Adaptive Security in an Oracle Database

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Published by
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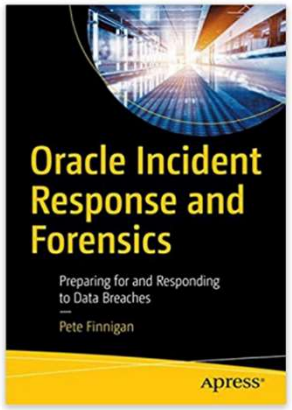

Pete Finnigan – Background, Who Am I?

- Oracle Security specialist and researcher
- CEO and founder of PeteFinnigan.com Limited in February 2003
- Writer of the longest running Oracle security blog
- Author of the Oracle Security step-by-step guide and “Oracle Expert Practices”, “Oracle Incident Response and Forensics” books
- Oracle ACE for security
- Member of the OakTable
- Speaker at various conferences
  - UKOUG, PSOUG, BlackHat, more..
- Published many times, see
  - http://www.petefinnigan.com for links
- Influenced industry standards
  - And governments

Agenda

- A bit of history
- Designing Audit Trails
- We use a toolkit
- Simple Policy based audit
- Adaptive Audit
- Adaptive Security

A bit of History

History of the Audit Events, Toolkit and Talks

- In 2009 piece of work to help design audit trails
  - Site had limited staff, little time to design, deploy, maintain any audit trails
  - I came up with some simple ideas, proof of concepts – to package up audit trails for them; inc policy based audit, IPS and simple firewall
  - They spent limited time to deploy a useful audit trail
- Similar piece of work in 2011 where limited team needed to deploy audit
- 2012 to 2015 extended the toolkit
- I wrote a presentation back in 2012 and presented it just once at a SIG on practical audit trails where I mentioned this toolkit for the first time
- This then became the basis of a one day class on the same subject
- Reworked that presentation in UKOUG 2015 conference
- Customer in 2016 needed an audit trail to deploy quickly
- Deployed now to customers in UK, Ireland and Germany
- **The ideas of audit design came from these pieces of work and talks**

Adaptive

- We must have audit to create adaptive audit
- We must have security to create adaptive security
- We most likely need audit to create adaptive security
- Audit is the key element

Designing Audit Trails

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Some People Think They Have Designed Audit

- I see sites with some audit settings
- This is not a WELL DESIGNED audit trail
- Usually these random set of parameters in the Oracle database will not catch a good range of events that could be an attack
- Some sites have application audit and OS audit
- BUT worse; lots of sites have no audit at the database engine level
- If there is a breach a lack of audit makes forensic response very difficult

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Design

- Before we get started implementing audit trails
- **Design** must be the first step
- The final chosen solution implements the design
- Therefore until you know the design you cannot specify the right solution – **right?**
- The solution could be “free” or “commercial” solution or even a combination of both – **we use our toolkit**
- Often people buy third party products and implement out of the box with no internal requirements!

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Create audit events based on "**I Want to know?**"

Create Audit Events

ID	Description	Category	Type	Report	Report Time
AE.1.0	Every connection to the database whether successful or not	ENGINE	COLLECT	NO	NONE
AE.1.1	Detect individuals sharing database one account	ENGINE	NORMAL	YES	SLOW
AE.1.2	Detect individuals who have access to multiple database accounts	ENGINE	NORMAL	YES	REGULAR
AE.1.3	Detect all failed logins	ENGINE	COLLECT	NO	NONE
AE.1.4	Detect a frequency of failed logins where the frequency is low (For example more than 3 per minute are detected)	ENGINE	NORMAL	YES	QUICK
AE.1.5	Detect a frequency of failed logins where the frequency is high (For example more than 50 per minute are detected). 1017, 28002 etc errors	SECURITY	ALERT	YES	IMMEDIATE
AE.1.6	Detect developer access (**note: This will be allowed in development databases**)	ENGINE	NORMAL	YES	REGULAR
AE.1.7	Capture access to dormant accounts (3 months dormant)	ENGINE	NORMAL	YES	REGULAR
AE.2.0	Capture all DDL activity in the database	ENGINE	COLLECT	NO	NONE
AE.2.1	Capture structural changes (for instance tablespaces, data files)	ENGINE	NORMAL	YES	REGULAR
AE.2.2	Detect any user changes (legitimate)	SECURITY	COLLECT	NO	NONE
AE.2.3	Detect any user changes (not legitimate)	SECURITY	ALERT	YES	IMMEDIATE
AE.2.4	Detect profile changes	SECURITY	NORMAL	YES	QUICK
AE.2.5	Detect any GRANTS for roles, system privileges or objects (not legitimate)	SECURITY	ALERT	YES	IMMEDIATE

