Database Security
The Past, the Present, the Future

Mark Kraynak
Director of Product Marketing
Imperva
mark@imperva.com

Imperva

Who we are

- Venture-backed, privately-owned company with operations and HQ in the US and Israel
- Leadership of Shlomo Kramer
  - Check Point co-founder
  - Co-developer of Stateful Inspection
  - Imperva Co-founder and CEO
- Deep expertise in security
  - Application, Database and Data Center Security Elite Specialists
    - Israeli Defense Force cyber warfare team
    - Private sector application, network, database and data center penetration testing and security consultants

Agenda

- Intro Demo: SQL Injection
- Noteworthy Data Thefts
- A Multi-Dimensional Problem
- SQL Injection Revisited
- Countermeasures Demonstration
- Effective countermeasures
- Q&A

Data Theft

Publicity & Governmental Action

- Legislation fuels publicity
  - 15 states with security breach laws with 4-10 more expected in 2005

- Publicity fuels more legislation
  - 20 more states considering additional security breach legislations
  - 10 US Senate bills introduced in 2005 (Identify Theft Protection Act)

Data Theft

Costs are Real for Businesses

FTC Consent Agreements

- Penalty - 20 yrs of bi-annual audits by outside security consultants
- **Microsoft**, **Petco**, and **Guess** for “deceptive claims” about security
- **BJ Wholesale** for "unfair" business practices of lax computer security and major credit card breach in 2004

Hard Dollar Estimates

- BJ Wholesaler - **$16M** reserve
- DSW - **$6.5M to $9.5M** set aside
- Polo Ralph Lauren - **$1.6M** claimed
- Chipotle's Mexican Grill - **$.75M** claim

"There is going to be a flood of lawsuits,"
- former Justice Department prosecutor

Data Breach Lawsuits

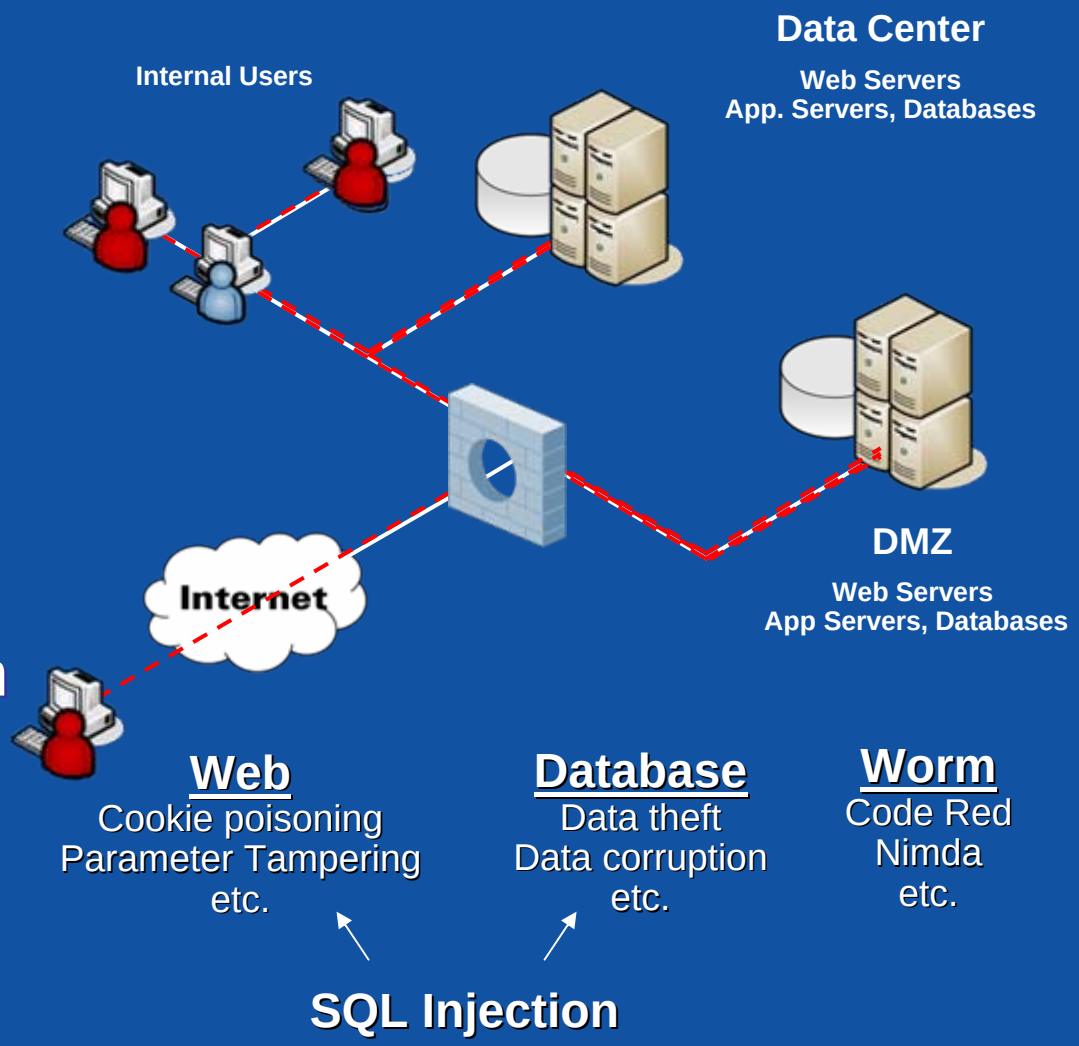
- Class action - CA law on "reasonable" security for customer information
  - **CardSystems Solutions ($120M)**
  - **LexisNexis**
  - **ChoicePoint**
- Ohio Attorney General - ”Implied warranty” to protect consumers info
  - **DSW Shoe Warehouse**

