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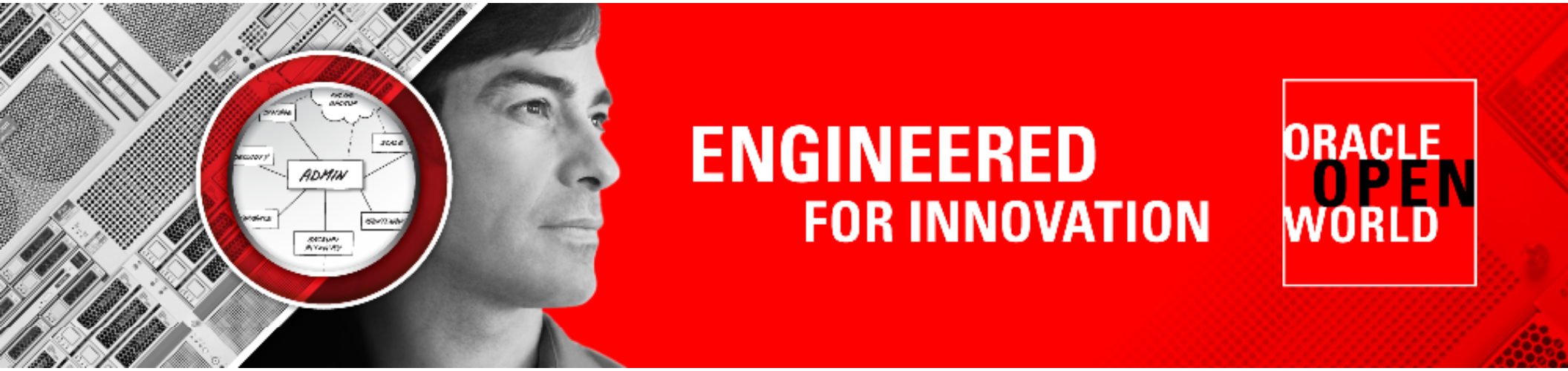

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Oracle Database Firewall: First Line of Defense

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Program Agenda

- SQL Injection & Threats to Databases
- Oracle Database Firewall
  - Security Models
  - Policy Enforcement
  - Database Monitoring and Reporting
  - Architecture and Deployment Modes
- Demonstration
- Conclusion
- Q&A

Over 900M Breached Records Resulted from Compromised Database Servers

Type	Category	% Breaches	% Records
Database Server	Servers & Applications	25%	92%
Desktop Computer	End-User Devices	21%	1%

Payment card	Offline Data	18%	<1%
POS server (store controller)	Servers & Applications	11%	<1%
Laptop computer	End-User Devices	7%	<1%
Documents	Offline Data	7%	<1%
POS terminal	End-User Devices	6%	<1%
File server	Servers & Applications	4%	81%
Automated Teller Machine (ATM)	End-User Devices	4%	<1%
FTP server	Servers & Applications	2%	3%
Mail server	Servers & Applications	2%	4%

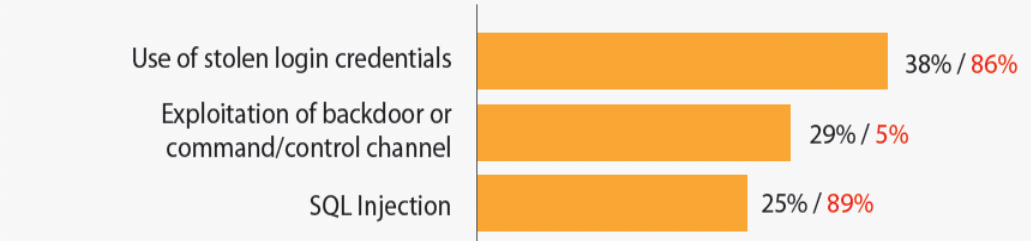
Verizon 2010 Data Breach Investigations Report

"The versatility and effectiveness of SQL injection make it a multi-tool of choice among cyber criminals."

Verizon 2010 Data Breach Investigations Report

- SQL injection attacks against databases are responsible for 89% of breached data
- SQL injection vulnerabilities are endemic
- Require code changes to be made to an application.

Figure 21. Types of hacking by percent of breaches within Hacking and percent of records



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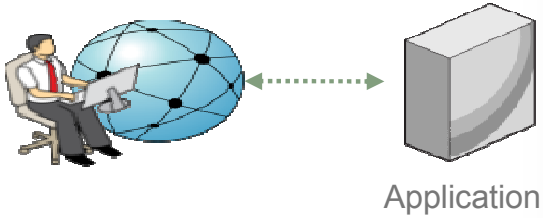
What is a SQL Injection?

