Creating DNA from Scratch for DNA-based Data Storage

SDDEC23-05

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Introduction

- Growing need for data storage
- Privacy concerns
- Problem Statement :
  - DNA sequencing is well-developed, but printing requires more work
  - Pressing need for a high-output, cost-effective technique for DNA printing.
  - Wide range of applications in fields such as data storage, biotechnology, medicine, and genomics.

Current DNA Technology

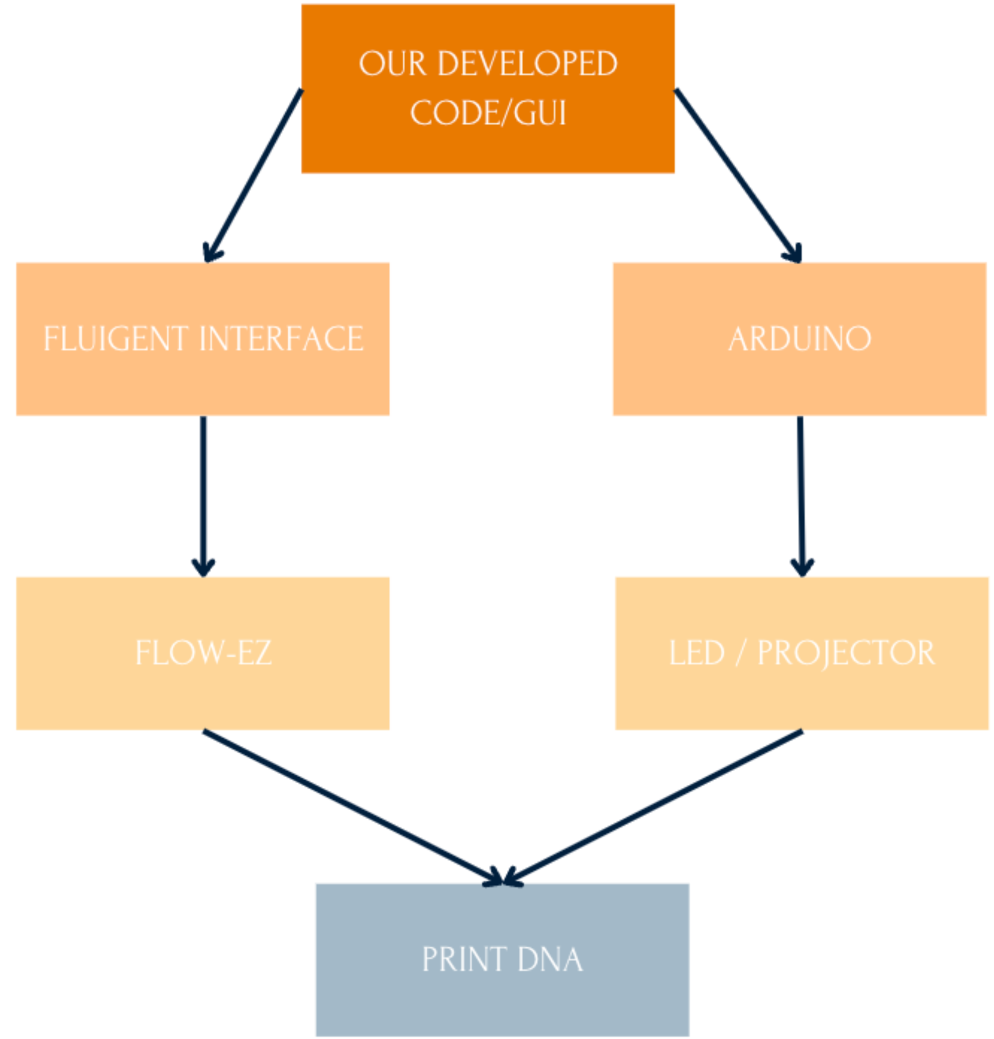
Oligonucleotide synthesis

- Creates specific strands of DNA for multiple purposes
  - Only able to produce short sequences (10 to 100 base pairs)
- A series of chemical reactions builds one nucleotide onto a strand at a time

Differences between Sequencing and Printing

- DNA Sequencing has made leaps and bounds
- Ordering DNA strands to be printed is time-consuming and costly
  - How do we plan to address the problem?

