**Roadmap: EEG-Based Brainwave Simulation System**

**🧪 1. Prototype Phase (Current Stage)**

**Goal: Test feasibility on one stimulus and replicate signal via ML.**

* ✅ Set up BCI hardware (Cyton, 8 channels + A1/A2)
* ✅ Build ERP experiment (e.g. red dot visual task with fixation)
* ✅ Record EEG data (via BrainFlow, OpenBCI GUI, or Python)
* ✅ Identify and extract **P1/N1** components from raw EEG
* ✅ Train ML model to **recreate ERP waveform** from stimulus tag

**Once Done:**

* Evaluate: Does the model reproduce ERP-like responses with new trials?
* If yes → scale up. If no → tweak preprocessing/modeling.

**🔄 2. Multi-Stimulus Expansion**

**Goal: Capture and classify ERPs for multiple types of stimuli**

Examples:

* Visual: Red circle, checkerboard, images
* Auditory: Beeps, tones, music
* Cognitive: Oddball task, Go/No-Go

**Tasks:**

* Design stimulus paradigms in PsychoPy
* Run multiple sessions over different days for consistency
* Label and segment EEG per stimulus
* Feature extraction: ERP peaks, spectral bands, time-windows
* Train model to **classify** stimulus type or predict ERP waveform

**🧠 3. Simulation Model Development**

**Goal: Predict brainwave response without actual EEG input.**

* Use your trained ML model to generate **simulated EEG** or ERP waveform
* Input = stimulus features (e.g. "visual: red circle")
* Output = predicted waveform (e.g. synthetic P1/N1 data)

**Model types to consider:**

* Recurrent Neural Networks (RNN/LSTM)
* Transformer-based models for time series
* Conditional GANs (generate ERP-style waveforms)

**📊 4. Evaluation & Validation**

**Goal: Verify the accuracy of simulation vs. real EEG**

* Compare real EEG to simulated EEG using:
  + Waveform shape similarity (RMSE, correlation)
  + ERP peak latencies and amplitudes
  + Classification accuracy (if used downstream)
* Cross-participant testing (optional but valuable)

**📃 5. Publish Research Paper**

**Goal: Contribute to the field and share your method**

Include:

* Rationale + problem statement
* Experimental design (hardware, stimulus, preprocessing)
* Model design and performance
* Real vs. simulated EEG comparison
* Limitations and future work

You can aim for **IEEE EMBC, NeurIPS workshops**, or **Frontiers in Neuroscience** depending on how technical vs cognitive the paper is.

**🧰 6. Application Development (Optional but Cool)**

**Goal: Build tools that use simulated EEG**

Ideas:

* Simulated BCI control testing (mouse, keyboard, games)
* Brainwave-based adaptive interfaces (e.g. emotion-based lighting)
* Offline training/testing environments for BCI apps

**📌 Summary of Phases:**

| **Phase** | **Focus** | **Output** |
| --- | --- | --- |
| 1. Prototype | 1 stimulus ERP + ML | Proof of concept |
| 2. Expansion | Multiple stimuli | Stimulus-to-ERP mapping |
| 3. Simulation | Generate EEG | Stimulus-to-EEG model |
| 4. Validation | Compare real vs fake | Quantitative results |
| 5. Paper | Formalize findings | Academic contribution |
| 6. Applications | Optional dev | Practical tools |