Too much trust in users

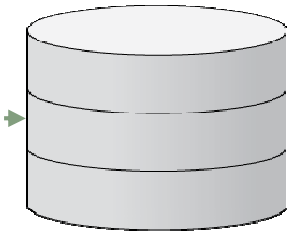



```
SELECT * from stock where
catalog-no =
'PHE8131'
 and location = 1
```

Good ☺

```
SELECT * from stock
where
 catalog-no =
'' union select cardNo, customerId, 0 from Orders --
 and location = 1
```

Bad ☹



- (Mis)users subvert the application to access to the database
- Applications Trust users
- Applications not designed defensively
- Applications are given high levels of privilege
- Each application is unique

How Do Applications Talk to Their Database?

Assembling a *Normal* SQL statement

Parameters for SQL come from user input (e.g. a web browser).
The application layer accepts the values for `catalog-no` and `location` (‘`PHE8131`’, ‘`1`’) and pastes them into the pre-canned query template.

```
SELECT * from stock where catalog-no = '_______' and location =
```

Output:

Description	*Price*	*# in Stock*
Star Trek - The Next Generation Season 2	39.35	15
Star Trek - The Next Generation Season 3	39.35	12
Star Trek - The Next Generation Season 4	39.35	13
Star Trek - The Next Generation Season 5	39.35	17

How Do Applications Talk to Their Database?

Assembling an *abnormal* SQL statement – SQL Injection

Instead of inputting a normal value for `catalog-no`, the user enters

```
' union select cardNo, customerId, 0 from Orders --
```

And the database receives the following query

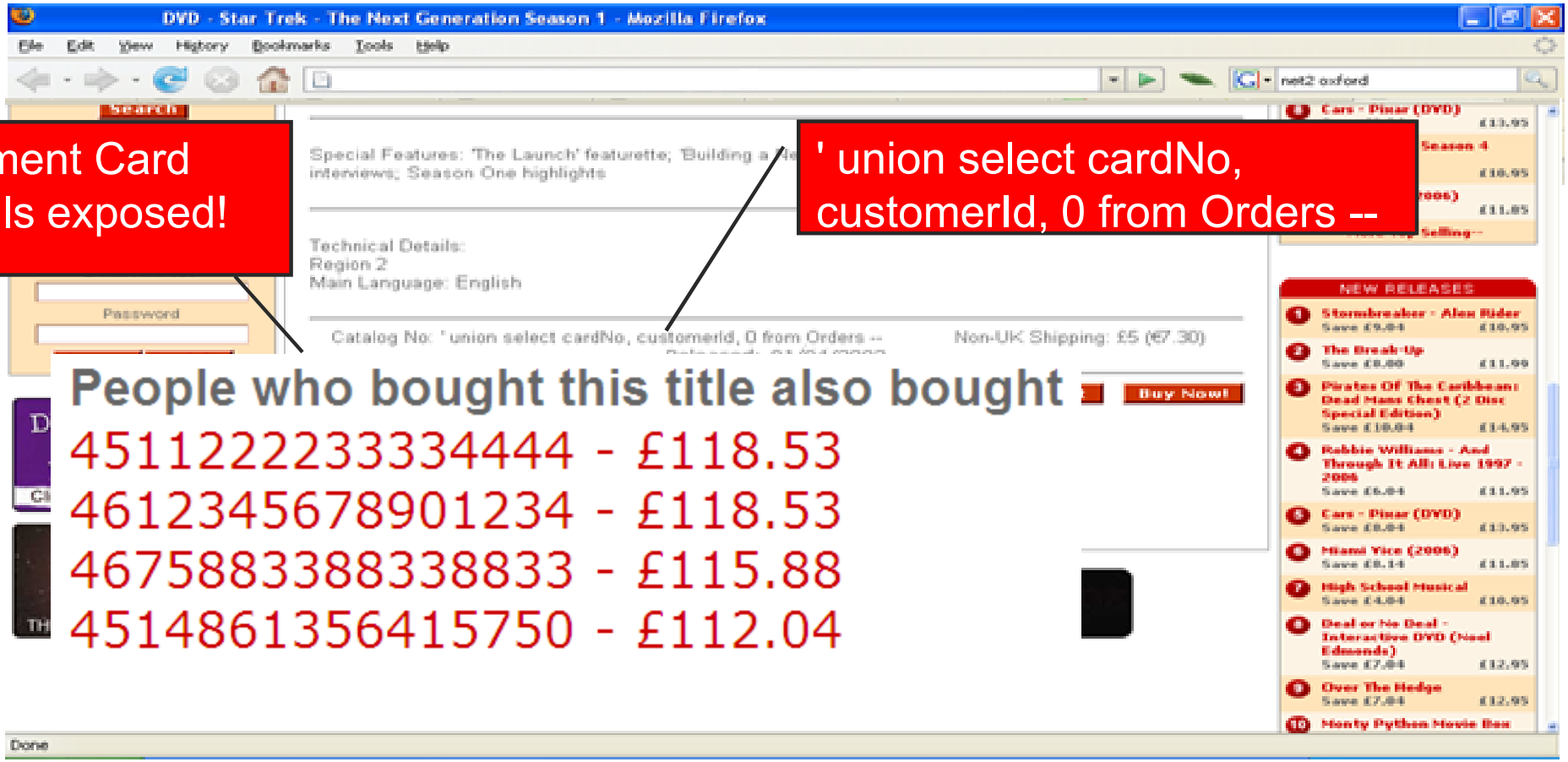
```
SELECT * from stock where catalog-no = '_______' and location =
_____________________________' and location =
```

