Printverse Technical Project Report

Executive Summary

Printverse is a production-ready full-stack application that converts natural language instructions into structured print settings. We built a complete software engineering system demonstrating modern cloud deployment, full-stack development, and DevOps practices.

Technology Stack:

- Frontend: React
- Backend: Node.js + Express
- Database: MongoDB Atlas
- NLP: OpenAI API
- Infrastructure: Google Cloud Platform (Compute Engine)
- Deployment: GitHub Actions CI/CD, PM2, Nginx

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1. Project Overview

We created Printverse to solve a simple problem: transform plain English instructions like "print 5 pages double-sided grayscale" into structured print settings. The application demonstrates how natural language processing can simplify user interaction with complex systems.

Our implementation spans the entire software development lifecycle—from frontend user experience through backend API design, database architecture, cloud infrastructure, and automated deployment pipelines.

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2. Architecture & File Structure

We organized our codebase into clean, professional modules:

Directory	Purpose
/public	Static files (legacy app.js, initial UI)
/src/client	React frontend application
/src/server	Complete backend services
/src/server/api	Print-related API handlers (printRoutes.js)
/src/server/models	MongoDB schemas (PrintSetting.js)
/src/server/routes	User-facing API endpoints (printSettingsRoutes.js)
/src/server/services	Core logic modules (nlpService.js, db.js)
server.js	Express entry point
.env	Environment variables (API keys, DB credentials)
package.json	Dependencies management
pnpm-lock.yaml	Dependency lock file

This structure reflects production-grade software engineering practices.

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3. Frontend Implementation (React)

Our React client provides an intuitive interface for users to interact with the printing system.

Key Features:

- Natural language input field for print instructions
- Real-time parsing display showing structured settings
- Save and load print presets
- Edit existing print configurations
- Interactive print demo button

React Responsibilities:

- Component state management
- Form input validation
- API communication with backend
- Rendering saved user presets
- Responsive UI for demonstration

The frontend is designed for clarity and ease of use, prioritizing the user experience while remaining minimal and focused.

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4. Backend Architecture (Node.js + Express)

Our backend implements a complete API layer with multiple responsibilities:

NLP Parsing Service

The `nlpService.js` module communicates with OpenAI's API, sending user instructions and receiving structured print settings in return. This transforms unstructured input into actionable configuration.

CRUD Operations

Users can fully manage their print settings:

- **Create:** New print presets
- **Read:** Retrieve saved configurations
- **Update:** Modify existing settings
- **Delete:** Remove presets

All operations persist data to MongoDB.

API Route Organization

We organized routes by feature domain:

- `/api/print` — Print operations
- `/api/print-settings` — Preset management

This design follows RESTful principles and maintains clear separation of concerns.

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5. Database: MongoDB Atlas

We use MongoDB Atlas (cloud-hosted) for persistent data storage, eliminating infrastructure management while ensuring scalability.

Collections:

- `Users` — Account information and authentication data
- `PrintSettings` — User-created print presets and configurations
- `SavedConfigurations` — Archived print settings

Mongoose Integration:
Our backend uses Mongoose ODM (Object Data Modeling) to define schemas, enforce data validation, and provide a clean interface to MongoDB.

GCP Connectivity:
We resolved initial connection issues by adjusting MongoDB Atlas IP access rules:

- Development: Allowed `0.0.0.0/0` (all IPs)
- Production: Whitelisted the GCP VM's static IP address

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6. Print Functionality (Demo)

Our print button uses the browser's native `window.print()` function, which:

- Triggers the operating system's print dialog
- Accesses the user's default printer
- Applies system-level print settings
- Does not require server-side printer communication

Current Limitation:
The browser controls the actual printing—we do not yet interface with physical printers directly.

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7. Future: Real Printer Integration

To enable direct printing without system dialogs, we would need to:

Component	Technology
Protocol	IPP (Internet Printing Protocol) or CUPS
Document Format	PDF conversion on backend
Settings Application	Programmatic print job configuration
Job Tracking	Queue management and status monitoring
Capabilities	Ink levels, paper status, printer health

Why the Server? Browsers cannot communicate directly with printers for security reasons. The backend must handle all printer operations.

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8. Google Cloud Platform Deployment

We deployed Printverse to Google Compute Engine as a production service.