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Build On The Audit Events

- Work backwards from the events to decide what raw audit to collect
- Then how to work out if event has occurred
- Then how to report
- Then how to alert
- Then how to escalate
- When you have this “table” decide on the technical solution that can be implemented and deployed

Audit Trail Toolkit

The Goal of the Toolkit

- As simple as `SQL> @atk` and a sophisticated audit trail is up and running
- Making it simple for organisations to deploy audit trails simply, with no resources
- No design, implement, test etc as we have done it for you already
- Used in ATC mode – space also is managed in each target database audited
- Simple to configure or not configured at all
- A complete solution to know what is happening at the database engine level for sites with limited resources

PFCLATK – “A”udit “T”rail tool”K”it

- Toolkit to aid audit trail deployment easily
- Simple pre-configure
- Policy based
- Alert based
- Multiple audit trails sources
- Add in factors (input hints)
- Separated schema design
- Manual 27 pages currently
- Version 2.4.0.0 currently
- Layered audit

Can be deployed to multiple databases and a central database

Elements of Design - Core

- The core features of our audit design are
  - Policies and events (There are 20 policies and 17 events)
  - Polled jobs and reports as checks (There are 7 job intervals)
  - Core PL/SQL API Package
  - Rules/policy/jobs/payload meta data
  - Audit trails specific to PFCLATK
  - System Triggers
  - DDL triggers
  - DML triggers
  - PL/SQL based
- Checks can be made via polled jobs to test if the audit is valid
- Raw data is collected, filters are jobs polled via DBMS_SCHEDULER; results added to alerts and alerts generates escalation

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Factors

Some factors are re-defined, some should be edited and more can be added easily

Factors allow the toolkit to be customised for a specific site

```
100    -- -----------------------------------------------------------------
101    atk.pfclatk.addfactor('SUPPORT-IP','192.168.56.1');
102    -- -----------------------------------------------------------------
103    -- LOW-FAILED: Define the number of failed logins per minute above
104    --             which an alert should be raised. This should be specified
105    --             per 30 minutes. So a number of 3 per minute would be set
106    --             to 90 for the 30 minute period.
107    -- -----------------------------------------------------------------
108    atk.pfclatk.addfactor('LOW-FAILED','60');
109    -- -----------------------------------------------------------------
110    -- HIGH-FAILED: Define the number of failed logins above which an alert
111    --             would be raised. This should be specified per 30 minutes
112    --             So for a number of 50 per minute that would be 30*50 =
       --             1500. This could indicate a scripted attack.
       -- -----------------------------------------------------------------
       atk.pfclatk.addfactor('HIGH-FAILED','1500');
       -- -----------------------------------------------------------------
       -- DEV-IP: Define the IP adress of all of your developers terminals
       --         here.
       --
       -- NOTE: For multiple developers add multiple entries here.
       -- -----------------------------------------------------------------
       atk.pfclatk.addfactor('DEV-IP','192.168.56.1');
       -- -----------------------------------------------------------------
       -- DBA-USER: Define the DBA user accounts allowed to be used as DBA.
       --           This could be SYS and SYSTEM but should really be seperate
       --           user accounts for each DBA
       --
       -- NOTE: For multiple DBA add multiple entries here.
       -- -----------------------------------------------------------------
       atk.pfclatk.addfactor('DBA-USER','SYS');
       atk.pfclatk.addfactor('DBA-USER','SYSTEM');
132    -- -----------------------------------------------------------------
133    -- ERROR-RATE: This is the trigger rate for the number of errors that
134    --             can occur for a single user/IP that could indicate an
135    --             attack.
136    -- -----------------------------------------------------------------
137    atk.pfclatk.addfactor('ERROR-LIMIT','8');
138    --
139    end;
140    /
```