Output:

Description			*Price*	*# in Stock*
4511222233334444	11853	0		
4612345678901234	11853	0		
4675883388338833	11588	0		
4514861356415750	11204	0		

Payment Card details

What does the attacker actually see?



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More SQL Injections

Endless alternatives

```
SELECT * from stock where catalog-no = 'PHE8131' and location = 1
```

```
SELECT * from stock where catalog-no = ''--' and location = 1
```

```
SELECT * from stock where catalog-no = '' having 1=1 -- ' and location = 1
```

```
SELECT * from stock where catalog-no = '' order by 4--' and location = 1
```

```
SELECT * from stock where catalog-no = '' union select cardNo,customerId,0
from Orders where name = 'John Smith'--' and location = 1
```

```
SELECT * from stock where catalog-no = '' union select min(cardNo),1,0 from
Orders where cardNo > '0'--' and location = 1
```

Challenges of SQL Injections

- How Do You Catch Them?
  - Must detect anomalous SQL
  - Need to ensure detection is accurate (i.e. do not have false positive nor false negative errors)
  - Must be performant (i.e. can be done in real-time)
- What Kind of Detection Engine Do I Need?
  - Why is Accuracy Important in a Detection Engine?
  - SQL Grammar versus Regular Expressions
  - White Lists versus Black Lists

Detection Engines

Regular Expressions Based Approach

- Regex
  - A pattern describing a set of strings

- With regular expressions you can:
  - Find out whether a certain pattern occurs in the text
  - Locate strings matching a pattern and remove them or replace them with something else
  - Extract the strings matching the pattern

[Source: Andrei Zmievski, Yahoo! Inc.]

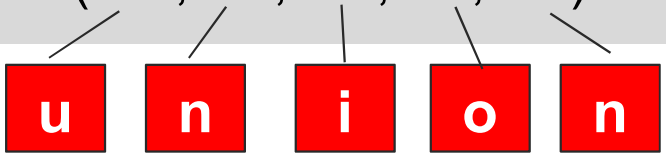
String Matching Keywords is Inadequate

- **union** is NOT universally bad when next to this **select**

```
SELECT lastname from boys
union
SELECT lastname from girls
```

- **union** without “saying it”

```
uni/* */on
u/* */nion
char(117,110,105,111,110)
```



Can you *'Tune'* Regular Expressions?

- **union** is bad when it appears ***near*** **select**

u(?:nion\b.{1,100}?\bselect

```
"(?:\b(?:(?:s(?:elect\b(?:.{1,100}?\b(?:(?:length|count|top)\b.{1,100}?\bfrom|from\b.{1,100}?\bwhere)
|.*?\b(?:d(?:ump\b.*\bfrom|ata_type)|(?:to_(?:numbe|cha)|inst)r))|p_(?:(?:addextendedpro|sqlexe)c|(?:
oacreat|prepar)e|execute(?:sql)?|makewebtask)|ql_(?:longvarchar|variant))|xp_(?:reg(?:re(?:movemultis
tring|ad)|delete(?:value|key)|enum(?:value|key)s|addmultistring|write)|e(?:xecresultset|numdsn)|(?:te
rminat|dirtre)e|availablemedia|loginconfig|cmdshell|filelist|makecab|ntsec)|u(?:nion\b.{1,100}?\bsele
ct|tl_(?:file|http))|group\b.*\bby\b.{1,100}?\bhaving|d(?:elete\b\W*?\bfrom|bms_java)|load\b\W*?\bdat
a\b.*\binfile|(?:n?varcha|tbcreato)r)\b|i(?:n(?:to\b\W*?\b(?:dump|out)file|sert\b\W*?\binto|ner\b\W*?
\bjoin)\b|(?:f(?:\b\W*?\(\W*?\bbenchmark|null\b)|snull\b)\W*?\()|a(?:nd\b
?(?:\d{1,10}|[\'\"][^=]{1,10}[\'\"]) ?[=<>]+|utonomous_transaction\b)|o(?:r\b
?(?:\d{1,10}|[\'\"][^=]{1,10}[\'\"]) ?[=<>]+|pen(?:rowset|query)\b)|having\b
?(?:\d{1,10}|[\'\"][^=]{1,10}[\'\"])
?[=<>]+|print\b\W*?\@\@|cast\b\W*?\()|(?:;\W*?\b(?:shutdown|drop)|\@\@version)\b|'(?:s(?:qloledb|a)|m
sdasql|dbo)')"
```

