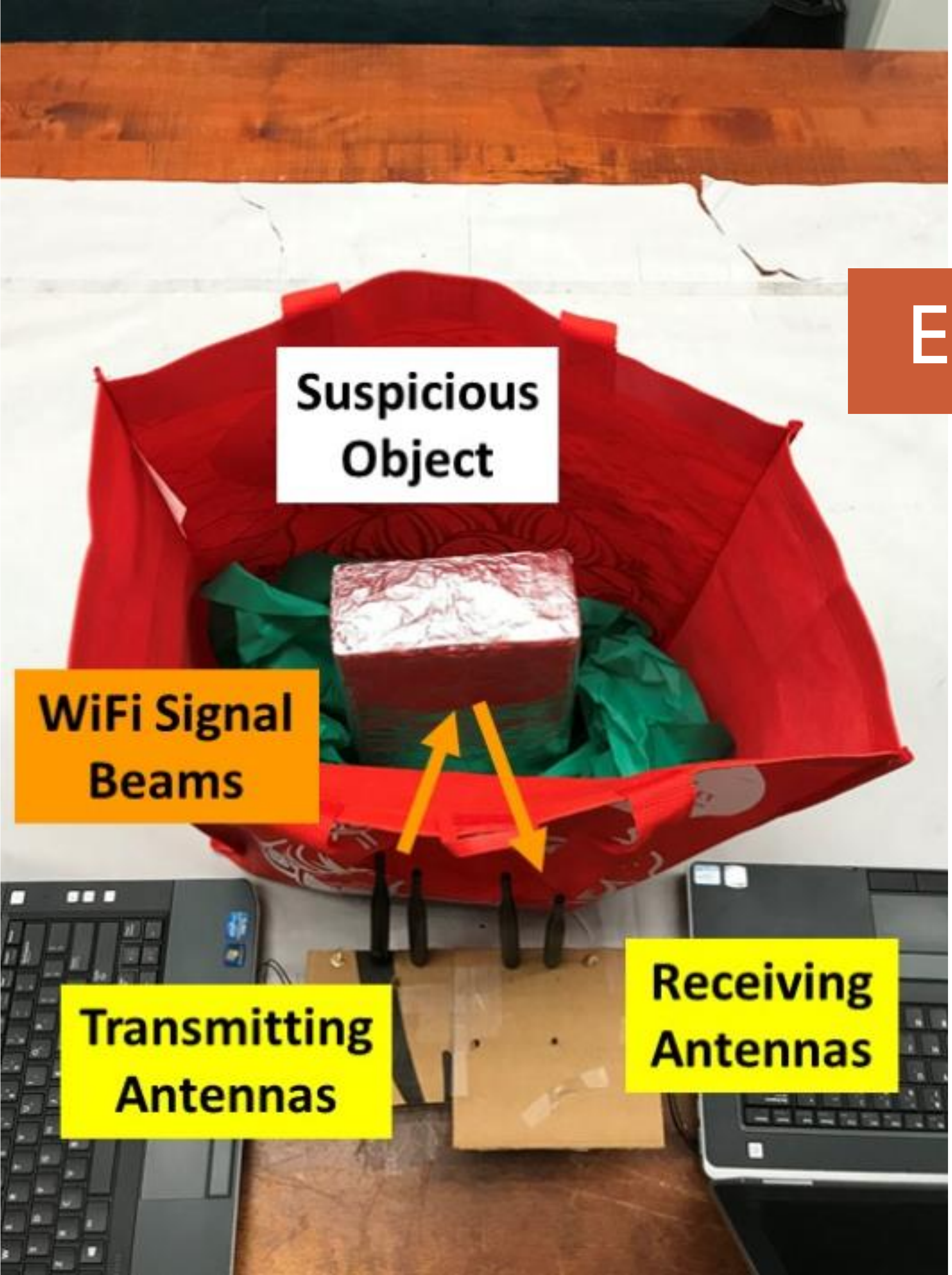


- Communications/Networking
- Signal and Information Processing
- Computational Sensing
- Machine Learning
- Systems and Controls
- Computer Engineering
- Software Engineering
- Cybersecurity
- Solid State Electronics