Source: WSJ 7/21/05 pB1

Database Threats and Vulnerabilities

A multi-dimensional problem

- Direct: Database breach
  - Internal sources
  - Very high value target
- Indirect: Web attacks
  - Targeted
  - External sources
  - “Custom” vulnerabilities
- Platform: Worm infection
  - External and internal sources
  - Generic attack



SQL Injection: A Pervasive Attack to Compromise Data

SQL Injection: What is it

- An attack methodology
  - Allows the attacker to alter SQL statements generated by an application (due to the lack of input validation)
  - SQL Injection opens up the full semantics of database access languages (so the attacker has a LOT of tools available)
- An application is vulnerable to SQL Injection as a result of the ***programming*** of the application itself
- Built-in database security and traditional network security solutions are hard-pressed to correct this issue
  - (we will demonstrate some of the reasons why…)

SQL Injection: Example 1

Authentication Circumvention

The Code:

```
…
SqlQry = "SELECT * FROM Users WHERE Username = '" &
Request.QueryString("User") & "' AND Password = '" &
Request.QueryString("Pass") & "'"
LoginRS.Open SqlQry, MyConn
If LoginRS.EOF Then Response.Write("Invalid Login")
…
```

When a normal user logs in, the following query is created:

```
SELECT * FROM Users WHERE Username = 'John'
AND Password = 'Smith'
```

The attacker, however, inserts *X' OR '1'='1* as the password, altering the query into the following (non empty) one:

```
SELECT * FROM Users WHERE Username = 'John'
AND Password = 'X' OR '1'='1'
```