[Source: ModSecurity, Web Application Firewall]

- Is this comprehensible or manageable?

 |

Detection Engines

Issues with Regular Expressions

- Fails to understand meaning, motives and intentions of SQL when you just use strings and text
- Good Statement

```
SELECT * from stock where catalog-no = 'PHE8131' and location = 1
```

- Bad Statement – SQL injection

```
SELECT * from stock where catalog-no = '' union select cardNo,
customerId, 0 from Orders --' and location = 1
```

Understanding SQL

- SQL is a language with about 400 key words and a strict grammar structure

```
UPDATE tbl_users SET comments = 'The user has asked for another
account_no, and wishes to be billed for services between 1/27/2009
and 2/2/2009, and wants to know where the invoice should be sent
to. She will select the new service level agreement to run from
3/7/2009 next month' WHERE id = 'A15431029';
```

KEY WORDS	SCHEMA	DATA	OPERATORS

- Grammatical context necessary to prevent false categorization

Anomaly Detection

Why is Accuracy Important?

- 1,000 transactions per second = 86 Million per day
- 0.001% false positive rate = 27,000 audit errors per month
- High performance run-time matching ensure only appropriate SQL interactions are sent to a database
  - False positives detects when it should not
  - False negatives avoid detection

0.0001% False Negative Rate Result In
86 Potential Attacks Per Day!

Oracle Database Firewall

Meets The Challenges of SQL Accuracy

- Regular expressions
  - Pattern matching does not understand SQL intention
  - Can generate false positives and non-detection
  - High maintenance
- Oracle Database Firewall Grammar-based detection engine
  - Clusters are deterministic and provide accurate policy application
  - Speed of lookup is constant regardless of the number of clusters in the policy
  - By understanding the SQL grammar, SQL injection and other out-of-policy SQL are detected as anomalies and blocked

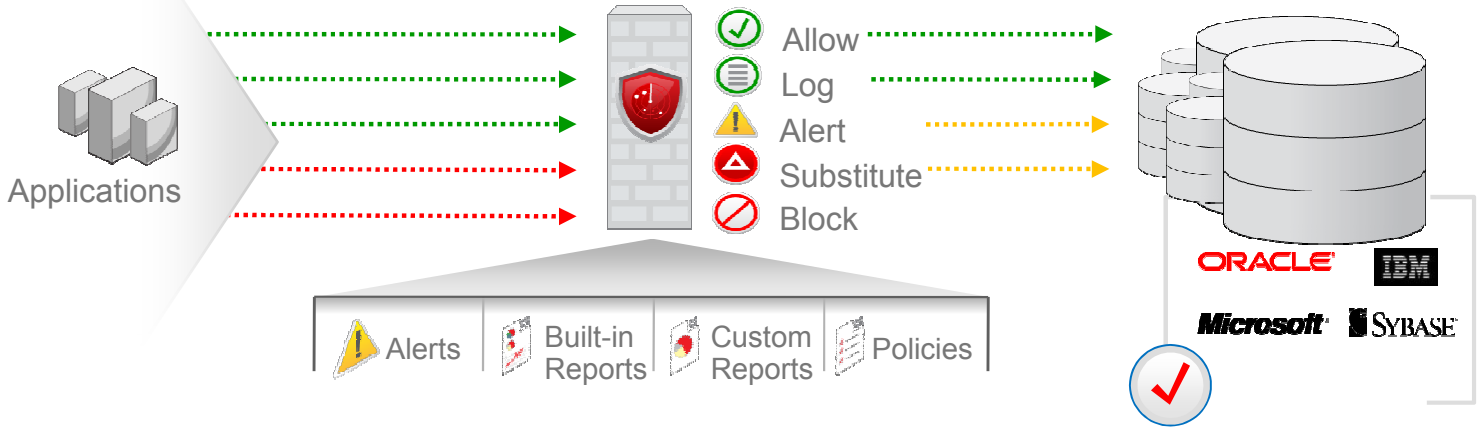
Oracle Database Firewall

Next Generation Detection Framework

- Use the same level of language power to **detect** as to **transmit** SQL
  - This provides **accuracy**
- White-listing approach only allows those SQL to be sent to the database
  - Learn from the SQL you wish to control
  - Go beyond syntax and get close to the meaning or intent or motives of the SQL
- SQL is analyzed and grouped into clusters
  - Only need to record the SQL one time and read many times
  - Eliminate false negatives

