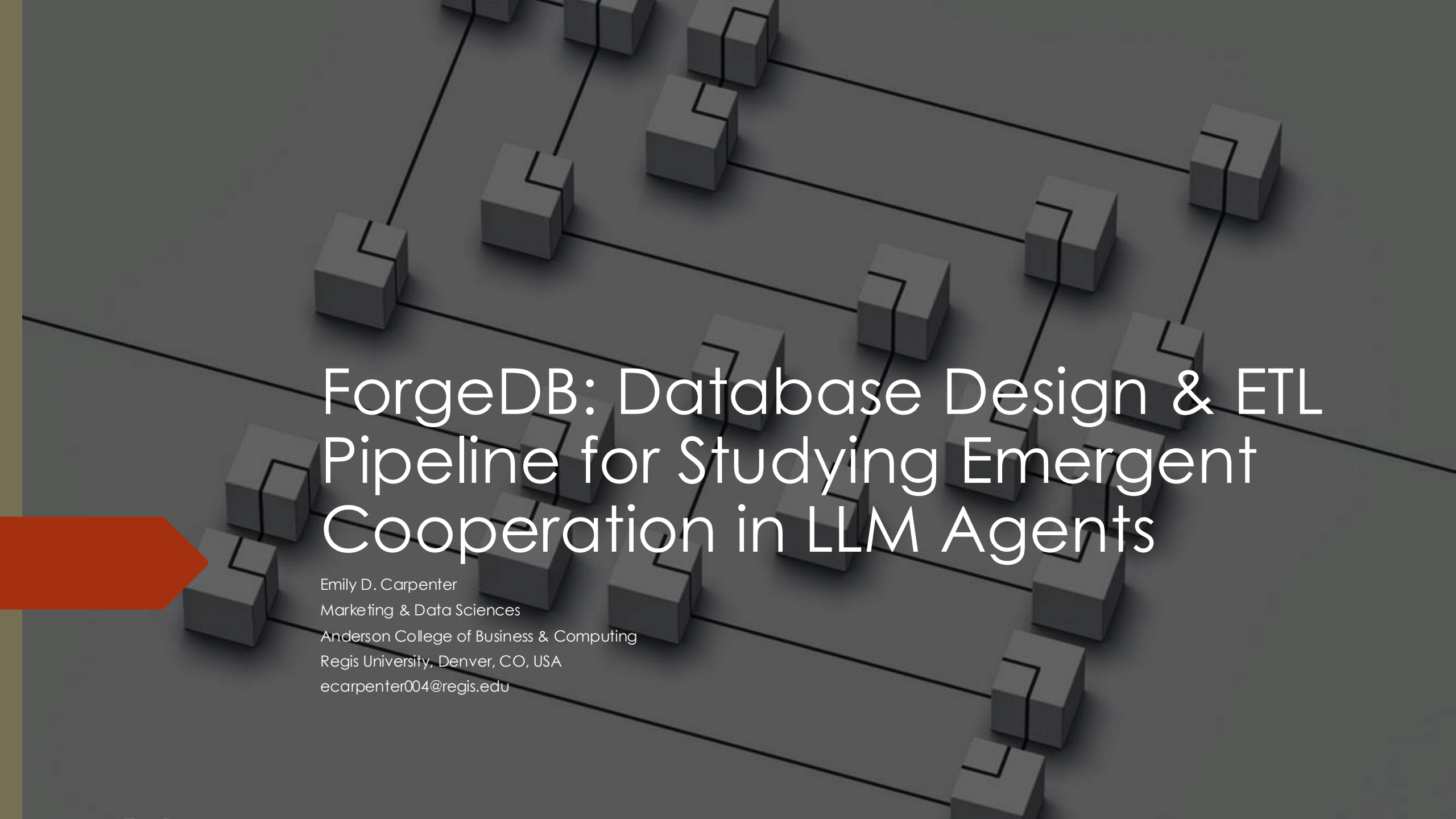

# ForgeDB: Database Design & ETL Pipeline for Studying Emergent Cooperation in LLM Agents

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# The GENESIS Research Project

- GENESIS investigates whether LLM agents can develop cooperative behaviors through the Iterated Prisoner's Dilemma (IPD) game
- Simulation framework produces JSON output files containing agent decisions, reasoning, and cooperation metrics
- Principal Researchers:
  - Dr. Douglas Hart
  - Dr. Kellen Sorauf

# Overview of Problem & Motivation

No centralized method exists to store, organize, and query results across experiments