SQL Injection: Example 2

Data Retrieval

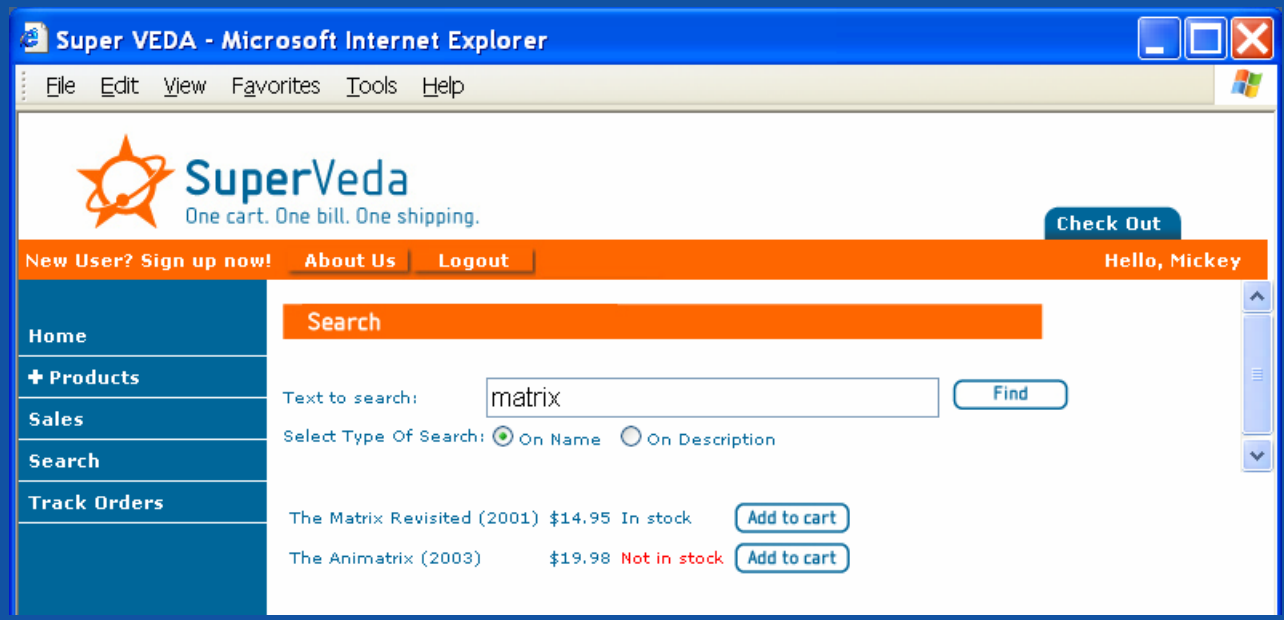
The Code:

```
SqlQry = "SELECT * FROM Products WHERE ProdDesc LIKE "
& "'%" Request.QueryString("SearchTerm") & "%'"
ProdsRS.Open SqlQry, MyConn
```

The query that is normally created when using the form is:

```
SELECT * FROM Products WHERE ProdDesc LIKE '%matrix%'
```

Showing all matching results:



SQL Injection: Example 2

Data Retrieval (Continued)

The attacker now uses the following string as the search term:

```
99'UNION SELECT null, null ,username ||';'|| password
||';'||ccnumber ||';'|| ccdate, null, null, 0, null
FROM Users--
```

Causing the original query to be altered into the following one:

```
SELECT * FROM Products WHERE ProdName LIKE '%99' UNION
SELECT null, null, username || ' ; ' || password ||
';' || ccnumber ||';'|| ccdate, null, null, 0, null
FROM Users --%'
```

As a result, the query now returns all products whose name terminates with '99' (probably none), as well as the list of the users, their passwords, and their credit card numbers

Countermeasures:
Common Approaches That Don’t Work

Countermeasures

Candidate 1: Error message hiding

Simplest and most common countermeasure against SQL Injection

- Achieved by simple configuration options (e.g. suppress error messages or set a custom error message)
- A classic ***Security By Obscurity*** approach

… why it won't work …

Blindfolded SQL Injection

Blindfolded SQL Injection

- What is it?
  - A set of techniques for the detection and exploitation of SQL Injection vulnerabilities
  - Eliminates the reliance on error messages
- The attacker employs Boolean tests determine whether an error has occurred

Blindfolded SQL Injection:

Identifying an Opportunity

- Testing for the existence of SQL Injection can be done simply by replacing a field with equivalent SQL syntax:
  - The number ***5*** can be represented in SQL as ***(6-1)***
  - The string ***'test'*** can be represented as ***'te'+'st'*** (in MS SQL) or ***'te'||'st'*** (in Oracle)
  - A date can be replaced with the database's date function
    - getdate() (MS SQL) or sysdate (Oracle)
- Matching results indicate that the system is vulnerable, while an error indicates that the syntax was not parsed by an SQL parser

Blindfolded SQL Injection:

Targeting the Attack Parameters

- Since errors are hidden / identical some form of differentiation is required
- Step #1 – Enumerating the number of columns
  - Done using an ORDER BY statement, which sorts by specific field
  - When an existing field is chosen, the result is sorted according to it. However, when a non-existent field is chosen, an error occurs
- Step #2 – Enumerating the type of fields
  - Create an initial request with all fields set to NULL
  - Type detection is done by guessing one field at a time
- Once field types are known, exploit is trivial

Blindfolded SQL Injection:

Identifying a Column

- Union Select null,null,null,null,null,null
  - Error = Syntax isn't right. We have a type issue.
- It takes some time, but we find the right combo:
- Union Select null,null,null,1,null,null…
  - No Error = Syntax & basic typing is right.
- Union Select 1,null,null,1,null,null…
  - No Error = 1st column is integer.
- Union Select 1,2,null,1,null,null
  - ERROR! = 2nd column is NOT integer.
- Union Select 1,'2',null,1,null,null
  - No Error = 2nd column is String.
- Continue until you understand the column types

Countermeasures

Candidate 2: Signature Protection

- Relies on the existing IDS/IPS infrastructure or on an easily installed signature protection component
- Attempts to detect common SQL Injection strings such as: UNION SELECT, OR 1=1, etc.