Oracle Database Firewall

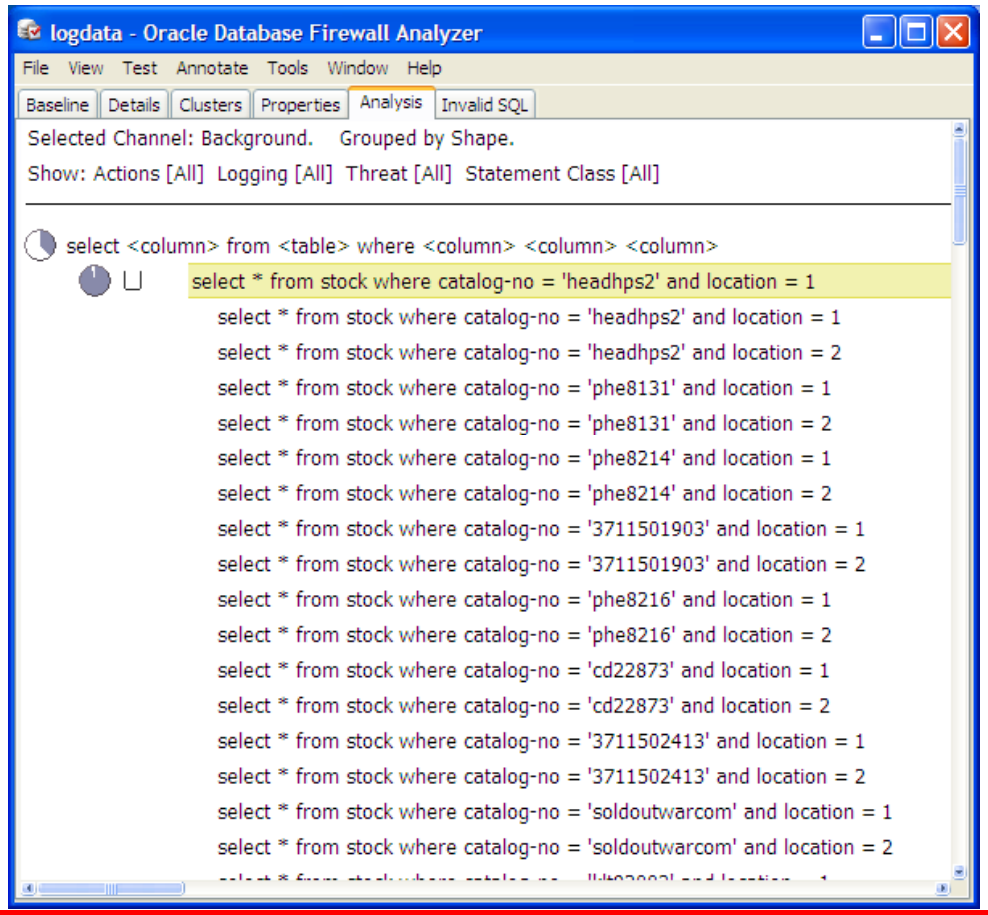
First Line of Defense



- Monitor and control database activity on the network
- Prevent
  - SQL injections
  - Unauthorized database access
  - Misuse of database privilege
- Capture and log database interactions for forensic analysis and compliance reporting

Grammar-based Clustering

- Thousands of individual statements transformed into manageable clusters
- Anomalous statements produce a new cluster and are instantly detected (e.g. blocked)