Whole System Breakdown



Goal of Our Project

- Continuation of prior team's work:
  - Create DNA from nucleotide solution
  - Upgrade from LCD to projector
  - Integrate micro-fluidic programming with GUI
  - Create a user-friendly front end for the DNA printer

Constraints

- 1st Constraint
  - Standard DNA Manipulation
- 2nd Constraint
  - Upgrading Display
- 3rd Constraint
  - Improving efficiency of Frontend

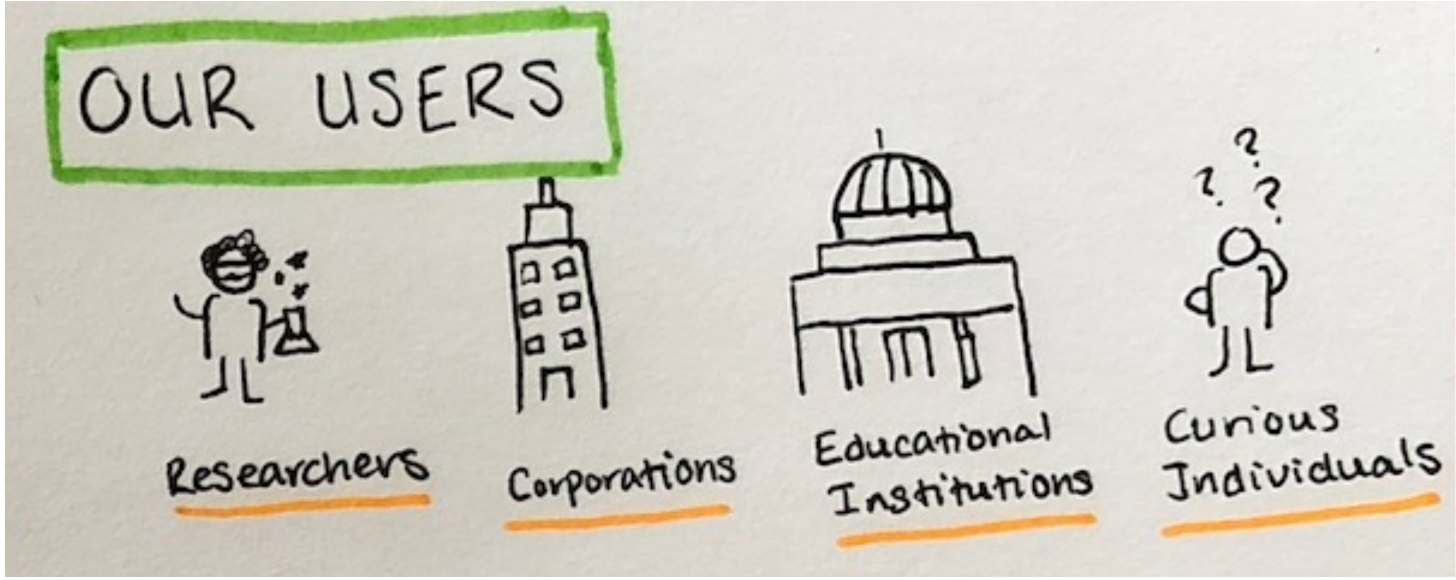
Engineering Standards

- Software and Hardware Standards
  - Guidelines for Life Cycle Management - 24748-1-2018
  - Test Processes - 29119-2-2021
  - Systems and Software Integration - P24748-6

- How do we apply these standards to address some constraints?

Users + Intended Use

- Who will use our project?
  - Corporations
  - Educational Institutions
  - Researchers
  - Geneticists
  - Data Analysists



Design Talk

Broader Context, User Needs, Technical Complexity, and more

Broader Context

Area	Description	Examples
Public health, safety, and welfare	Shared goal of DNA storage brings impact to all shareholders	Creating jobs / opportunities for research when money is dumped into it.
Global, cultural, and social	Culturally appropriate project aims to preserve DNA integrity for data storage, with far-reaching implications	Ethical and cultural implications of DNA modification to prevent genetic disorders from being inherited
Environmental	Environmentally responsible research with potential positive impacts, including lower energy consumption	Energy requirements for nucleotide synthesis and DNA data extraction currently undetermined
Economic	Significant economic implications: Potential to revolutionize data storage and reduce costs	Every business would store data this way because it would be cheaper and more efficient.