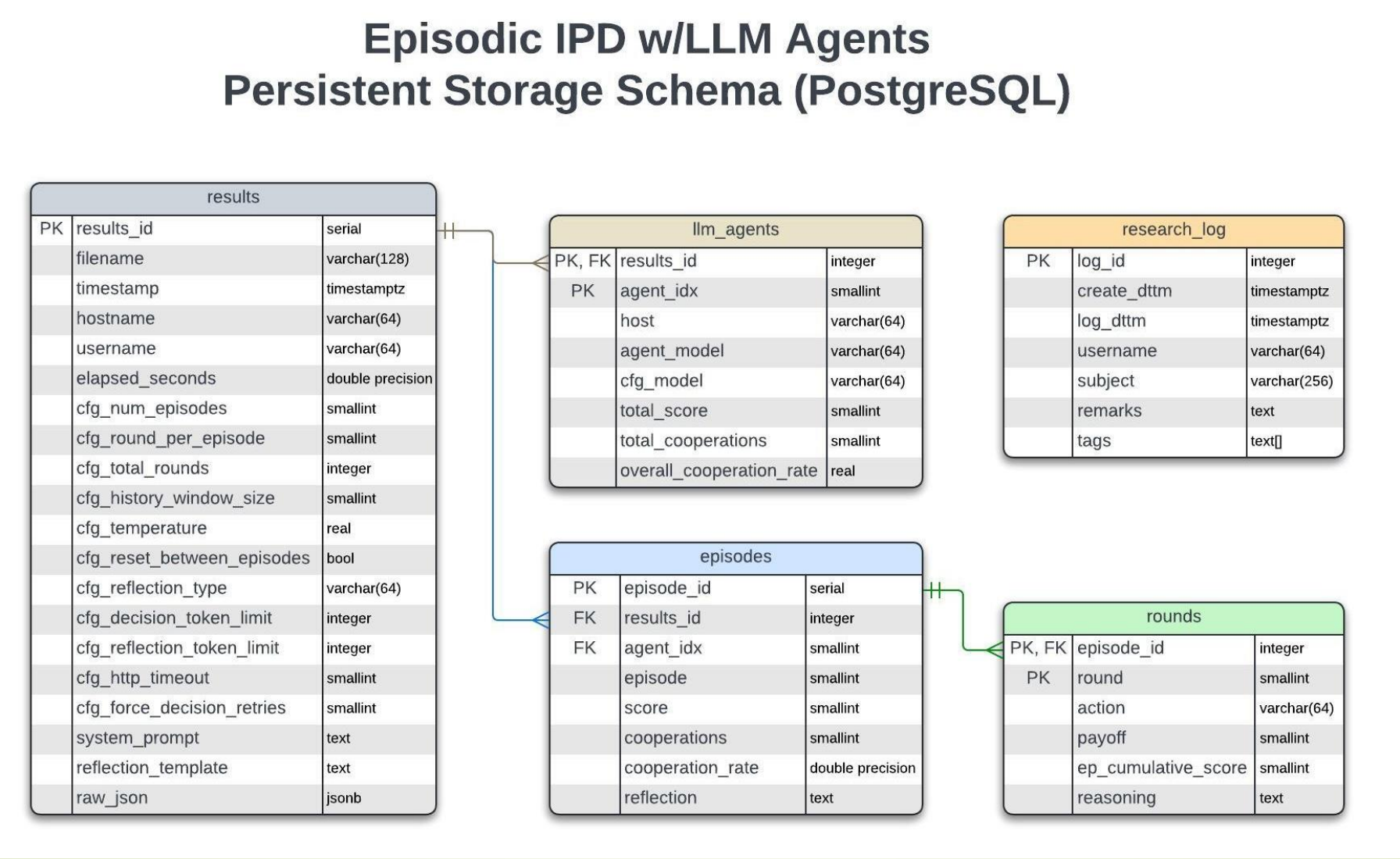
Multiple researchers are generating data on a shared compute cluster with participants rotating through the project each semester

**Need**: *persistent storage infrastructure to enable cross-experiment analysis through long-term research project*

# Data Collection & Preparation Approach: DB Design

- PostgreSQL selected for open-source licensing, JSONB support, and native Python integration via Psycopg 3 library package
- Normalized schema with 5 tables: RESULTS, LLM_AGENTS, EPISODES, ROUNDS, and RESEARCH_LOG
- Six SQL views created as pre-built query abstractions at experiment, episode, and round levels of granularity
- Referential integrity implemented from RESULTS to all child tables
- All objects organized under a common DB schema (ipd2) to allow future game types to coexist in the DB under separate schemas

# DB Entity Relationship Diagram



# Data Collection & Preparation Approach: ETL Pipeline (ForgeDB)

- Python module (ForgeDB) created using Psycopg 3 to interface with the PostgreSQL database
- CLI support for JSON import as single files, directories, glob patterns, and multiple files in single shell command
- Python API provides access to DB via pre-built query methods that return DataFrames for use in analysis
- Adhoc SQL queries also supported through the query() method to meet custom analysis needs
- Unique constraints established to prevent importing duplicate experiment files
- All import activity logged to a forgedb.log file for auditing and troubleshooting

# Analysis Methods and Key Findings: What the Infrastructure Enables

Researchers can query results across all experiments regardless of which participant generated the data or whether a participant continues working on the project

Pre-built SQL views support analysis at multiple levels: high-level experiment summaries, episode cooperation trajectories, and round-by-round agent behavior comparisons

Episode summary view directly supports visualization of cooperation rate trends across experiments

Adhoc SQL queries are supported through the ForgeDB query() method for custom analysis needs

The Research Log table provides a centralized shared lab notebook independent of experiment data

Comprehensive documentation provided that contains guidelines on installation, configuration, and use of the storage solution for long-term maintainability of infrastructure

# Conclusion & Future Work

- Delivered a complete persistent storage solution: PostgreSQL database, Python ETL module, multiple SQL views, and researcher documentation
- Infrastructure provides a single authoritative source of data for ongoing GENESIS research across semesters
- Schema design allows future game types to coexist under separate database schemas
- Future consideration: NoSQL alternatives (MongoDB, CouchDB, DynamoDB) for faster deployment as research goals evolve that don't easily fit an RDBMS infrastructure solution
- System designed for handoff — principals and future students can maintain and extend without the original developer

# References


- Hart, D., & Sorauf, K. (2025). *GENESIS project: From cooperation to conscience* [Unpublished project documentation]. Regis University.
- The PostgreSQL Global Development Group. (n.d.). *PostgreSQL* [Computer software]. https://www.postgresql.org/
- Varrazzo, D., & The Psycopg Team. (n.d.). *Psycopg 3* [Computer software]. https://www.psycopg.org/psycopg3/
- Anthropic. (2025–2026). *Claude* [AI assistant]. https://claude.ai/

# Questions?