BUT

- Signatures can only be practically applied to HTTP traffic
  - SQL Injection strings are not different than valid SQL statements.
- Placing strict signatures on keywords such as INSERT, SELECT and DELETE, and characters such as ‘, = and -- will cause the security mechanism to block valid requests

… why it won’t work …

SQL Injection Signature Evasion

SQL Injection Signature Evasion

- A set of techniques which allow an attacker to evade signature protection mechanisms
- Methods include
  - Detecting signature protection (EASY)
  - Generic evasion techniques
  - SQL language specific evasion techniques

SQL Injection Signature Evasion:
Generic Evasion Techniques

- Non-SQL Specific
- Employs common IDS evasion techniques, such as:
  - IP Fragmentation
  - TCP Segmentation
  - White Space Diversification
  - Various Encodings (HTTP/UTF8/Unicode/etc)

- Vulnerability to these techniques is a result of poor implementation rather than an inherent problem

SQL Injection Signature Evasion

SQL-Based Techniques

- Technique #1 – Value equivalence (instead of OR 1=1)
  - OR 'Simple' = 'Simple'
  - Make the expression look different but still be the same.
    - Adding N will make the value an nvarchar:
    - OR 'Simple' = N'Simple‘
  - Concatenation at the SQL level:
    - OR 'Simple' = 'Sim'+'ple‘ (MS-SQL)
    - OR ‘Simple’ = ‘Sim’||’ple’ (Oracle)
- What if the signature detection is looking at a much wider expression like OR followed by = ?
  - OR 'Simple' LIKE 'Sim%'
  - OR 'Simple' > 'S‘
- SQL is a rich toolset: there are unlimited numbers of examples:
  - OR 'Simple' IN ('Simple')
  - OR 'S' BETWEEN 'R' AND 'T'

SQL Signature Evasion

SQL Based Techniques

- Technique #2 – White Space Equivalence / Comments
  - Used to evade signatures that contain white spaces, such as
    - `OR 1=1`
    - `UNION SELECT`
    - `EXEC SP_`
- Using Comments
  - http://localhost/showproducts.asp?CatID=99’UNI/**/ON /**/ SE/**/LECT

SQL Based Techniques

- Technique #3 – String Equivalence
  - Basic string equivalence is done by executing a concatenated string (Most DBs have more than one way of doing so), such as:
    - ; EXEC('INS'+'ERT INTO…'
    - ; EXECUTE('INS'||'ERT INTO…'
  - A possible string equivalence is through its hexadecimal representation, allowing the keyword SELECT to be represented as 0x73656c656374

Countermeasures
Candidate 3: DB Access Control Lists (ACLs)

- Least privileges applied to the application account
- Protects the database against system level attacks that require special system privileges, such as the following:

```
(Oracle examples)
    ; DROP USER <name>
    ; DROP TABLE <name>
    ; GRANT CONNECT, RESOURCES
    ; SHUTDOWN ABORT
(MS-SQL examples)
    ; EXEC MASTER.XP_CMDSHELL('cmd.exe /e dir') --
    ; SHUTDOWN --
    ; DROP DATABASE MyApp –
```

… why it won't (completely) work …

SQL Injection Denial of Service

SQL Injection Denial of Service

- A set of techniques to launch Denial of Service attacks against databases
  - Direct or through SQL Injection
- Basic SQL DoS techniques require the application to be running a privileged user account
- Advanced techniques allow the attacker to perform various destructive activities through a user account with limited privileges
  - Making the server unavailable
  - Corrupting data

SQL Denial of Service

Data Corruption/Destruction

- While not a classic DoS attack, Data destruction/corruption may often render the application useless
- Recovery time may be significant
  - Instead of a reboot, data restoration is required
- Attacker looks for pages which perform DELETE or UPDATE statements based on a parameter provided by the user
- Injecting an *OR 1=1* (or equivalent) string will cause the query to delete or alter the entire contents of the table.
  - For instance, injecting into a password change form:

```
UPDATE Users SET Password='BOGUS' WHERE Username='User'
 OR '1'='1'
```