User Needs

Researchers and STEM Institutions

- Affordably **experiment with DNA pairs because it will allow them to advance their research faster.**

Educational Institutions

- Decrease **the lead times of outsourcing DNA printing.**

Private Corporations

- Increase **efficiency in storing data.**

Technical Complexity

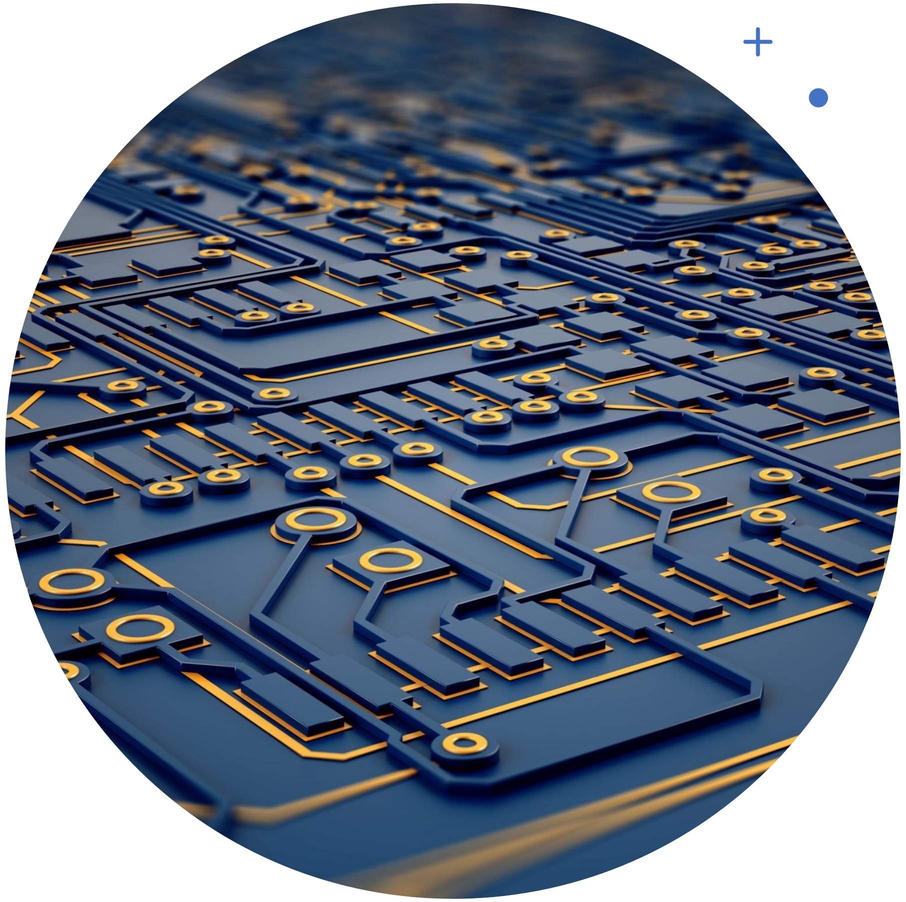
- **Software:** Create a fully integrated program connecting with both the flow and hardware along with implementing it into an easily usable user GUI

- **Hardware:** Optimize LCD so it keeps up with the rate we need it to without the heat interacting with the DNA to the Flow System
  - New Design: Test and optimize a new display system and projector to interact with our Flow System

- **Flow System:** Quickly, reliably, and repeatedly send chemicals through a custom-made cell and countering any potential problems working with fluids which we have never been taught to work with.

