Case Study Project

Design and Creative Technologies

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1. Executive Summary

This report presents the secure system design for ***CuraNexus Analytics***, a mid-sized analytics company integrating **hospital and retail data** streams into a unified platform. The application accepts user input, writes to and retrieves from a SQL database, and enforces strict access control aligned with ISO/IEC 27001:2022, NIST SP 800-64 Rev.2, and OWASP Secure Coding Guidelines (2024).

The design adopts a **Secure-by-Design** (SbD) philosophy, embedding security from the earliest development phases to ensure confidentiality, integrity, and availability (CIA triad). Controls address input validation, injection prevention, encryption, authentication, and role-based access management. The approach prioritizes human-centric usability while maintaining compliance and resilience.

2. Request Phase – Secure Data Input and Validation

Insecure input handling remains a major vulnerability (Sutton, 2022); therefore, security begins at the input layer and is enforced server-side (OWASP ASVS 4.0). All inputs undergo type/length validation and Unicode NFC normalization to prevent spoofing. Examples: names ≤ 100 chars, numeric IDs ≤ 10 digits, emails validated per RFC 5321. Client checks assist usability but the server rules (ASVS V5.1.2).

All database access uses parameterized queries or stored procedures—never raw SQL. Allow-list validation and output encoding neutralize SQLi and XSS risks (OWASP, 2024).

Wildcard safety: Business searches use suffix-only patterns (term%), escaping % and _ before parameter binding. Indexing and pagination prevent full-table scans (Xiao & Xiao, 2021). Wildcard search (safe LIKE). Where business requires wildcards:

- UI constrains to suffix-only patterns (term%) and caps term length.
- Backend escapes %, _, and \ in user input and binds patterns as parameters.
- Queries use covering indexes and pagination (e.g., limit 100, cursor-based) to avoid table scans and enumeration.
    - Example: user enters O'B% → backend binds O\'B\% to LIKE ?.

Authentication & sessions (NIST SP 800-63B): MFA is mandatory for admins and privileged actions. Passwords require ≥ 12 chars, PBKDF2-HMAC-SHA-256 hashing, and breach screening. Progressive throttling (1 → 2 → 4 s delays) and SIEM alerts block brute-force. JWTs are RSA-signed with short expiry and contain no sensitive claims.

Database service accounts (app_reader, app_writer, app_admin) are stored in AWS Secrets Manager with KMS encryption (AES-256). Credentials rotate every 90 days and are injected at runtime; no passwords exist in code (NIST SP 800-53 IA-5).

Request integrity: All state-changing calls require CSRF tokens, SameSite=strict cookies, and origin checks. Error messages remain generic to avoid data leaks. Secrets are injected from a vault at runtime; logs record user ID, IP, timestamp but never PII or credentials. Events flow to the central SIEM under ACSC Essential Eight controls (ISO/IEC 27001 §12.4).

"Secure coding standards are the foundation of resilience against injection and authentication flaws." (Sutton, 2022)

2.1.Field Specifications and Validation Logic

All input fields are constrained to prevent overflow and injection attacks:

Field	Max Length	Validation Rule	Justification
Name	100 chars	`^[A-Za-z\s'-]{2,100}$`	Accommodates hyphenated surnames and cultural naming (e.g., "O'Brien", "García-López") per Unicode TR36
Street Address	150 chars	`^[A-Za-z\s'-]{5,150}$`	Longest Australian street name is ~60 chars; 150 allows for unit numbers and landmarks
Postal Code	4 chars	`^\d{4}$`	Australian postcodes are exactly 4 digits (NIST SP 800-63B §5.1.3)
State/Suburb	15 chars	`^[A-Za-z\s'-]{5,15}$`	
City	30 chars	`^[A-Za-z\s'-]{5,30}$`	
Phone	15 chars	`^\+?[\d\s()-]{10,15}$`	ITU E.164 international format supports +61 country code + 10 digits
Email	254 chars	RFC 5321 regex	Maximum email length per SMTP standard
Medical Status	ENUM	Dropdown (no free text)	Prevents injection; values: {Sick, Healthy, Cancer, Deceased, Flu, Covid}
Credit Card	19 chars	`^\d{13,19}$` (masked display)	Visa/MC/Amex range; stored encrypted per PCI-DSS 3.2.1

These lengths balance usability (international names, long addresses) with buffer overflow prevention (OWASP ASVS V5.1.2).

Overflow protection: Requests exceeding limits are rejected with HTTP 400 (“Field [name] exceeds maximum length [X]”). Server-side validation precedes ORM processing to fail fast (ASVS V5.1.2). Example: Python/Django ORM:

```python
# Safe parameterized search with suffix-only LIKE
term = normalize_to_nfc(clean_user_term(user_input))
term = escape_like(term)  # escapes %, _, \
if not valid_search_term(term): raise BadRequest()
qs = Patient.objects.filter(last_name__istartswith=term)[:100]  # indexed, paginated
```

Figure 1: Python code snippet with parameterized search using suffix-only LIKE.