## ECE Out Front

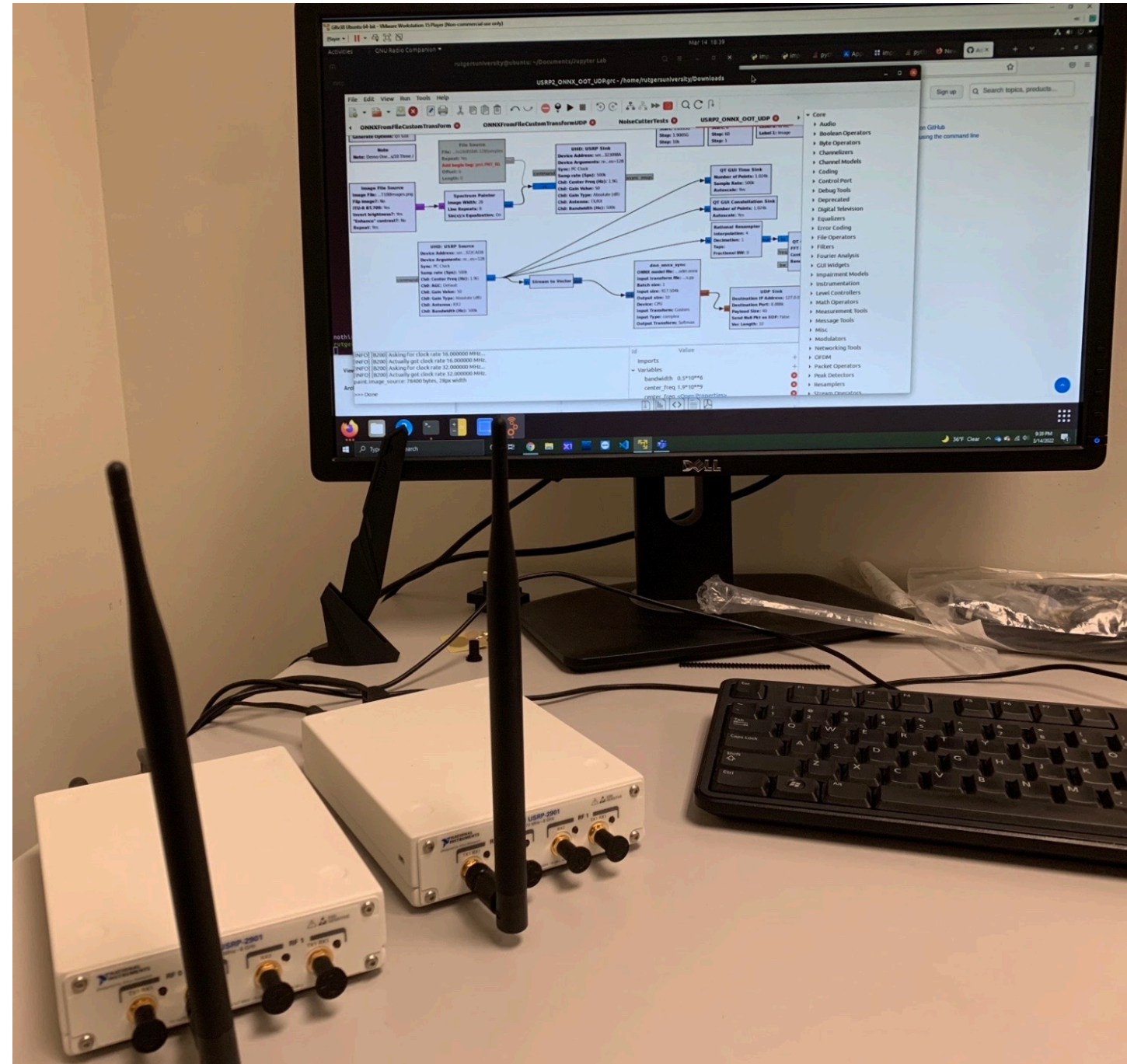
Prof. Javanmard is developing an all-electronic platform that can rapidly identify drug-resistant cancer cells in patients and prescribe a course of treatment.