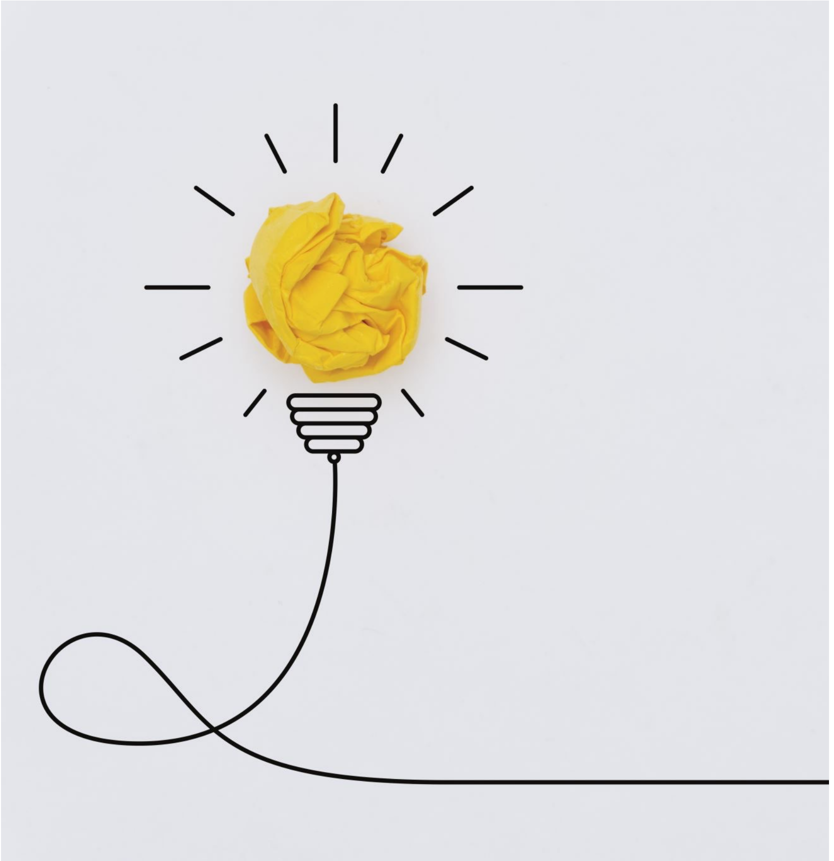
Design Decisions

- Software
  - GUI, hardware interface, DNA input/analysis and pattern generation
- Hardware
  - LCD panel, UV/blue LED source
  - New Design: Projector
- Flow System
  - Flow cell fabrication, Fluigent system



Ideation

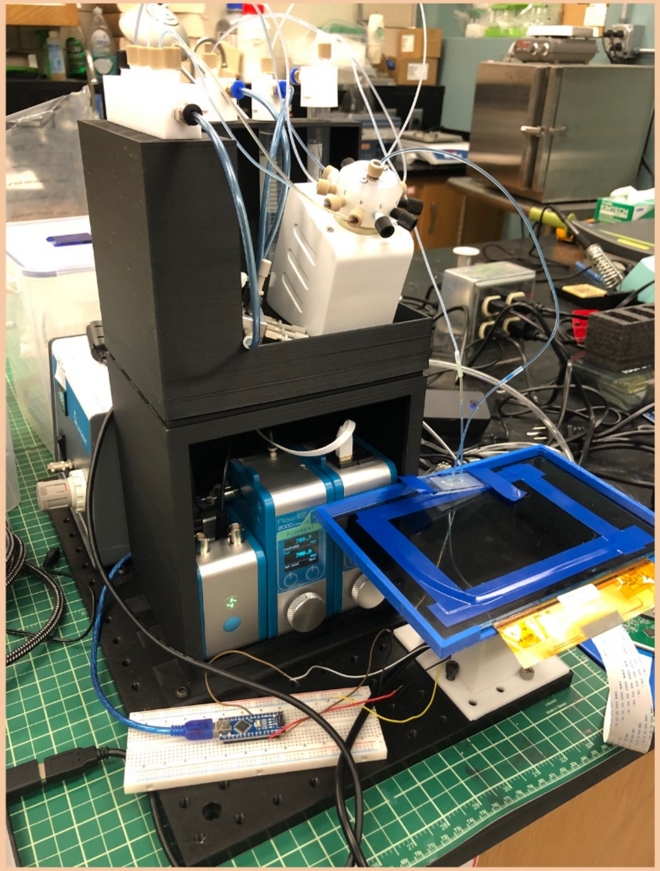
- SCAMPER Method
  - Creative thinking technique
  - Generate new ideas or solutions of an existing idea or product.



Decision-Making and Trade-Off

- SCAMPER method
  - Advantage: Clear framework
  - Disadvantage: Restricts free-flowing idea generation

Design Visual and Description



Figures show the current printer, flow control system, and various other components

- From what the last team left us with:
  - High-powered LED and LCD
  - A micro-fluidic system
  - Control interface
  - 3-D printed housing unit and air compressor

Functionality

This 3-D printer is compact enough to fit into a lab or research institution. Due to its size, it is well-suited for research settings where space may be limited.

Areas of Concern and Development

- The difficulties and concerns come into play with the integration of software and hardware.
  - There is separate software that manages the flow control system, separate software for the 3-D printer and LED board, and countless other hardware pieces that need to work together.

