Active Directory Security Best Practices

“Top 11 Security Mistakes in Active Directory and How to Avoid Them”
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Agenda

- Who We Are
- Intro
- Top 11 Security Mistakes in Active Directory and How to Avoid Them
Who We Are

- Friedwart Kuhn
  - Head of Microsoft Security Team @ERNW
  - 15+ years experience in security assessments, administration, publications and trainings
  - IT security professional with a focus on Windows Security and Active Directory Security

- Heinrich Wiederkehr
  - Member of Microsoft Security Team @ERNW
  - 5+ years in security assessments and trainings
  - IT security professional with a focus on Windows Security and Active Directory Security
Active Directory Assessment Tool

- Creates security transparency in complex ADs
- Identifies technical & organizational issues
- Mitigation recommendations based on a decade of experience in enterprise environments

- Learn more: https://www.ernw-sectools.de/products/
TROOPERS AD Security Track

- Brought together world’s most prolific AD security experts
- Unique opportunity to learn and exchange

See also
- https://insinuator.net/2019/04/troopers-chill/
- https://insinuator.net/2019/03/the-mmm-in-community/
Intro

- As main authentication backend Active Directory (AD) holds the keys to the crown jewels in nearly every organization.

- AD is heavily targeted by attackers that are using powerful, publicly available tool sets.

- Defense of AD environments often overlooks some typical design, implementation, configuration and operational mistakes.

- We focus on eleven typical ‘mistake areas’ and we describe how to avoid or fix them.
Mistake No. 1: Lack of AD Governance
The Problem: Lack of AD Governance

- Large enterprise ADs are
  - Historically grown
  - Distributed over different regions, companies, cultures
  - Built up and administered in different ways

- This is generally even true for a big AD of one company in one region...

- Enterprises claim to have IT governance, but they usually do not have AD governance
The Solution: Dedicated AD Governance

- Tasks of the AD Governance Board
  - Govern high-level security & design controls
  - Have an idea of an overall Target AD Design
  - Provide organizational and technical guidance such as:
    - How to implement Admin Tiers
    - How to implement PAWs
    - Hardening Guidelines for DCs, Servers, Clients, non-Windows members
    - Etc.

- Members of the Governance Board: at least experienced AD architects, AD security specialists and AD administrators/operators. The CISO should be a member too.
Mistake No. 2: Admins (and Service Accounts) Logging on Everywhere
The Problem: Admins Logging on Everywhere...
1. Bad guy targets workstations en masse
2. User running as local admin compromised, bad guy harvests credentials.
3. Bad guy starts “credentials crabwalk”
4. Bad guy finds host with domain privileged credentials, steals, and elevates privileges
5. Bad guy owns network, can harvest what he wants.

Result of Mistake 2...

Access: Users and Workstations

Power: Domain Controllers

Data: Servers and Applications

This slide is from: Mark Simos, Nicholas DiCola; “TWC: Pass-the-Hash and Credential Theft Mitigation Architectures”
The Solution: Implement Administrative Tiers

**Tier 0**
- Domain Controllers, Domain Admin
- Workstations, Special Tier 0 Systems (Patch, AV, Mgmt)
- Enterprise & Domain Admins
- BUILTIN\Administrators
- General: Tier 0 Admins

**Tier 1**
- Application Servers
- Server/App Admin
- Workstations, Tier 1 Mgmt Systems
- Server Admins, Server Services
- Application Admins
- General: Tier 1 Admins

**Tier 2**
- Internet Connected Workstations of Standard Users
- Workstation Admins (Tier 2 Admins)

**Tier 3**
- Standard Users
**Tier Model Principles**

**Classify:** *Every single* security principal, system, or application **has to be classified as belonging only to one tier**

**Restrict Logons:** Security principals of a higher tier **must never log on to** a resource on a lower tier (→ Implement logon restrictions)

**Restrict Control:** Security principals of a lower tier **must never control resources of a higher tier** (→ Implement control restrictions)
Control Restrictions vs. Logon Restrictions
Implementation Guidelines

- Begin with Tier 0
  - Followed by Tier 1 and then Tier 2
- Use compartments in Tier 1
- Do not let service accounts undermine the Administrative Tier model
- Provide admins with detailed technical guidelines (about the consequences of logon & control restrictions)
- Expect a long-term project...
Summary

- The most important and comprehensive Active Directory-specific security control with respect to credential theft & reuse
- Basis for many other technical controls
- Future (Windows) administration model
- Requires modification in admin mindset
- Admins will have more accounts and hence higher operational effort

Alternatives
- None
Mistake No. 3: Using “Dirty Sources”
The Problem: Security Dependencies

- Security dependencies are not always as trustworthy as the object being secured. For example:

  - Infect Media
  - Compromise Vector
  - Installation Media
  - OS or Application Install
  - Administration Task
  - Compromise Vector
  - User Workstation
  - Compromise Vector
  - User Workstation

- OS or Application Install
- Compromise Vector
- Administration Task
- Compromise Vector
The Solution: Clean Source Principle

- Any subject in control of an object is a security dependency of that object
  - The assurances for all security dependencies must be at or above the desired security level of the object itself
  - **Control is transitive!** (For example if A controls B and B controls C, then A also indirectly controls C.)