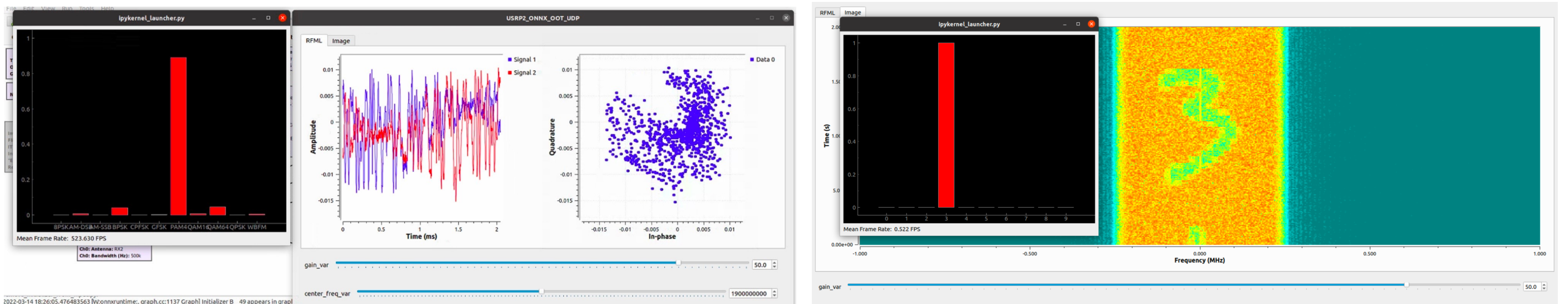
## ECE Out Front

Prof. Jennifer Chen's suspicious object detection system can easily detect weapons, bombs, and explosive chemicals in bags. It uses a system that analyzes what happens when WiFi signals penetrate and bounce off objects and materials.

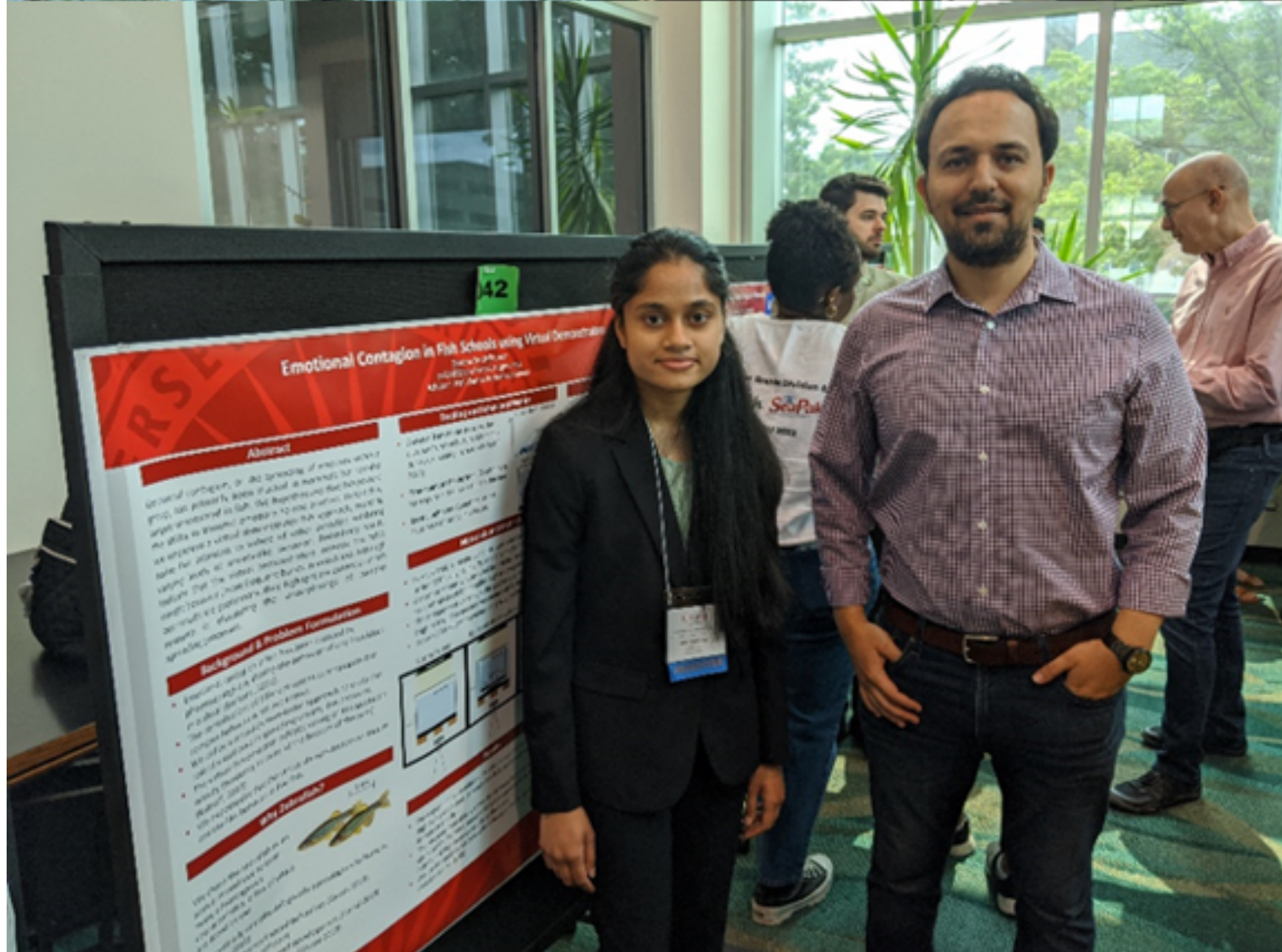
# Example project: 5G radios in software (Morriel Kasher)