3. Retrieve Phase – Secure Data Retrieval and Encryption

The Retrieve Phase ensures secure data queries and delivery. Data in transit uses TLS 1.3 with forward secrecy, and data at rest uses AES-256-GCM with annual key rotation (Calder, 2020). All queries use the ORM or vetted stored procedures; no raw SQL exists in app code. Service accounts follow least privilege principles (ISO/IEC 27002 §9), with governance standards.

Endpoints enforce explicit filters and record caps (max 100). Wildcards use suffix-only patterns to protect indexes and prevent pattern injection (Xiao & Xiao, 2021). For integrity checks, each query verifies scope and volume: doctors cannot view retail data; queries >10 000 records trigger pagination and SIEM alerts. SHA-256 digests authenticate response integrity.

Output encoding & session security: Dynamic content is HTML-escaped; cookies set Secure, HttpOnly, SameSite=Strict. HSTS and certificate pinning ensure continuous HTTPS trust.

Backup & availability: Daily encrypted backups reside in AWS S3 Glacier (verified quarterly). Read replicas across zones maintain uptime. Each retrieval is logged with session ID and timestamp in immutable Elasticsearch indices (WORM, 12-month retention) (Vacca, 2014).

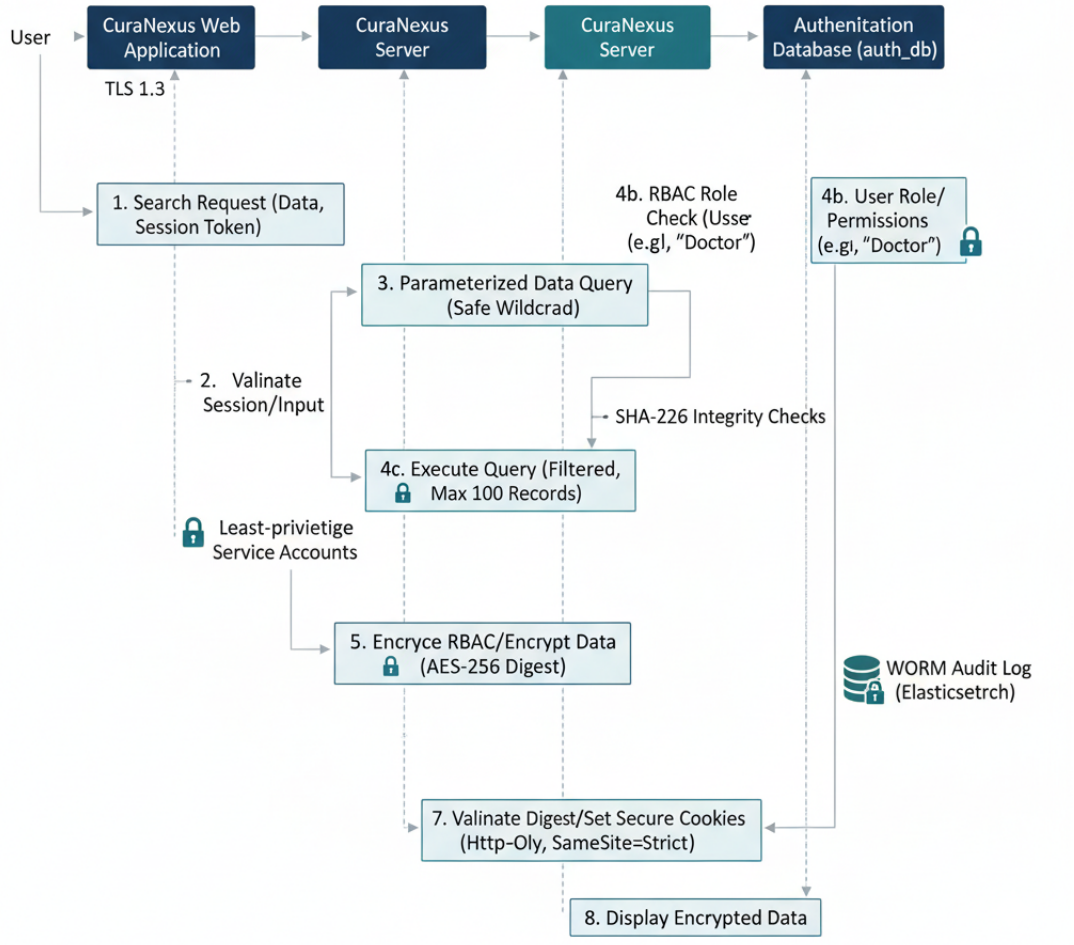

Figure 1: Data Retrieval and Encryption Flow (User → Input Validation → DB Query → RBAC Check → Encrypted Response)

"Encryption is not an afterthought—it is the backbone of trust in digital systems." (Calder, 2020)

4. Review Phase – Role-Based Access Control and Auditing

CuraNexus enforces **Role-Based Access Control** (RBAC) to translate organizational policy into technical enforcement, with roles and scopes explicitly defined and audited quarterly.