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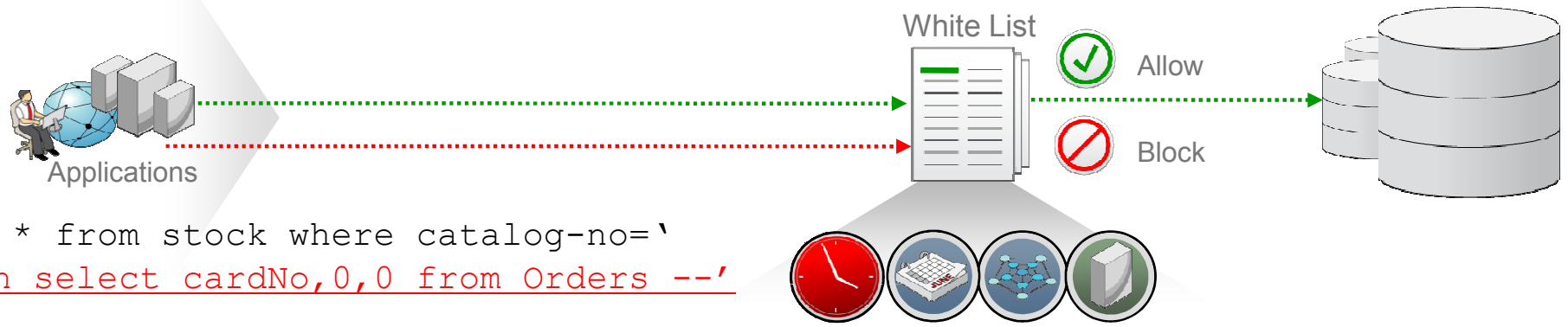
Positive Security Model

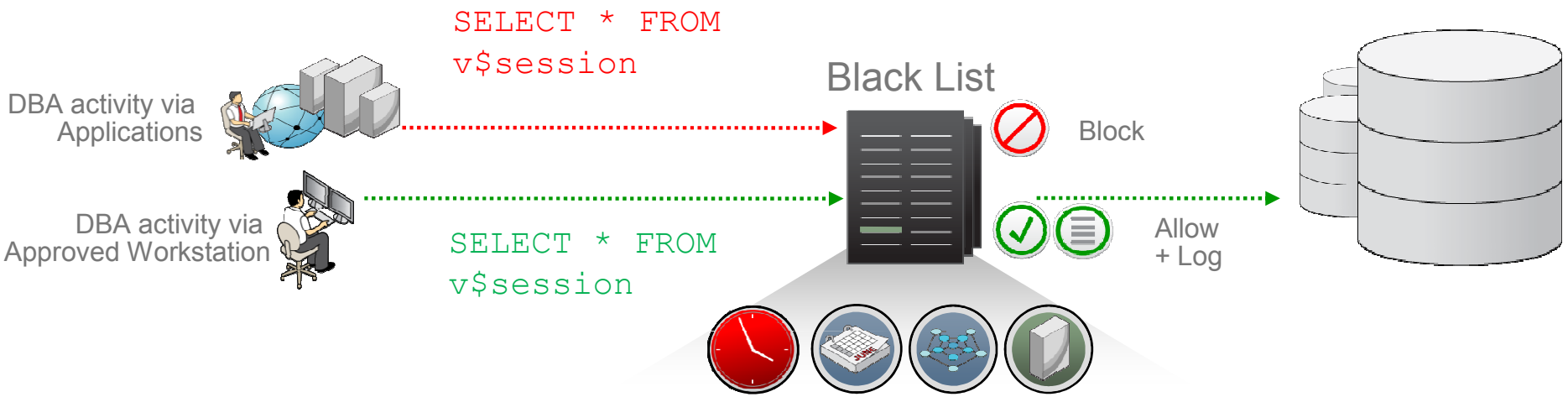
```
SELECT * from stock where catalog-no='PHE8131'
```




```
SELECT * from stock where catalog-no='
' union select cardNo,0,0 from Orders --'
```

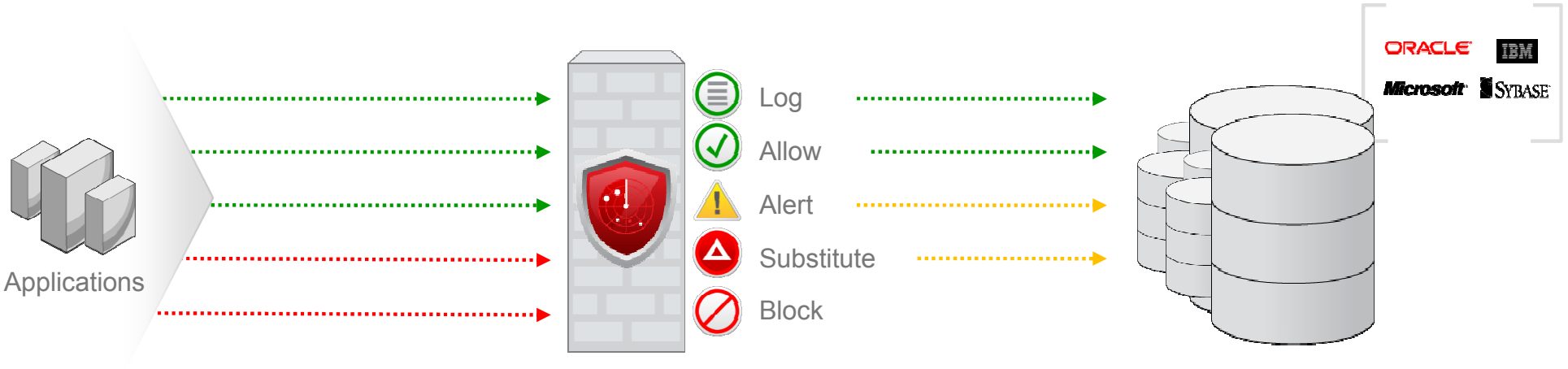
- "Allowed" behavior can be defined for any user or application
- Automated whitelist generation for any application
- Many factors to define policy (e.g. network, application, etc)
- Out-of-policy Database network interactions instantly blocked