- Part of the Air Force Research Lab Beyond 5G SDR University Challenge
- Goal: use machine learning to understand the wireless spectrum in real time using software-defined radios.
- Started out as an independent UG research project
- Became a senior capstone design project
- Morriel continued for graduate school at Rutgers and is working with Prof. Predrag Spasojevic.



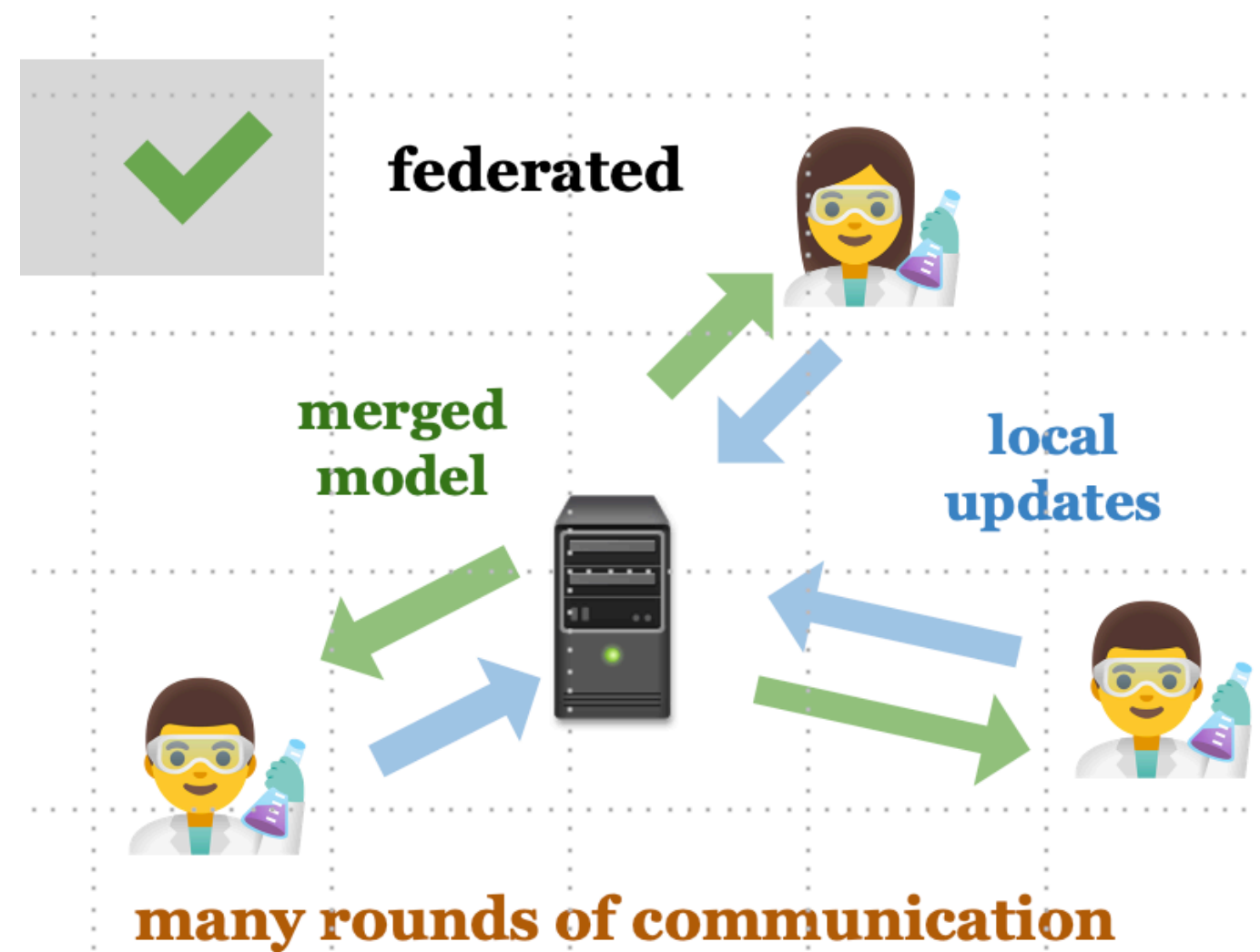
# Example: Emotion propagation in fish (Sahana Senthilkumar)