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Audit Policies

```
begin
  -- create the policy
  atk.pfclatk.createpolicy('PROFILEPRIVILEGE');

  -- audit profiles
  atk.pfclatk.createandaddrule('PROFILEPRIVILEGE','Create Profile','CORE-S','create profile');
  atk.pfclatk.createandaddrule('PROFILEPRIVILEGE','Drop Profile','CORE-S','drop profile');
  atk.pfclatk.createandaddrule('PROFILEPRIVILEGE','Alter Profile','CORE-S','alter profile');
  atk.pfclatk.createandaddrule('PROFILEPRIVILEGE','Profile','CORE-S','profile');

  -- ----------------------------------------------------------------
  -- Add filter job to detect non-ligitimate profile changes - i.e. use
  -- of PROFILE system privileges; not use of statement PROFILE and not use
  -- of a DBA IP address and not use of a DBA account; so if a DBA
  -- uses a non DBA account from his own IP it should be detected
  -- ----------------------------------------------------------------

  atk.pfclatk.addfilter('NON-AUTH-PROFILE-CHANGE','PROFILEPRIVILEGE','HALFHOUR',
      '[Alert] Non-legitimate profile privilege change',
      'select ''A non-authorised user change {''||a.action_name||''} on {''||a.obj_name||''} by

  -- enable the policy
  atk.pfclatk.enablepolicy('PROFILEPRIVILEGE');
end;
/
```

