2. Failure and Recovery Simulation

2.1 Database State Before Failure

```
-- Initial Database State
CREATE TABLE accounts (
    id INT PRIMARY KEY,
    name VARCHAR(50),
    balance DECIMAL(10,2)
);

INSERT INTO accounts VALUES
(1, 'Alice', 1000.00),
(2, 'Bob', 500.00),
(3, 'Charlie', 750.00);
```

Initial State:

```
{
  "accounts": [
    {"id": 1, "name": "Alice", "balance": 1000.00},
    {"id": 2, "name": "Bob", "balance": 500.00},
    {"id": 3, "name": "Charlie", "balance": 750.00}
  ]
}
```

2.2 Transaction Execution and Failure

```
-- Transaction T1 - Money Transfer
BEGIN TRANSACTION T1;
UPDATE accounts SET balance = balance - 100 WHERE id = 1;  -- Completed
-- SYSTEM FAILURE OCCURS HERE --
UPDATE accounts SET balance = balance + 100 WHERE id = 2;  -- Not executed
COMMIT;  -- Not reached
```

State After Failure (Inconsistent):

```
{
  "accounts": [
    {"id": 1, "name": "Alice", "balance": 900.00},  // Modified
    {"id": 2, "name": "Bob", "balance": 500.00},    // Unchanged
    {"id": 3, "name": "Charlie", "balance": 750.00} // Unchanged
  ]
}
```

2.3 Recovery Process

```
-- Recovery SQL Script
-- Step 1: Analyze transaction log
SELECT * FROM transaction_log
WHERE transaction_id = 'T1'
ORDER BY lsn;

-- Step 2: Identify uncommitted transactions
SELECT DISTINCT transaction_id
FROM transaction_log
WHERE transaction_id NOT IN (
    SELECT transaction_id FROM transaction_log
    WHERE operation = 'COMMIT'
);

-- Step 3: UNDO incomplete transactions
UPDATE accounts SET balance = balance + 100 WHERE id = 1;  -- Reverse T1

-- Step 4: Verify consistency
SELECT SUM(balance) FROM accounts;  -- Should equal original total
```

Recovery Log:

```
[11:15:30] [RECOVERY] System restart detected
[11:15:30] [RECOVERY] Analyzing transaction log...
[11:15:31] [RECOVERY] Found uncommitted transaction: T1
[11:15:31] [RECOVERY] UNDO: UPDATE accounts SET balance = balance + 100
WHERE id = 1
[11:15:32] [RECOVERY] Database restored to consistent state
[11:15:32] [RECOVERY] Total balance verified: $2250.00
[11:15:32] [RECOVERY] Recovery completed successfully
```

2.4 ACID Properties During Recovery

Property	Description	Recovery Impact
Atomicity	All-or-nothing execution	Incomplete transactions are rolled back
Consistency	Database integrity maintained	Constraints verified after recovery
Isolation	Concurrent transaction separation	Locks released during rollback

Durability	Committed changes persist	Only committed data survives failure