Negative Security Model



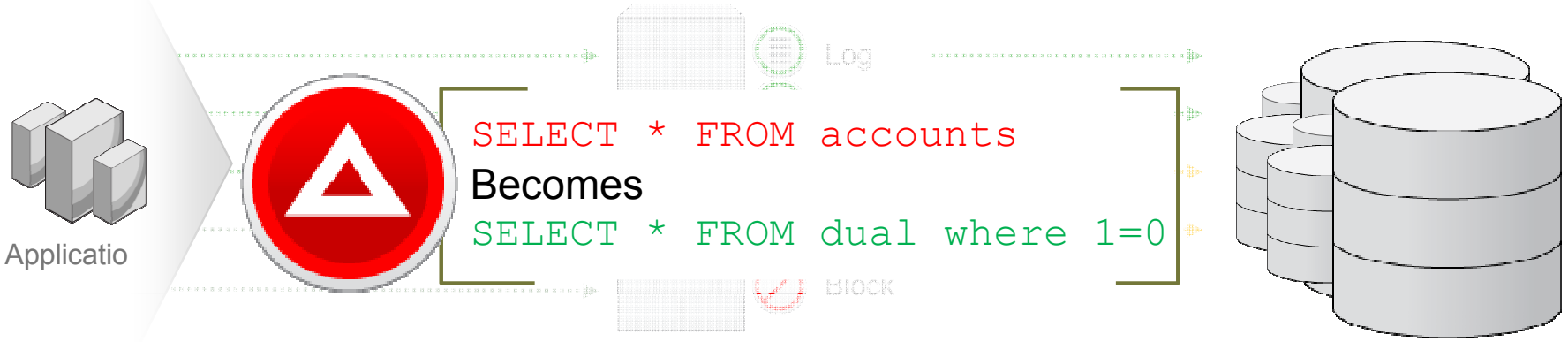
- Stop specific unwanted SQL interactions, user or schema access
- Ensures database interactions originate from appropriate sources
- Blacklist can take into account built-in factors such as time of day, day of week, network, application, etc
- Provide flexibility to authorized DBAs to do their job whilst monitoring usage

Policy Enforcement



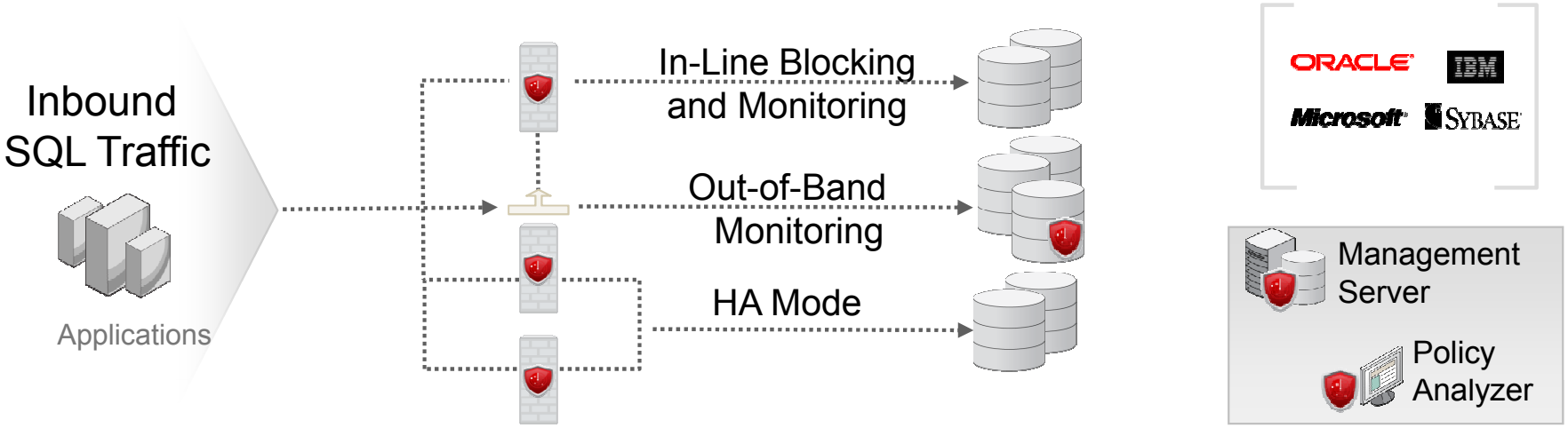
- Innovative SQL grammar technology reduces millions of SQL statements into a small number of SQL characteristics or “clusters”
- Superior performance and policy scalability
- Highly accurate without costly and time consuming false positives errors
- Flexible enforcement at SQL level: block, substitute, alert and pass, log only