SQL Denial of Service

Resource Consumption

- Resource consumption attacks can be achieved by a read-only user
- Classic DoS: Attacker can prevent others from using the server
- Can be performed through several techniques, such as:
  - Creating a very large record set created from a correlated query:

```
SELECT A1.*, B1.* FROM A AS A1, B AS B1
WHERE EXISTS (SELECT A2.*, B3.* FROM A AS A2, B AS B3
              WHERE A1.AID = A2.AID)
AND EXISTS (SELECT B2.*, A3.* FROM B AS B2, A AS A3
            WHERE B1.BID = B2.BID)
```

  - Executing endless loops:

```
BEGIN DECLARE @A INT;
       WHILE (1=1) BEGIN
                IF (1=2) BEGIN
                         SET @A = 1;
                END
       END
END
```

Effective Countermeasures

The Right Solution – Data security in 3 layers

- **The Application** – Write secure code
  - Use Prepared Statements/Parametric Queries
  - Use Stored Procedures
  - Validate Input (length, type, character set)
- **The Database** – Apply available features
  - Restrict database user permissions
  - Impose resource quotas/limit profiles
  - Audit database activity and logs
- **External Mechanism**
  - Use solutions that are aware of application context
  - Revalidate some of the security tasks such as input validation and logging
  - Perform tests on incoming requests and outgoing responses based on expected behavior