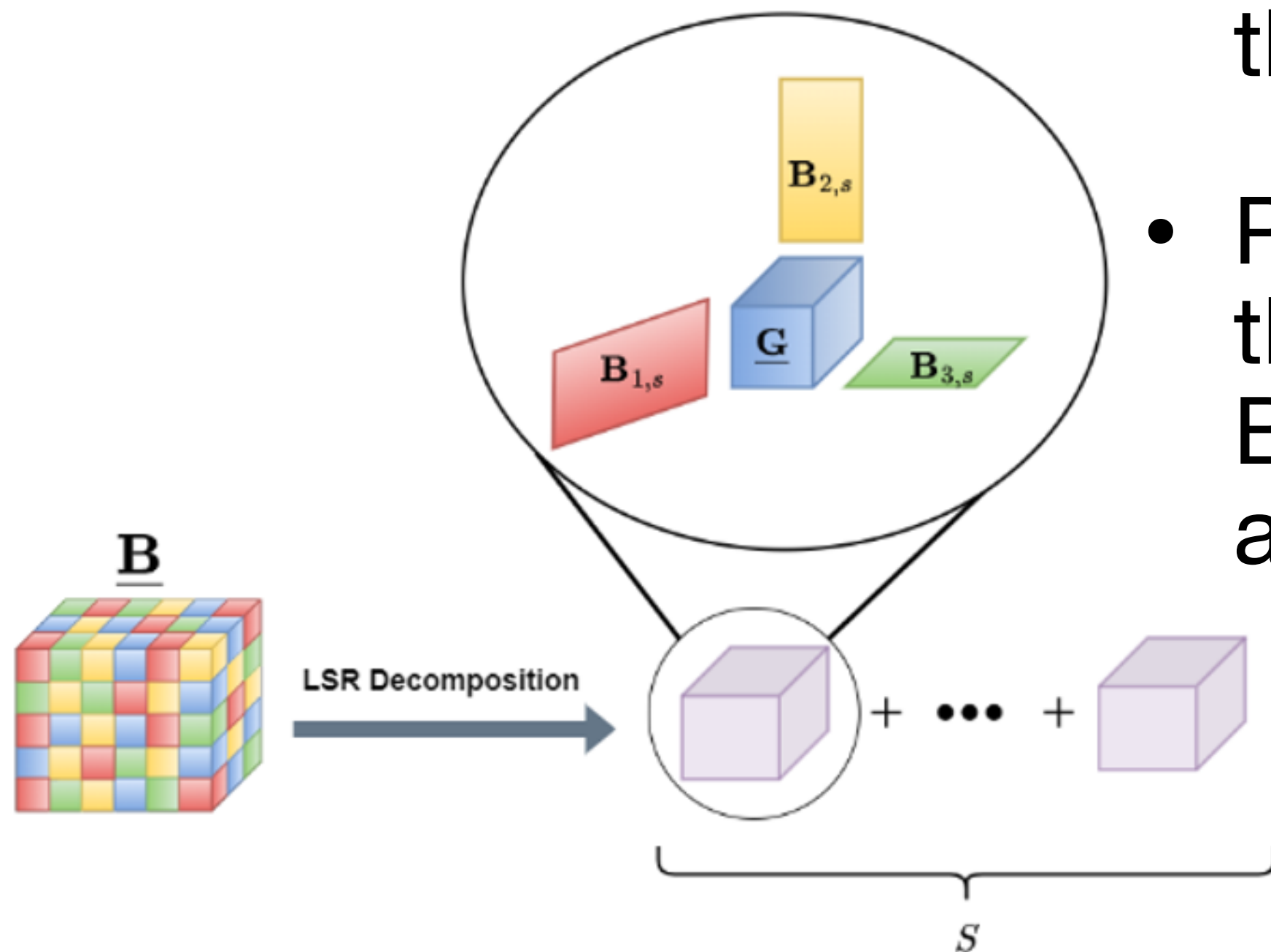
- We want to understand complex spreading processes:
  - social networks (viral content, misinformation)
  - power grids (cascading failures)
- Fish communicate information very efficiently: can we learn more about these phenomena from them?
- Sahana used signal processing tools and tracking methods, statistical analyses with information-theoretic tools to understand causal transmission.
- Summer 2023 research is in a journal paper that is currently under review with Prof. Burbano-Lombana.
- Sahana did this after freshman year!