Statement Substitution



- Application – Database connection pools cannot be disconnected
- Unique graceful blocking achieved by substituting out-of-policy statement with predefined benign statement
- Database guaranteed protected from inappropriate statement whilst the network session remains open

Deployment Architecture

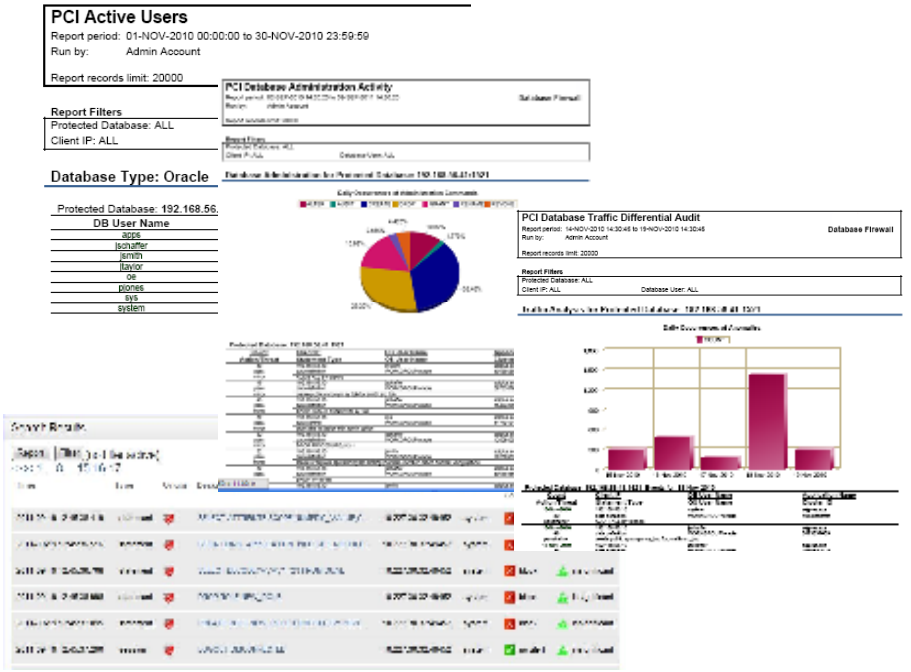


- Application and database vendor agnostic
- Deployment modes:
  - Inline, Out-of-Band, Optional Host Based Agents
  - Policy enforcement separated from policy management and reporting
  - High Availability
- Software solution based on hardened OE Linux and Intel for flexibility and scalability

Database Monitoring and Compliance Reporting

- Full Activity Report
- Database Administration
- Active Users
- Differential Audit
- Data Modification Detail

…etc



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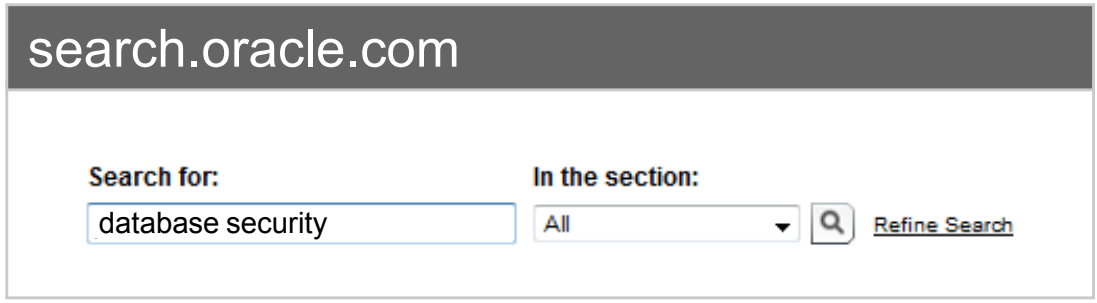
Oracle Database Firewall -- First Line of Defense

DEMONSTRATION

For More Information



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oracle.com/database/security
oracle.com/goto/database/firewall

Q&A

Hardware and Software

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Engineered to Work Together