Role	Access Scope	Privileges
Standard Users (Doctors, Retail Analysts)	Read-only to relevant data domain	View reports and analytics dashboards
Accounting / Management Users	Read & Write to financial or billing modules	Upload transaction or medical billing data
Privileged IT / Admin Users	Full control with elevated audit accountability	Manage roles, monitor logs, perform maintenance

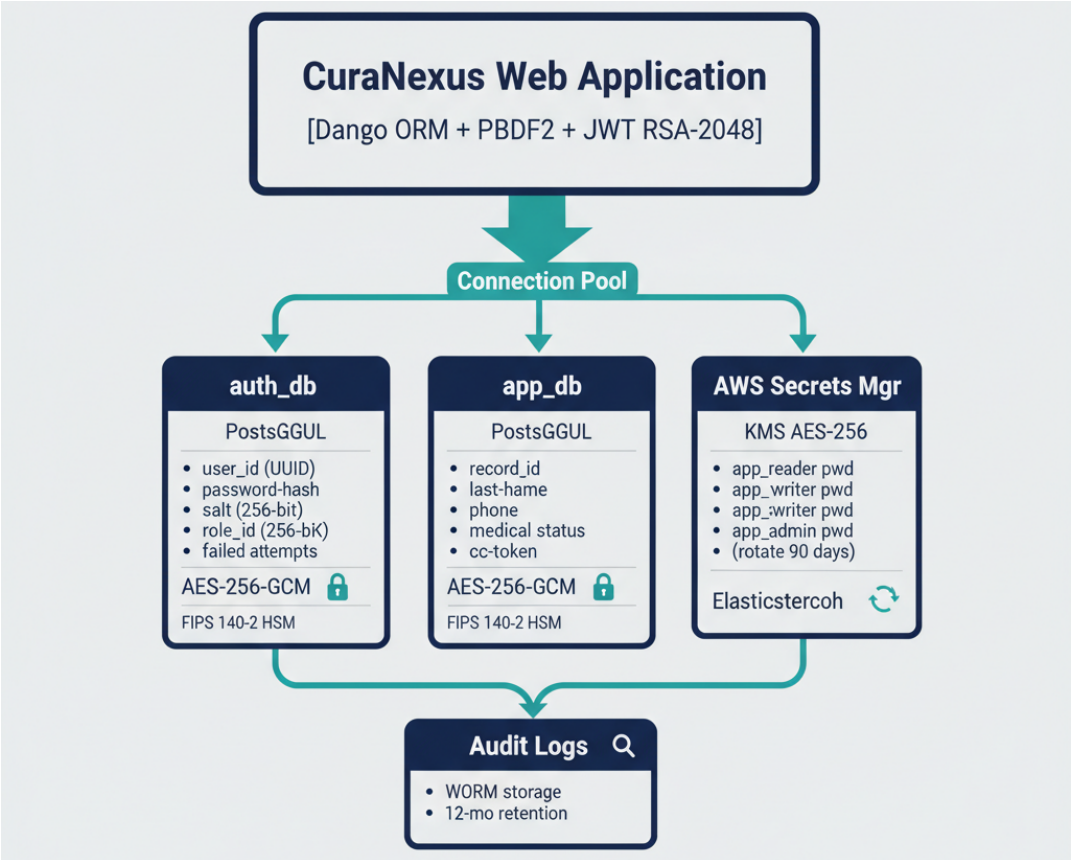

Figure 2: Database Architecture – Separation of Authentication and Application Data

Each access token carries embedded claims (role, department, expiry) signed with RSA-2048. Separation of Duties (SoD) ensures admins cannot modify audit logs or self-grant privileges (ISO/IEC 27001 §9.2). Sessions expire after 20 minutes idle or upon network change.

Join-Move-Leave (JML) lifecycle: Access is provisioned at onboarding, modified on internal transfer, and automatically revoked at offboarding. Dual approval is required for privileged roles, and quarterly access attestation validates least-privilege compliance (ISO/IEC 27005).

Audit logs capture every access event with hash-chained entries for tamper evidence and store them in immutable Elasticsearch clusters for 12 months. Alerts are correlated in SIEM and reviewed by the Information Security Manager within 24 hours of detection.

The RBAC architecture supports both business continuity and forensic traceability, aligning with NIST SP 800-64 Rev. 2 and ISO 27001.

