NeuroHarmony is a forward-thinking project that aims to revolutionize the way neurophysiological data is managed and utilized.The need for a robust management system for scientific data sharing and analysis has increased significantly over the last decade. By leveraging Web3 technologies, it addresses key issues of data ownership, security, accessibility, and collaboration. This project has the potential to significantly accelerate neuroscience research, empower individuals, as well as address common problems with data silos and lack of transparency in research.

NeuroHarmony aims to create a secure, transparent, and collaborative platform for sharing, analyzing, and utilizing neurophysiological data (ECG, EEG, EOG) to advance neuroscience research. It leverages Web3 technologies for data ownership, secure sharing, and incentivized participation.

Integration of Neo: To enhance NeuroHarmony’s capabilities, we are integrating Neo, a Python library designed for handling neurophysiological data. Neo provides:

Data Standardization: It supports multiple file formats (Neuralynx, Plexon, Blackrock, etc.), ensuring seamless data integration from various sources.

Interoperability: Works with OpenNeuro datasets and other neurodata repositories, making it easier for researchers to collaborate.

It is a complex project but has potential to make significant contributions to neuroscience research and individual well being.

Action items-

Data Integration – Develop mechanisms for uploading and structuring EEG/ECG/EOG data from OpenNeuroDatasets.https://github.com/OpenNeuroDatasets/ https://www.ieeg.org/ https://doi.gin.g-node.org/keywords/eog/ https://doi.gin.g-node.org/keywords/emg/ ( pls pick one dataset from each of these websites - different formats to integrate and demo the platform)

Integrate Neo - https://neo.readthedocs.io/en/latest/api\_reference.html

Access Control & Permissions – Implement role-based access using smart contracts and decentralized identity (DID).

Collaboration Features – Add real-time annotations, discussion forums, and version-controlled dataset management.

On-Chain Proposal System – Allow researchers to submit funding proposals, with community voting enabled.Write and audit smart contracts to manage grant applications, voting, and fund disbursement. (Funding model :DAO Based grants/ Quadratic funding/ Staking pools)

Tokenized Reward System for Open Science Contributions - Sharing data and reviewing findings earns tokens. Add leaderboards, badges, and staking options to boost engagement. Interoperability with existing DeSci platforms (eg: Research hub)

\*TIP- I would refer to https://github.com/ResearchHub as an example and modify it for neuroscience research for tokenomics.

https://www.researchhub.com/

Create innovative tools and applications that foster decentralized collaboration, data sharing, and community-driven science. Deliverables: Decentralized apps that facilitate collaboration among researchers. Platforms for transparent funding and grant allocation for scientific research. Systems to reward contributors with tokens for their contributions to open science.

To Develop and Maintain decentralized collaboration, data sharing, and community-driven science, we can create a suite of decentralized applications (dApps) and tools. Below are the deliverables, along with Python and Solidity code for the below functionalities are authored

I. Core Platform Components (Decentralized Applications - dApps):

● A. NeuroData Marketplace (dApp):

○ Functionality: A primary interface for listing, discovering, and accessing neurophysiological datasets (EEG, ECG, EOG, EMG). Leverages IPFS for data storage and retrieval, with metadata stored on the blockchain.

○ Data Integration (Action Item #1):

■ Connect to External Repositories: Develop importers/connectors for:

■ OpenNeuro: Implement a process to ingest data from OpenNeuro. Focus initially on a specific dataset (e.g., a resting-state EEG dataset from OpenNeuro) to demonstrate functionality. Map OpenNeuro's BIDS (Brain Imaging Data Structure) format to NeuroHarmony's internal representation.

■ IEEG Portal: Build functionality to ingest data from the IEEG Portal. Initially focus on a specific dataset (e.g., a seizure detection dataset from IEEG).

■ G-Node (doi.gin.g-node.org): Use a specific EOG dataset as a proof of concept.

■ Data standardization: Integrate Neo to parse and standardize data from all ingested datasets (Neuralynx, Plexon, Blackrock, etc.)