Effective Countermeasures: External Mechanism

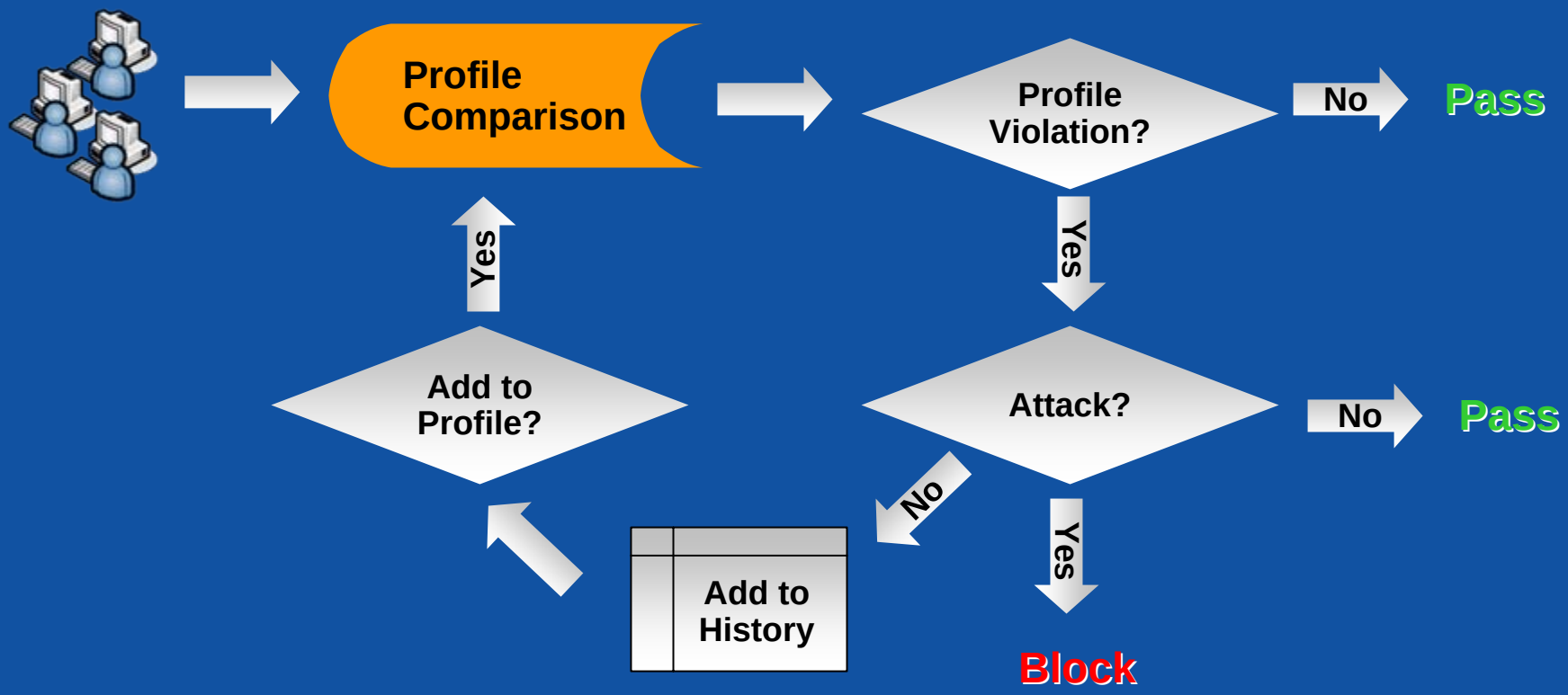
A Model for Database Security

- *Dynamic Profiling* models appropriate database usage
  - Database objects
    - Queries, stored procedures, privileged operations, system objects, etc
  - Users
    - Auditable trail of user access and activity
  - Business activities and transactions
    - Prevents rogue users from overstepping permissions
  - Time of day and Location
    - Reduces “comfort zone” of rogue users attempting malicious operations outside of normal work locations or work hours
  - Application / Access Method
    - Prevents stolen / abused credentials (i.e. rogue user using an application’s credentials)
  - Requests per second / Data Consumption Rate
    - Prevents DoS attacks and alerts on inappropriate spikes in data use
- Audit and Secure based on usage dynamics
  - Verify real-time usage vs. the baseline
  - Audit deviations from baseline
  - Enforce baseline (as appropriate)

Effective Countermeasures: External Mechanism

SQL Profiling

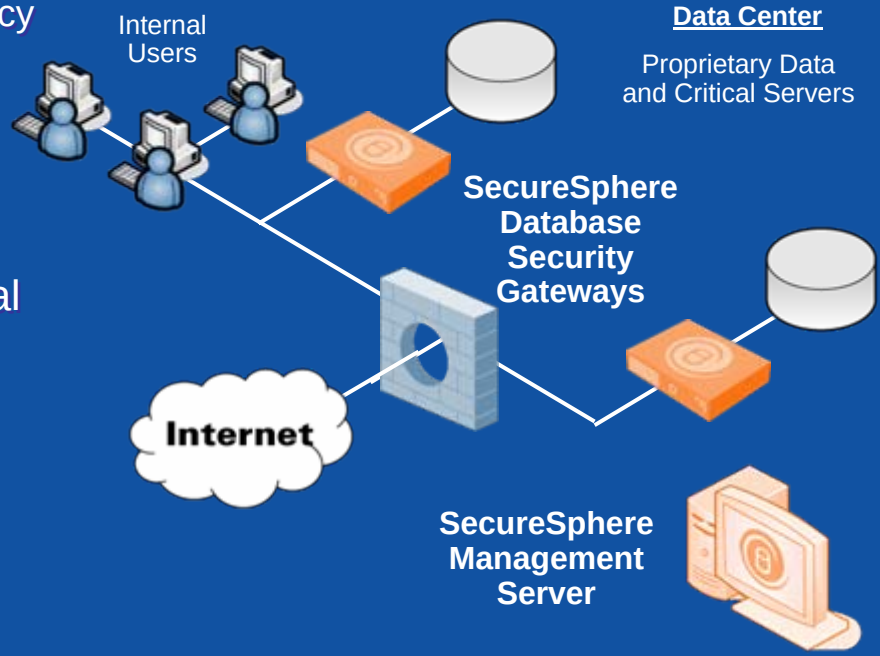
A continuously evolving model of database and application structure, design and deployment



Imperva SecureSphere

Database Security Gateway

- Assessment
  - Models Database Usage
    - Dynamic Profiling learns from traffic
    - Automatically generates security policy
    - Support manual adjustments to policy
  - Identifies Usage Vulnerabilities
- Audit
  - Logs all activity (incl. DBA)
  - Identifies activities that matter in real time
- Protection
  - Alerts (blocks) attacks and policy violations
  - Stops platform attacks
    - Database server software
    - Operating system



Additional Information

Live Webinars

Register at **www.imperva.com/go/webinar93**

For more information or a copy of the
"SQL Injection" white paper,
contact me:

Mark Kraynak
mark@imperva.com

THANK YOU!