"Role-based control systems translate business policy into enforceable technical boundaries." (Vacca, 2014)

5. Mitigation Methods

A **DREAD**-based analysis quantifies *CuraNexus's* high-priority risks.

Factor	Score (1-10)	Description
Damage potential	10	Insiders already have authorized access; exfiltration of hospital data would violate privacy regulations and destroy client trust.
Reproducibility	6	Requires intent and opportunity; not easily repeatable without detection after initial incident.

Exploitability	8	Authorized users can copy data to USB drives or personal cloud storage with little technical barrier.
Affected Users	7	Primarily impacts the 100-person Doctors group handling sensitive medical records.
Discoverability	4	Insider threats are notoriously difficult to predict; behavioral analytics required for detection.
DREAD Score	7.0/10	High. Continuous monitoring essential.

Mitigation measures:

- Parameterized queries prevent injection attempts.
- Least privilege limits exposure to compromised accounts.
- MFA reduces credential theft success rates.
- Automated alerts and SIEM correlation rules detect anomalies in real time.

According to Vellani (2007), “quantified risk frameworks like DREAD enable prioritization of remediation efforts and security investment.”

Residual risk remains low after applying compensating controls and continual improvement under the Plan-Do-Check-Act (PDCA) model.

6. Encryption and Key Management

Encryption keys are centrally managed using an HSM (Hardware Security Module) with periodic rotation every 12 months or after any breach event.

- **Data Encryption:** AES-256-GCM for all SQL tables containing personally identifiable information (PII).
- **Key Exchange:** RSA-2048 for secure key transfer and handshake.

- **Secure Hashing:** SHA-256 applied to sensitive identifiers (e.g., Medicare IDs).

Keys are separated by environment (production/test) and stored outside application containers. Only the Information Security Manager can approve key rotation cycles.

TLS configurations disable legacy protocols (SSL, TLS 1.2) and weak ciphers. HSTS headers ensure encrypted continuity between user and system. Periodic key audits and penetration testing validate the integrity of the encryption ecosystem (Erbschloe, 2005).

7. Integration with ISMS and Business Continuity

CuraNexus aligns this software design with its Information Security Management System (ISMS) from Assessment 2. Incident response (IRP) and business continuity (BCP) are connected:

- **IRP** triggers when anomaly thresholds in SIEM exceed limits.
- **BCP** ensures data restoration within 4 hours (RTO) using encrypted cloud backups.
- **Post-incident reviews** update security playbooks per ISO 22301 and ISO/IEC 27035.

This ensures not only protection against breaches but rapid containment and learning cycles, hallmarks of Secure-by-Design resilience (Mead & Woody, 2017).

8. Conclusion

Through proactive design, **CuraNexus Analytics** embeds security into every **development layer - people, process, and technology**. From validated input to encrypted storage and risk-based access control, the system exemplifies SBD principles guided by international standards. By continuously auditing, encrypting, and training, *CuraNexus* reduces risk exposure, builds trust, and ensures operational resilience in handling sensitive hospital and retail data.

9. Appendices

9.1. Appendix A - Glossary

Term	Meaning	Description
AES-256 (GCM)	Advanced Encryption Standard	Uses 256-bit keys in Galois/Counter Mode; protects data at rest.
BCP	Business Continuity Plan	A strategy defining how critical systems and data are restored following a disruption.
CIA Triad	Confidentiality, Integrity and Availability	Core security model comprising Confidentiality, Integrity and Availability.
CSRF	Cross-Site Request Forgery	Attack that tricks a user into performing unwanted actions on a trusted web application.
HSM	Hardware Security Module	Dedicated hardware device used to generate, store and manage cryptographic keys securely.
ISMS	Information Security Management System	ISO/IEC 27001 framework governing information-security policies, procedures and continual improvement.
JWT	JSON Web Token	Signed token format for securely transmitting authentication claims between client and server.
MFA	Multi-Factor Authentication	Login control requiring two or more independent factors to verify user identity.
RBAC	Role-Based Access Control	Authorization model assigning permissions to roles rather than individuals.
SIEM	Security Information and Event Management	Centralized platform that aggregates, correlates and analyses logs for threat detection.
TLS 1.3	Transport Layer Security	Cryptographic protocol securing data in transit with forward secrecy and modern cipher suites.
PDCA	Plan-Do-Check-Act	Continuous-improvement cycle used in ISO management systems to maintain and enhance controls.

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- OpenAI ChatGPT (GPT-5): Used to assist with outlining, refining structure, improving clarity of academic language, and supporting with APA 7th referencing conventions.

I confirm that the use of the AI tool has been in accordance with the Torrens University Australia Academic Integrity Policy and TUA, Think and MDS's Position Paper on the Use of AI. I confirm that the final output is authored by me and represents my own critical thinking, analysis, and synthesis of sources. I take full responsibility for the final content of this report.

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