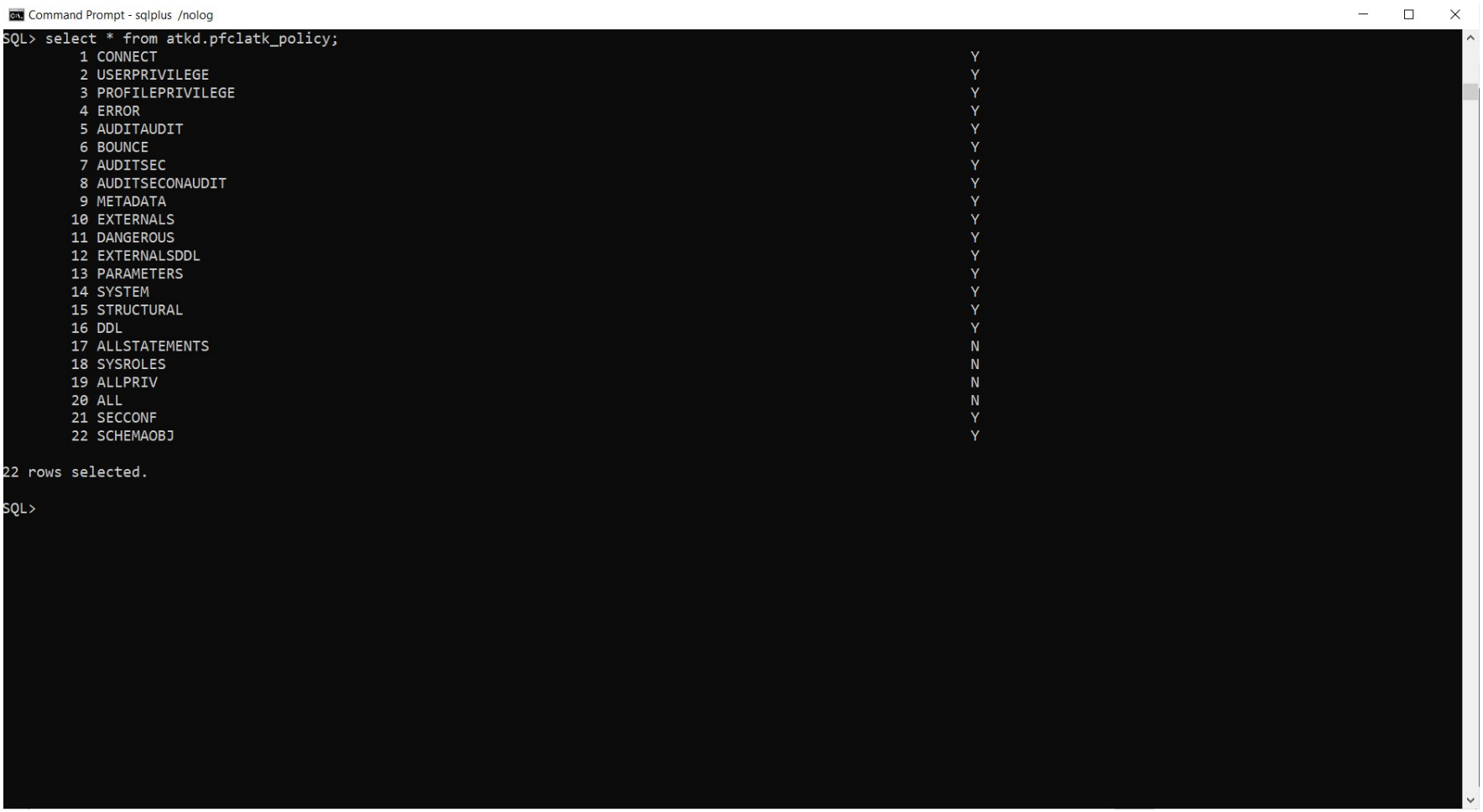
- Policies declare collection of raw data and also events
- PFCLATK policies are different to Unified audit – we filter on collected data after storage to look for abuse; Unified audit filters before storage
- Core audit, DML, System triggers