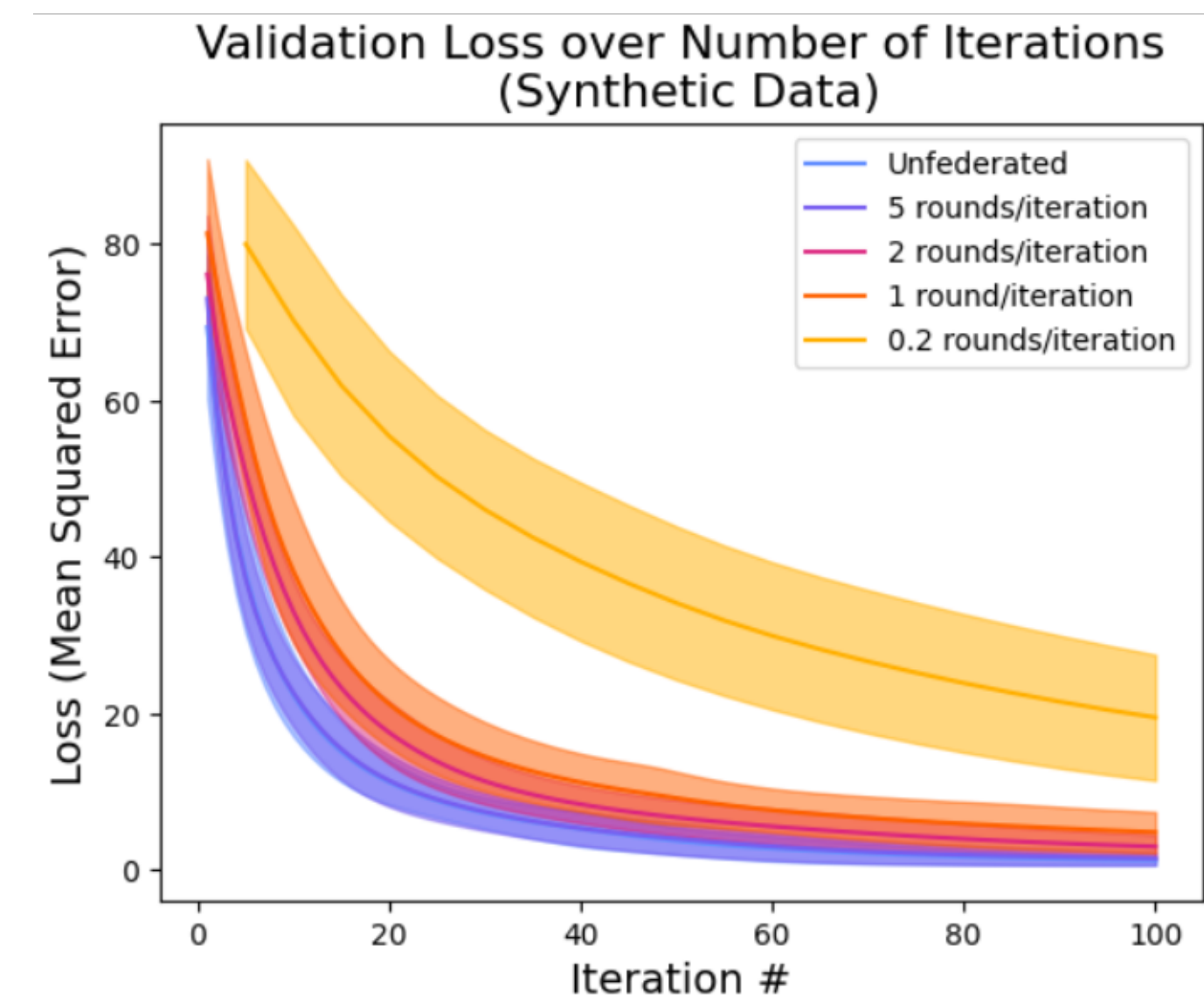
# Example: Federated ML for regression (Jose Hoyos Sanchez)



- Collaborative clinical studies face privacy concerns and high data complexity.
- Data can be multidimensional (especially medical imaging).
- Goal was to design a **federated learning** algorithm to allow researchers to do a joint analysis without sharing the “raw” data.