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■ Data Upload/Structuring: Enable researchers to upload their own data, guiding them through a structured process to ensure metadata completeness and adherence to standards. Provide tools to automatically convert data into a standardized format (e.g., using Neo to convert to a common internal representation).

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○ Neo Integration (Action Item #2):

■ Data Parsing: Utilize Neo to parse uploaded data into Neo's Block, Segment, RecordingChannel objects for easy manipulation.

■ Standardization: Neo can normalize data from different formats, ensuring consistency across the platform. This simplifies downstream analysis.

■ Visualisation: Integrate Neo's plotting functionality for quick data previews.

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○ Smart Contract Integration:

■ Data Provenance: Track the origin, processing steps, and modifications of datasets.

■ Data Licensing: Implement smart contracts to manage data licenses (e.g., Creative Commons), ensuring proper attribution and usage rights.

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● B. NeuroAnalysis Workbench (dApp):

○ Functionality: A suite of tools for analyzing neurophysiological data. Focuses on decentralized execution of algorithms.

○ Analysis Modules: Initially, offer basic analysis modules:

■ Preprocessing: Noise reduction, filtering, artifact removal (using Neo and other Python libraries).

■ Feature Extraction: Time-domain, frequency-domain analysis (e.g., power spectral density, event-related potentials).

■ Machine Learning: Integrate with decentralized ML frameworks for classification, regression, and clustering tasks.

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○ Decentralized Computation: Explore options for executing analysis pipelines on a decentralized network (e.g., using secure enclaves or federated learning). This preserves data privacy while enabling collaborative analysis.

○ Result Storage: Store analysis results (features, models, reports) securely on IPFS, linked to the original data and analysis pipeline on the blockchain.

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● C. NeuroCollaborative Hub (dApp):

○ Functionality: Provides tools for researchers to collaborate on projects, share insights, and co-author publications.

○ Real-time Annotations (Action Item #4):

■ Enable researchers to annotate data directly within the NeuroData Marketplace or NeuroAnalysis Workbench.

■ Store annotations on the blockchain, ensuring immutability and provenance.

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○ Discussion Forums (Action Item #4):

■ Implement decentralized discussion forums using IPFS for content storage and blockchain for moderation.

■ Categorize forums by dataset, analysis method, or research topic.

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○ Version-Controlled Dataset Management (Action Item #4):

■ Use Git-like version control for datasets, allowing researchers to track changes, revert to previous versions, and branch data for experimentation.

■ Store version history on the blockchain.

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II. Governance and Funding (dApp):

● A. NeuroGrant DAO (Decentralized Autonomous Organization):

○ Functionality: A DAO responsible for allocating funds to neuroscience research projects.

○ On-Chain Proposal System (Action Item #5):

■ Researchers submit funding proposals through the DAO interface.

■ Proposals include project descriptions, budgets, timelines, and team credentials.

■ Proposals are stored on IPFS, with hashes stored on the blockchain.

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○ Community Voting (Action Item #5):

■ Token holders (see below) vote on proposals using their tokens.

■ Implement a voting mechanism (e.g., quadratic voting) to prioritize projects with broad community support.

■ Voting results are recorded on the blockchain.

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○ Smart Contracts:

■ Grant Application Contract: Manages the submission and review of grant applications.

■ Voting Contract: Implements the voting mechanism and tallying of votes.

■ Fund Disbursement Contract: Releases funds to approved projects based on milestones and performance.

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○ Funding Models:

■ DAO-Based Grants: Token holders collectively decide which projects receive funding.

■ Quadratic Funding: Funds are matched based on the number of individual contributors, amplifying the impact of community support.

■ Staking Pools: Researchers can stake their tokens to support specific projects, earning rewards if the projects are successful.

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III. Tokenomics and Incentivization:

● A. NEURO Token:

○ Utility: The primary token for the NeuroHarmony ecosystem.

○ Use Cases:

■ Governance: Voting on funding proposals and platform upgrades.

■ Rewards: Earning tokens for contributing data, providing annotations, reviewing research, and participating in the community.