Testing

Unit Testing, Interfaces, Integration, and more

Unit Testing

3D Printer

- Running test prints using software and code we created/improved

Flow Control

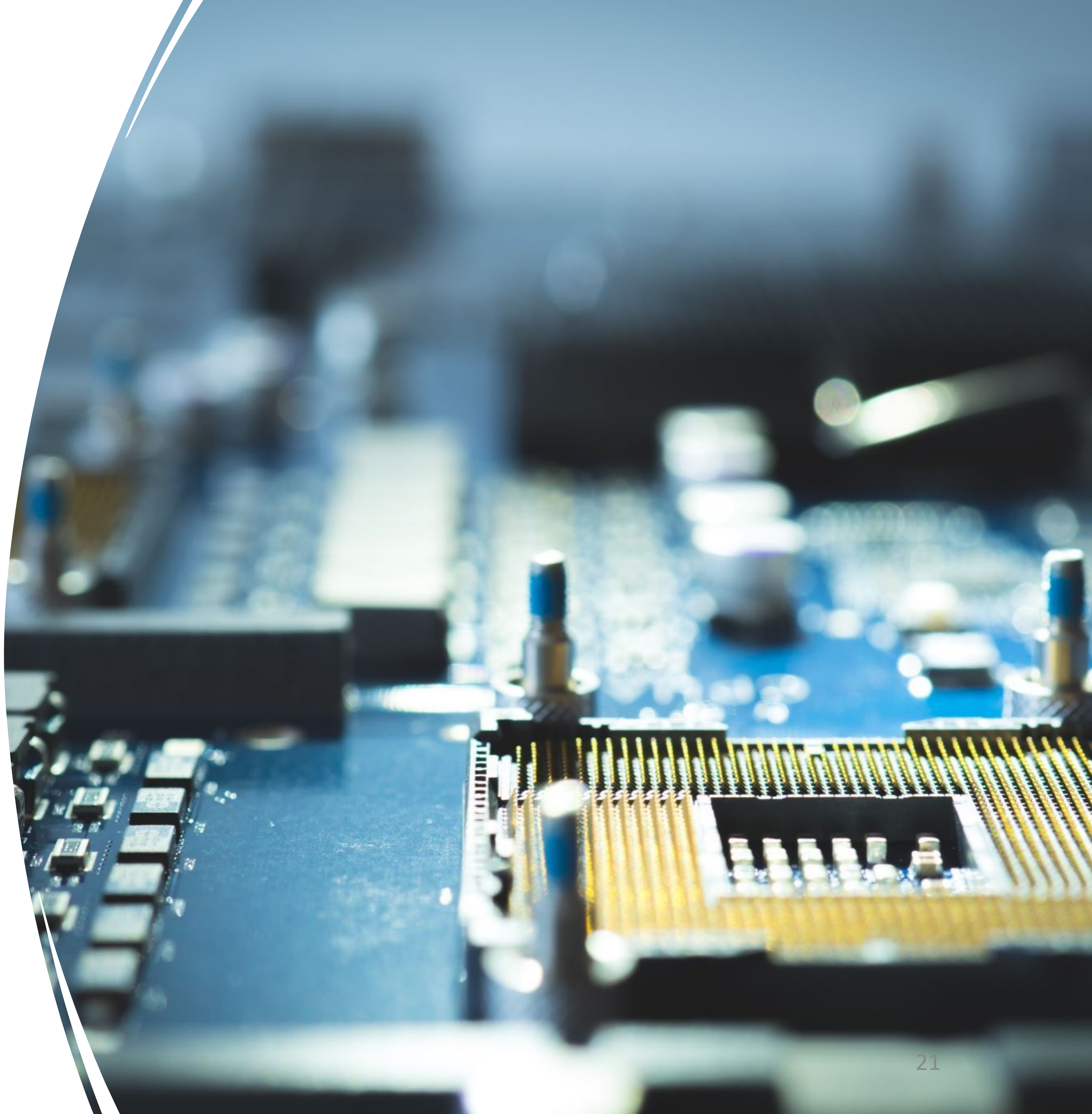
- Using Fluigent's software OxyGEN and ink to run standard test cycle

Projector

- The current LED board has been in talks to be upgraded to a projector. The new system will need to be tested with the current Arduino and hardware.

Interfaces

- 3D printer and the flow control system
  - The Fluigent system comes with software called 'OxyGEN'
- Display with various software and hardware components
  - Arduino, GUI, etc.