Audit of Audit

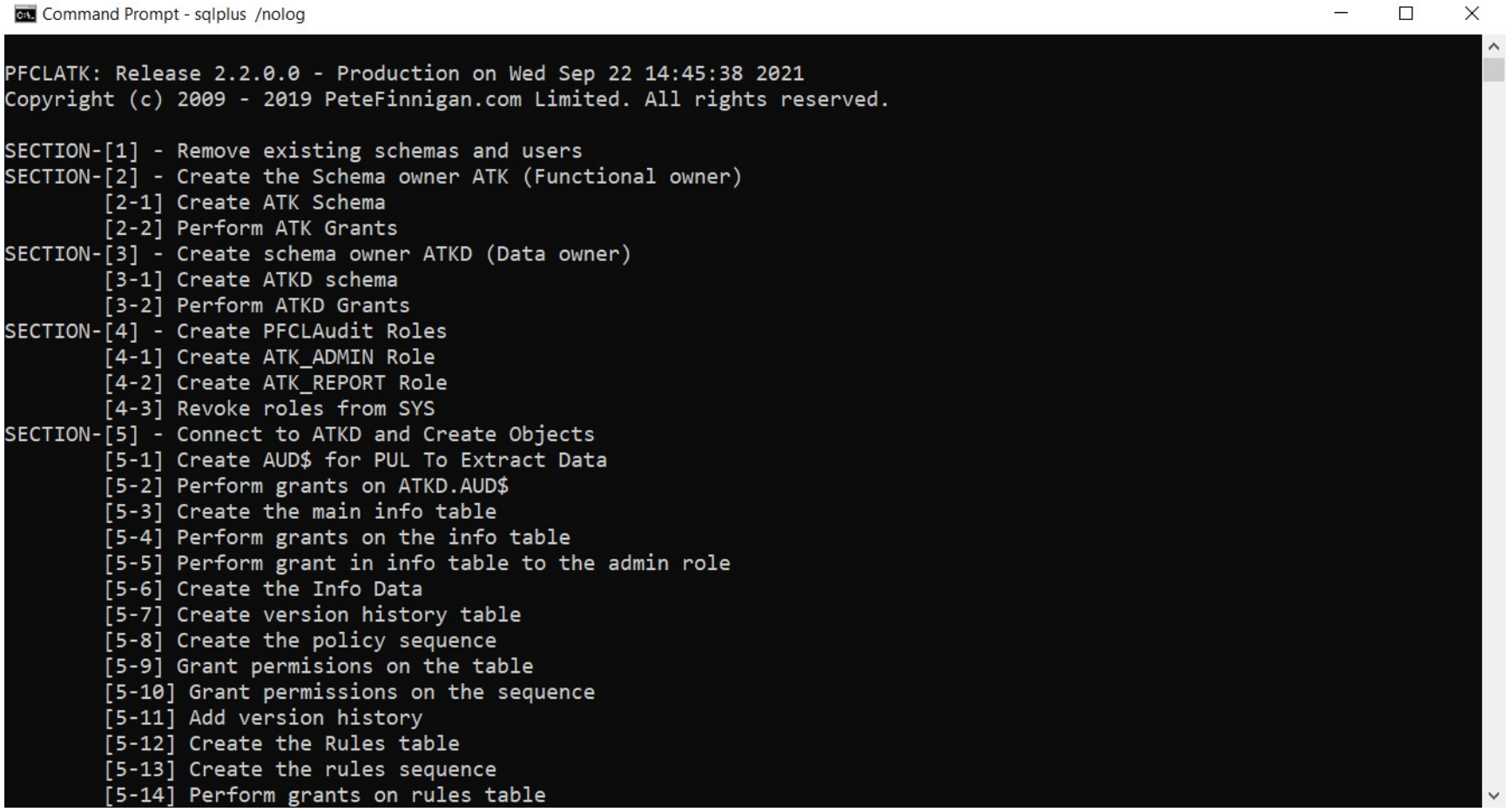
- A multi-layer approach is needed
  - Audit of core trail tables such as AUD$
  - Audit of core audit settings such as AUDIT$
  - Audit of triggers (Event, DDL and DML)
  - Audit of custom logs
  - Audit of audit functionality, packages and other objects
  - All can be set up as policies in PFCLATK