- Paper submitted to a conference this fall with RU grad student Batoul Taki, Prof. Sarwate, and Prof. Bajwa.



**What is research anyway?**

# Warming up with a few questions



- What do you think does “doing research” involves?
- What about it seems interesting or appealing to you?
- What do you think you’ll get out of it?



# Why do research?

## There are a ton of reasons

There are many benefits to doing undergraduate research:

- Get to learn about the cutting-edge (more than you get in classes).
- Develop professional skills: lab work, programming, technical writing, technical communication.
- Get to see what grad school might be like.
- Work more closely with professors (recommendation letters, references).
- Can get paid (in money or course credit)

# Research is multifaceted

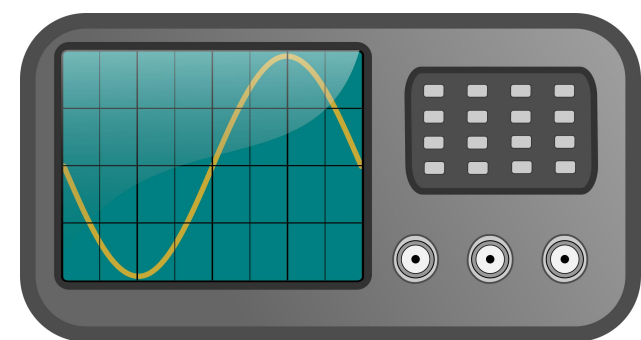
**There's no single answer...**

In a research project you get to work on a project with a professor or their research group. What you do depends a lot on the kind of project!

- Group projects vs. individual projects
- Finding related work (reading papers) vs. running experiments
- Programming vs. “hands-on” work with lab equipment
- Mostly remote vs. mostly in-person
- During the semester vs. during the summer

# What would I do in a research project?

The work is quite variable



- Reading papers and background research
- Programming/simulations
- Data analysis and visualization
- Fabricating or testing devices
- Building circuits/boards/sensors
- Data collection

# Do I know enough to do research?

It depends on what you want to do...



Some projects definitely require having some background knowledge or skills from specific courses. Other projects may be accessible to first-year students.

More important is that you are:

- Interested and open-minded
- Resourceful and motivated
- Willing to put in the work

You might not have an opportunity to work on your dream project, but you can still get a lot out of it.

# Do I have the time to do research?

**Successful work takes time!**

Think of research as a serious time commitment: *as much as a regular class.*



- Regular meeting times each week
- Required time in lab, time sheets, etc.
- Maintaining consistent communication about progress.

Most importantly, you have to be self-driven and make time each week **even though there are no homework deadlines or quizzes.**



# Finding a research project

# Different ways to get started

There are many options

## At Rutgers

- **UG Research Programs:** WINLAB Summer Internship, Aresty Center, JJ Slade (for seniors)
- **Work directly with a prof/PI:** not usually a formal application process, less “structure”

**Sign up for mailing lists to get announcements**

**Work @RU can sometimes be for pay or course credit**

## Outside Rutgers (summer)

- Research Experience for Undergraduates (REU) programs at many different universities on different topics.
- **Research internships:** many at government or government-funded labs: Department of Energy, National labs, NIST, MIT Lincoln Labs, JHU Applied Physics Lab.

**Deadlines are end of Fall Semester to Early Spring Semester**

**Need 1-2 Letters of Recommendation**

# Looking for a research position

## Overview of steps to take



Most professors will not have a job advertisement for “open positions” so you have to ***do some legwork***:

1. **Self-reflection:** what am I interested in and what do I want to get out of it?
2. **Look at your options:** labs/professors’s websites or Google Scholar (<https://scholar.google.com/>) will give you a sense of what they work on.
3. **“Pre-research research”:** challenge yourself by looking at some recent papers.