Deployment Process

Step 1: Virtual Machine Setup

- Created Ubuntu Compute Engine instance
- Installed Node.js runtime
- Installed Git for repository access
- Installed PM2 for process management
- Installed Nginx as reverse proxy

Step 2: Frontend Build
npm run build # or pnpm equivalent

Step 3: Backend Process Management
PM2 manages the Node.js backend with:

- Automatic restart on crashes
- Process monitoring and logging
- Memory and CPU tracking
- Multiple instance management

Step 4: Nginx Configuration
server {
server_name print-verse.com www.print-verse.com;

```
location / {
    proxy_pass http://localhost:5000;
    proxy_set_header Host $host;
    proxy_set_header X-Real-IP $remote_addr;
}
```

}

Step 5: Firewall Rules

- Opened port 80 (HTTP)
- Opened port 443 (HTTPS)
- Restricted other ports

Result:
Our application runs continuously on the GCP VM, handling requests 24/7.

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9. Custom Domain & DNS Configuration

We made Printverse accessible at `print-verse.com` through DNS mapping.

Domain Setup Steps

1. **Domain Purchase**
   - Registered through GoDaddy or Namecheap
   - Secured both root and www variants
2. **DNS Records Created**
   - **A Record (root):** print-verse.com → [GCP_STATIC_IP]
   - **A Record (www):** www.print-verse.com → [GCP_STATIC_IP]
3. **Nginx Configuration Updated**
   - Added server blocks for both domain variants
   - Ensured requests route to `localhost:5000` backend
4. **DNS Propagation**
   - Waited for global DNS cache update (typically 15 minutes to 48 hours)
   - Verified accessibility globally
5. **Testing & Verification**
   - Website now reachable at https://www.print-verse.com

- SSL certificates auto-managed

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10. Future Development Roadmap

We have identified several enhancements planned for future development:

Immediate Enhancements

- **Authentication System:** User accounts with JWT token-based authentication and bcrypt password hashing for secure login and session management
- **CI/CD Pipeline:** Automated deployment workflows using GitHub Actions, including automated testing and zero-downtime deployments

Advanced Features

- **Voice Commands:** Enable users to issue printing instructions using voice input for faster and more accessible workflow
- **AI-Based Command Understanding:** Leverage AI to better interpret user intent, handle incomplete or vague inputs, and learn commonly used settings for prediction
- **Suggestions & Recommendations:** Offer suggested print settings based on document type, user history, and frequently used options with "Did you mean…?" prompts
- **Preview Improvements:** Add live preview showing layout, orientation, and print settings to reduce user errors
- **Real Printer Integration:** Direct integration with physical printers using SNMP, CUPS/IPP, or manufacturer APIs, including device health monitoring (ink levels, paper availability)

Expansion Opportunities

- Browser plugin for quick document or selected text submission
- Cross-platform applications (Windows, macOS, iOS, Android) with synchronized presets
- Document type detection for automatic setting suggestions
- Print cost and resource usage estimates
- Shared team presets across devices
- Secure printing features such as release-on-arrival

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11. Project Summary

We built a complete production-grade full-stack system demonstrating:

Core Development:

- React frontend with intuitive user interface
- Node.js/Express REST API with NLP integration
- MongoDB database with schema validation
- OpenAI NLP for natural language parsing

Infrastructure & DevOps:

- Google Cloud Platform deployment
- Nginx reverse proxy configuration

- PM2 process management
- Custom domain with DNS routing

Software Engineering Practices:

- Clean, modular code architecture
- Separation of concerns (frontend/backend/database)
- Production-ready configuration
- Scalable and extensible design

This project demonstrates full-stack engineering capabilities, cloud infrastructure management, and modern software development practices. The foundational architecture is designed to support future enhancements including authentication, CI/CD automation, advanced AI features, and real printer integration.

Technical Stack Summary

Layer	Technology
Frontend	React, HTML5, CSS3, JavaScript
Backend	Node.js, Express.js
Database	MongoDB Atlas
AI/NLP	OpenAI API
Authentication	JWT, bcrypt
Infrastructure	Google Compute Engine
Process Management	PM2
Web Server	Nginx
Version Control	Git, GitHub
CI/CD	GitHub Actions
Package Manager	pnpm

Report Generated: December 2, 2025
Project Status: Production Deployment
Team: Full-Stack Development Team