Simple Policy Based Audit Trails

Policies I Will Implement



Install the Audit Events and Toolkit



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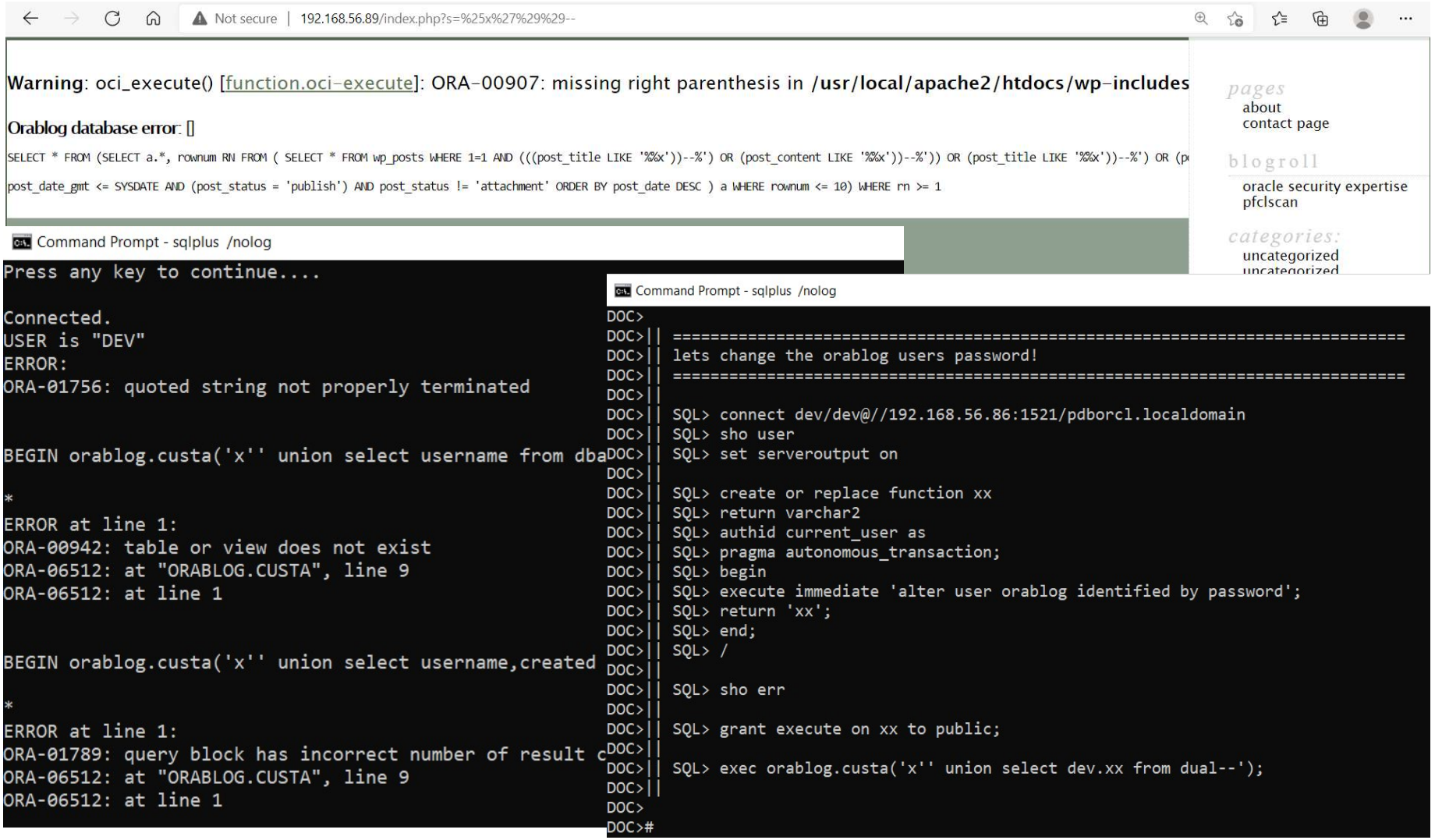
Some Audit Results From Hacks



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Audit Trail Report

- We catch the NOAUDIT
- We catch the password changes
- We catch all errors, 942, 1789, 907, 911 etc
- We catch the creation of the hack procedure
- **All events are not caught 100% but the attack was not based on the audit design!!**