Google Scholar



# Digging a little deeper

## Gauging your interests and their interests

1. What projects have they been working on recently?  
**Research topics are often different than class topics!**
2. Try to read the abstract/intro of a paper that sounds interesting.  
**Show that you have curiosity and self-motivation.**
  - What real-world issue this paper is trying to address?
  - What kind of work is involved? Programming? Designing circuits? Lots of experiments and comparisons? Proving theorems?
3. If it seems interesting... email the professor.  
**Do not copy-paste the same email.**

The image shows a screenshot of a research paper title with several annotations. The title is "A Deep Learning Framework Based on Dynamic Channel Selection for Early Classification of Left and Right Hand Motor Imagery Tasks". Below the title are the publisher "IEEE", a "Cite This" button, and a "PDF" button. The authors are listed as "Jiazhen Hong ; Foroogh Shamsi ; Laleh Najafizadeh All Authors".

Annotations with arrows pointing to the title:

- What is deep learning? (points to "Deep Learning")
- Is a "framework" an algorithm? (points to "Framework")
- What is channel selection? What makes it "dynamic"? (points to "Dynamic Channel Selection")
- What kind of imagery? (points to "Motor Imagery")

# How not to email

What's wrong with this?



Dear Professor,

I hope you are doing well! My name is [REDACTED] and I am very interested in any research opportunities you might have. I'm attaching my resumé. Please let me know if you have time to meet with me.

Sincerely,

[REDACTED]

# Some tips for a good email

Being thoughtful makes a good impression



Things to do in an email:

- **Make it personal:** Introduce yourself!
- **Show that you've done some pre-research research!**
  - Why is research interesting to you?
  - What paper did you look at? What was interesting/confusing?
  - What kind of work are you interested in?
- **Respect people's time.**
  - Suggest a few times you are free.
  - Zoom or in-person or either?

# An example email

Don't copy paste this either 😊💧

Dear [REDACTED]

My name is [REDACTED] and I am a sophomore majoring in ECE. I am taking probability this semester and am enjoying it quite a lot. I wanted to get a chance to use what I learned outside of class and I thought doing a research project would be a good way to do that. I am also considering grad school in the future.

I tried to read your paper on “High Dimensional Inference with Random Maximum A-Posteriori Perturbations” but it was a bit challenging for me. I looked up “Gibbs distributions” but I found physics stuff that I wasn't sure had to do with the image processing in Figure 1. I want learn more about “applied probability” though, especially if there was some programming component. Do you have projects like that?

If you have time to talk about this or other research opportunities, please let me know! I am generally on Busch campus Monday, Tuesday, and Friday, and am free before noon or after 4:40.

Sincerely,

[REDACTED]

Explains who you are and what you're interested in

Show that you did a little pre-research

Open to new ideas, suggest specific times to meet

# Possible responses

It can go many different ways

- **Sure, please come to my office on Monday at 10:** yay!
- **No response:** wait a few days and then send a follow-up.
- **I'm busy for the next N weeks, after that is ok:** do they have time to supervise another project? Can you talk to a grad student?
- **I don't have time for another student:** don't take it personally!
- **I don't have an appropriate project right now:** see above!



# Doing research for credit or pay

## Feels awkward to bring up...

Formal research programs offer credit or a stipend (pay):

- More structured programs at RU (Aresty, JJ Slade) give course credit.
- Summer programs (REUs, internships) almost always come with a stipend.

These have an application process, often have a professional development component, and students are accountable.

For independent research, there are two options:

- Credit for “Special Problems” (ECE 491/492) requires proof of commitment.
- If getting paid is important, professors sometimes have “class 5 hourly” funds.

# Is unpaid research worth it?

## Maybe, maybe not

Research @RU with a professor/grad student/lab doesn't have the same accountability mechanisms. Even with the best intentions students can drop off/ghost or put research as the lowest priority. Many students "try it out" (unpaid) for a semester.

- "Trying it out" gives you a chance to back out if you decide you don't like it, but it means you are possibly doing work and getting only "experience".
- Using a "research contract" can help create some accountability.
- Ask up front whether you can switch to credit/pay if things go well (and what is the criterion for "going well").

# Doing the work

## Succeeding in your research experience

- **Get organized.** Consider using a research journal or some other way of keeping track of what you've done and what you plan to do.
- **Be prepared for surprises (good, bad, and ugly).** Research has a lot of starts and stops.
- **Stay in communication with your advisor/mentor.** Don't ghost!
- **Engage in self-reflection.** Remember why you are doing this research project and how it fits into your goals.