Integration Testing

- Integration of Units
  - Our requirements was combining systems designed by the prior year's team
    - Example: utilizing the interfaces such as the integration of the Arduino, software, projector, and the flow control system

System Testing

- Performance/usability tests on each unit
- Usability tests on the prior team's work to see if changes need to be made before we begin whole system integration
- Improve individual units, perform regression testing to make sure our changes do their intended purpose
- Start with smaller integration tests before full-system testing

Regression Testing

Evaluate	Implement	Test
Evaluate the functionality of pre-existing systems	Implement our changes • New display, new piping in flow control system, etc.	Test the functionality of those systems with our modifications / changes • Track changes with notes • The documentation will allow us to follow the code and debug more efficiently

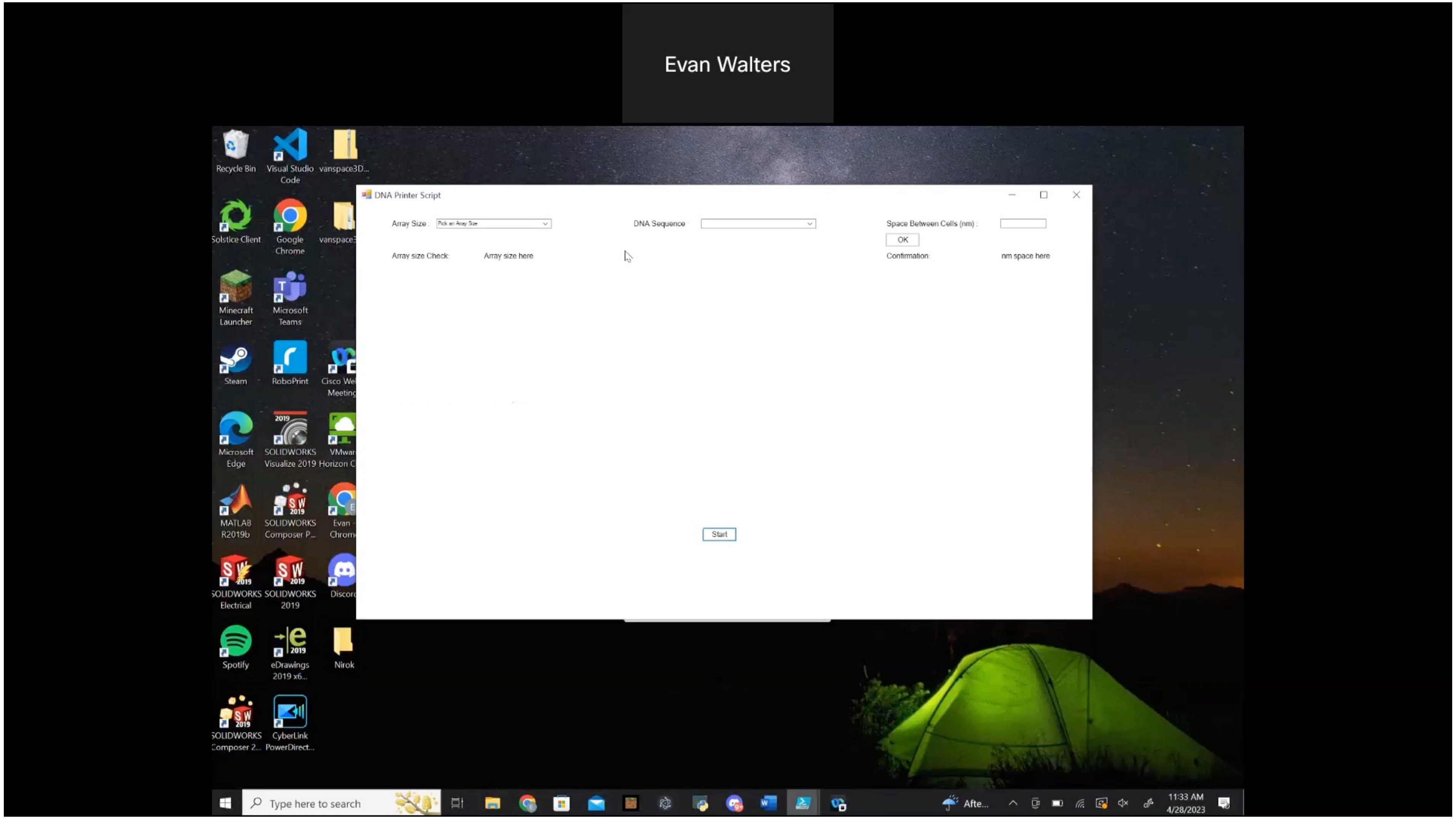
Acceptance Testing

- Professor Lu will be with us for every testing stage prior to acceptance testing
  - Easy to involve with acceptance testing

- Multi-year investment
  - Aim for improvement

- Acceptance testing = beta testing or integration testing

Demonstration of GUI and Semester Progress



Questions?