Command Prompt - sqlplus /nolog

```
                                                                                                                        RE

DD-BE   22-SEP-21 03.10.52.713992 PM +01:00 DEV        grant execute on xx                        DEV        WORKGROUP\DESKTOP-R  Pete        163002 192.168.56.1
AUDIT   22-SEP-21 03.10.52.716622 PM +01:00 DEV        DEV.XX              GRANT OBJECT                      WORKGROUP\DESKTOP-R7 Pete        163002
AUDIT   22-SEP-21 03.10.52.728008 PM +01:00 DEV        ORABLOG.CUSTA       EXECUTE PROCEDURE                 WORKGROUP\DESKTOP-R7 Pete        163002
AUDIT   22-SEP-21 03.10.52.729926 PM +01:00 DEV        ORABLOG.CREDIT_CARD SESSION REC                       WORKGROUP\DESKTOP-R7 Pete        163002
NO-BE   22-SEP-21 03.10.52.732449 PM +01:00 DEV        noaudit select on o                        DEV        WORKGROUP\DESKTOP-R  Pete        163002 192.168.56.1
DD-BE   22-SEP-21 03.10.52.733946 PM +01:00 DEV        noaudit select on o                        DEV        WORKGROUP\DESKTOP-R  Pete        163002 192.168.56.1
AUDIT   22-SEP-21 03.10.52.736187 PM +01:00 DEV        ORABLOG.CREDIT_CARD NOAUDIT OBJECT                    WORKGROUP\DESKTOP-R7 Pete        163002
LOGOF   22-SEP-21 03.10.54.609230 PM +01:00 DEV                                                   DEV        WORKGROUP\DESKTOP-R  Pete        163002 192.168.56.1
AUDIT   22-SEP-21 03.10.54.612925 PM +01:00 DEV        .                   LOGOFF                            WORKGROUP\DESKTOP-R7 Pete        163002
LOGON   22-SEP-21 03.10.54.661608 PM +01:00 SYS                                                   SYS        WORKGROUP\DESKTOP-R  Pete    4294967295 192.168.56.1
LOGOF   22-SEP-21 03.11.00.140215 PM +01:00 SYS                                                   SYS        WORKGROUP\DESKTOP-R  Pete    4294967295 192.168.56.1
AUDIT   22-SEP-21 03.11.00.196948 PM +01:00 DEV        .                   LOGON                             WORKGROUP\DESKTOP-R7 Pete        163003 Authenticated b CREATE S
ESSION

                                                                                                                                                 y: DATABASE; Cl
                                                                                                                                                 ient address: (
                                                                                                                                                 ADDRESS=(PROTOC
                                                                                                                                                 OL=tcp)(HOST=19
                                                                                                                                                 2.168.56.1)(POR
                                                                                                                                                 T=1043))

LOGON   22-SEP-21 03.11.00.198875 PM +01:00 DEV                                                   DEV        WORKGROUP\DESKTOP-R  Pete        163003 192.168.56.1
AUDIT   22-SEP-21 03.11.00.200549 PM +01:00 DEV        SYS.DBMS_DEBUG_JDWP EXECUTE PROCEDURE                 WORKGROUP\DESKTOP-R7 Pete        163003
AUDIT   22-SEP-21 03.11.00.201956 PM +01:00 DEV        SYS.AUD$            SELECT                            WORKGROUP\DESKTOP-R7 Pete        163003
DD-BE   22-SEP-21 03.11.00.213281 PM +01:00 DEV        create or replace f                        DEV        WORKGROUP\DESKTOP-R  Pete        163003 192.168.56.1
AUDIT   22-SEP-21 03.11.00.222751 PM +01:00 DEV        DEV.XX              CREATE FUNCTION                   WORKGROUP\DESKTOP-R7 Pete        163003                CREATE P
ROCEDU

                                                                                                                                                                RE

DD-BE   22-SEP-21 03.11.00.241730 PM +01:00 DEV        grant execute on xx                        DEV        WORKGROUP\DESKTOP-R  Pete        163003 192.168.56.1
AUDIT   22-SEP-21 03.11.00.242732 PM +01:00 DEV        SYS.DBMS_DEBUG_JDWP EXECUTE PROCEDURE                 WORKGROUP\DESKTOP-R7 Pete        163003
AUDIT   22-SEP-21 03.11.00.245078 PM +01:00 DEV        DEV.XX              GRANT OBJECT                      WORKGROUP\DESKTOP-R7 Pete        163003
AUDIT   22-SEP-21 03.11.00.255571 PM +01:00 DEV        ORABLOG.CUSTA       EXECUTE PROCEDURE                 WORKGROUP\DESKTOP-R7 Pete        163003
DD-BE   22-SEP-21 03.11.00.260781 PM +01:00 DEV        alter user orablog                         DEV        WORKGROUP\DESKTOP-R  Pete        163003 192.168.56.1
AUDIT   22-SEP-21 03.11.00.264281 PM +01:00 DEV        .ORABLOG            ALTER USER                        WORKGROUP\DESKTOP-R7 Pete        163003
LOGOF   22-SEP-21 03.11.02.915059 PM +01:00 DEV                                                   DEV        WORKGROUP\DESKTOP-R  Pete        163003 192.168.56.1
AUDIT   22-SEP-21 03.11.02.918414 PM +01:00 DEV        .                   LOGOFF                            WORKGROUP\DESKTOP-R7 Pete        163003
LOGON   22-SEP-21 03.11.02.969985 PM +01:00 SYS                                                   SYS        WORKGROUP\DESKTOP-R  Pete    4294967295 192.168.56.1
AU-BE   22-SEP-21 03.11.02.986466 PM +01:00 SYS        audit select on ora                        SYS        WORKGROUP\DESKTOP-R  Pete    4294967295 192.168.56.1
DD-BE   22-SEP-21 03.11.02.988030 PM +01:00 SYS        audit select on ora                        SYS        WORKGROUP\DESKTOP-R  Pete    4294967295 192.168.56.1
DD-BE   22-SEP-21 03.11.02.995716 PM +01:00 SYS        alter user orablog                         SYS        WORKGROUP\DESKTOP-R  Pete    4294967295 192.168.56.1
LOGON   22-SEP-21 03.11.14.072448 PM +01:00 SYS                                                   SYS        oel1124.localdomain  oracle      163004
```