■ Staking: Staking tokens to support research projects or earn passive income.

■ Access: Potentially using tokens to access premium features or datasets.

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○ Token Distribution:

■ Initial distribution to early contributors, researchers, and developers.

■ Ongoing distribution through a rewards program.

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● B. Reward System (Action Item #6):

○ Data Sharing: Researchers earn NEURO tokens for contributing high-quality, well-annotated datasets to the NeuroData Marketplace. The amount of reward is tied to dataset size, quality, and usage.

○ Data Review: Experts earn NEURO tokens for reviewing and validating datasets.

○ Analysis Contribution: Researchers earn NEURO tokens for developing and sharing analysis pipelines and models.

○ Community Participation: Researchers earn NEURO tokens for participating in discussions, answering questions, and contributing to the NeuroCollaborative Hub.

○ Leaderboards and Badges: Gamify the reward system with leaderboards and badges to recognize top contributors.

○ Staking Options: Allow users to stake their NEURO tokens to earn additional rewards or support specific research projects.

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● C. Interoperability with DeSci Platforms (Action Item #6 - ResearchHub Example):

○ Integration with ResearchHub: Explore ways to integrate NeuroHarmony with ResearchHub. Potential integrations:

■ Cross-posting of Research: Allow researchers to easily share their NeuroHarmony-related findings on ResearchHub.

■ Cross-linking of Data: Link NeuroHarmony datasets and analysis pipelines to relevant publications on ResearchHub.

■ Shared Token Ecosystem: Potentially explore opportunities to integrate the NEURO token with ResearchHub's token economy.

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○ Develop a similar incentivization framework as ResearchHub but tailored to neuroscience.

○ Leverage ResearchHub's functionalities for discussions, paper review, and community building, adapting it to the specific needs of neurophysiological research.

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IV. Technical Considerations:

● Blockchain Platform: Consider using a scalable and efficient blockchain platform (e.g., Polygon, Avalanche, or a Layer-2 solution on Ethereum) to minimize transaction costs and improve performance.

● Decentralized Storage: Utilize IPFS for storing large datasets and other content.

● Smart Contract Security: Thoroughly audit all smart contracts by reputable security firms to prevent vulnerabilities.

● Frontend Development: Develop user-friendly dApps using modern web development frameworks (e.g., React, Vue.js).

● Data Privacy: Implement privacy-preserving techniques (e.g., differential privacy, federated learning) to protect sensitive data.

● Scalability: Design the platform to handle a growing number of users, datasets, and analysis pipelines.

V. Development Roadmap:

1. Phase 1: Proof of Concept (MVP):

○ Develop a basic version of the NeuroData Marketplace with limited functionality.

○ Integrate Neo for data parsing and standardization.

○ Implement basic data upload and download functionality.

○ Connect to one or two datasets from OpenNeuro, IEEG Portal, G-Node.

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3. Phase 2: Core Functionality:

○ Develop the NeuroAnalysis Workbench with basic analysis modules.

○ Implement the NeuroCollaborative Hub with real-time annotations and discussion forums.

○ Design and deploy the NEURO token.

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5. Phase 3: Governance and Scaling:

○ Implement the NeuroGrant DAO with on-chain proposal system and community voting.

○ Expand the range of analysis modules in the NeuroAnalysis Workbench.

○ Improve the scalability and performance of the platform.

○ Explore interoperability with other DeSci platforms.

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VI. Key Deliverables:

● Decentralized Apps: The core dApps described above (NeuroData Marketplace, NeuroAnalysis Workbench, NeuroCollaborative Hub, NeuroGrant DAO).

● Smart Contracts: Secure and audited smart contracts for data licensing, grant management, voting, and token distribution.

● Tokenized Reward System: A functioning system for rewarding contributors with NEURO tokens.

● API Documentation: Comprehensive API documentation to enable third-party developers to build on the NeuroHarmony platform.

● Community Documentation: Documentation and tutorials to guide researchers on how to use the platform.