Adaptive Audit

Adaptive Audit

- **Change the audit trail based on security at the time**
- Based on a real attack happening – in progress – or a perceived attack happening the audit capture can be increased
- This, as with adaptive security would be reduced after the perceived attack
- Adaptive Audit is useful because in normal circumstances we would not want to collect excessive audit trails but during an attack we may do so.
- For example if the application schema has limited audit normally we increase to audit all access during an attack
- These ideas need to be designed carefully to ensure that the audit does not become a ”Denial Of Service”
- Example
  - A schema changes its password from the web server; so audit all actions in the session or audit all actions in the schema by all users

What is Conditional Audit?

- Audit would be more powerful if conditionally applied
  - Oracles Fine Grained Audit (FGA) attests to this
  - Oracles Unified Audit from 12c also attests to this but still is underpinned by core audit facilities
- Trigger based security can use some element of conditionality
  - When clause can be used to limit the trigger body to certain conditions such as time based, user based privilege based and SYS_CONTEXT() based and more
  - OF clause can limit a trigger to certain columns BUT has little value in conditional audit other than protection – see integrity
  - A trigger body is PL/SQL so any conditional audit can be programmed in
- Secure contexts can be used to control granularity in triggers, audit functions and more across the database – set up at logon
- Conditional security in core audit is not feasible BUT
  - We can process the records records after collection via reports/jobs
  - This is in essence what unified audit is doing

Adaptive Security

No one is doing this BUT WE COULD

The ultimate – one database is being attacked and it "tells" all others to change audit and security

Adaptive Security

- Adaptive security is not part of audit trail design but adaptive security could be controlled by audit results and reports
- Create multiple levels of security i.e. defcon5, 4, 3, 2,1
- Adaptive security is where
  - Security is changed dynamically based on a real attack happening or perceived real attack happening
  - Normally this would be to tighten security to defend the database because of the current attack
  - After an attack the reverse could normally occur to remove the additional restrictions
- Examples
  - Detect change of a password and lock the user whose password was changed
  - Detect change of audit by a schema (user) and kill the user doing it
  - These can be implemented in triggers as VP/IPS or specific payloads as jobs

Conclusions

- Secure the data in your database
- Include an audit trail
- When you are secure
  - Think about adaptive audit
  - Think about adaptive security

Questions

?

Adaptive Security in an Oracle Database