- Most common areas of control are:
  - the hardware where systems are installed,
  - the installation media for the systems,
  - the architecture and configuration of the system,
  - and daily operations.
Clean Source Principle: Administration

- Provide a dedicated secure administration environment for sensitive tasks that is protected from Internet attacks and sophisticated threat vectors
  - On an operating system level: Implement Privileged Access Workstations (PAW)
  - On an Active Directory level: Implement Enhanced Security Administration Environment (ESAE) and/or PRIV Forest(s)
Clean Source Principle: PAWs

- PAW hardware profiles can be:
  - **Dedicated hardware**
    - Separate dedicated devices for user tasks vs. administrative tasks
  - **Simultaneous use**
    - Single device that can run user tasks and administrative tasks concurrently by taking advantage of OS or presentation virtualization. For example:
      - Adding a local user VM
      - Adding RemoteApp, RDP, or a VDI
Clean Source Principle:
ESAE/PRIV Forest

- Dedicated administrative forest
  - Hosts administrative accounts, workstations, groups
  - Environment has stronger security controls than the production environment

- ESAE forest moves all sensitive objects for Tier 0 administration to a separate forest
  - Except the krbtgt account and most likely service accounts
  - Balance between security benefit and operational effort unfavourable in a 1:1 relationship
    - Much better if one ESAE forest is used for multiple productive forests

- PRIV forest moves administrative identities for Tier 1 & 2 administration to a separate forest and combines this with a PAM solution (e.g. MIM 2016)
Exemplary Secure Administration Environment Models

- **Prerequisite:** Admin Tiering must be implemented

- **Option 1:**
  - Tier 0 managed exclusively via PAWs

- **Option 2:**
  - Tier 0 managed by a Local ESAE Forest (utilizing PAWs)

- **Option 3:**
  - Tier 0 managed by a Global ESAE Forest (utilizing PAWs; used for management of multiple forests)

- **Optional:** Combining the administration model with a PRIV Forest
Mistake No. 4: (AD) Borders Not Under Control
The Problem: AD Borders Neither Well-defined Nor Controlled: Trusts

- Trusts are established without a (security) assessment of the trusted party
- Often too many trusts
- Trusts are “too open”
- Established trusts persist over many years
- Configuration errors: Privileged accounts of the trusted forest have a privileged group membership in the trusting forest
- Trusts can be mapped with Directory Ranger
  - https://insinuator.net/2018/12/directoryranger-1-1-0-introduces-informational-audit-checks/
Too many trusts...
Example: Pass-the-Credential via AD Trust Relationship

**Power:**
- Domain Controllers

**Data:**
- Servers and Applications

**Access:**
- Users and Workstations

**Trusted Domain**

**Trusting Domain**

**External Trust:**
- Unidirectional SID filtering disabled
The Solution: AD Border & Trust Management

- Be reluctant to and sparse with AD Trusts
- Perform a security assessment of the trusted AD **before** establishing the Trust...
  - ...and know your own vulnerabilities ;-)
- Configure Trusts preferably:
  - Uni-directional
  - With Selective Authentication
- Ensure that high privileged accounts span only their home AD Domain
- Review Trusts at least every six months
- Create a Trust Policy with that content ;-)
Mistake No. 5: Best Practices Lost in Time
The Problem: Basics Are Overlooked

- Many AD security best practices exist for many years, but seem to be forgotten
  - Affects technical as well as operational controls

- Most often seen in assessments:
  - Missing or outdated documentation
  - Insufficient network separation
  - Misconfiguration of the AdminSDHolder object
  - Orphaned AD objects
  - Delegation of permission underrepresented
The Solution: Do the Basics

- **Complete Documentation**
  - Alignment with real configuration
  - Ensures protection and accurate view on the current state of the environment
  - Allows new personnel to become familiar with the environment in case of personnel shortages (e.g. illness)

- **Network Isolation**
  - Network infrastructure (physical) should reflect AD infrastructure (logical)
    - Avoid flat network structures
  - Network boundaries can be Forests or Administrative Tiers
AdminSDHolder Object

- Container object in the domain directory partition
- Security descriptor of this object is used as a template for all protected groups and users (e.g. Domain Admins)
  - If descriptors differ they are overwritten with those of the AdminSDHolder object
- The descriptor on this object should only be changed if absolutely necessary
  - Otherwise a new vector for a complete AD compromise is added
The Solution: Do the Basics

○ AD Clean-up Process
  ○ Implement a process that takes care of:
    ○ Orphaned user accounts (from personnel which left the company)
    ○ Orphaned computer objects (from decommissioned systems)
    ○ Obsolescent group memberships

○ AD Delegated Permissions
  ○ Allows delegating permissions without adding users to privileged groups
  ○ Grants users or groups only the permissions they need
  ○ Available via the Microsoft Management Console (MMC)
Mistake No. 6: Too Many and Too Privileged Service Accounts
The Problem: Overabundance of Service Accounts

- Not all service accounts are "real" service accounts
  - Sometimes misused as personal accounts

- Most of the time passwords never expire
  - Often in combination with weak passwords

- Service accounts often over-privileged
  - Typical example: service accounts member of Domain Admins group

⚠️ Usually one of the first targets of an attacker
The Solution: Service Account House Keeping

- Regularly check service accounts for validity
  - Remove all unneeded and pseudo service accounts

- Remove the “Password never expires” flag on as many service accounts as possible

- Make more service accounts (Group) Managed Service Accounts

- Remove unnecessary privileges from service accounts
  - Utilize Active Directory Delegated Permissions
  - Utilize Temporary Group Membership feature of Server 2016
Mistake No. 7: Too Many Admins
The Problem: Over-privileged Accounts

- Users often receive admin rights too easily
  - Locally, as well as in AD
  - Combined with missing role separation

- Service accounts also affected (see mistake no. 6)

- Active Directory Delegated Permissions rarely used
  - Instead focus on built-in groups
  - Prevents granular modification of rights

- Existing privileges not regularly checked

- Some numbers from various assessments:
  - Example Domain I:
    - Enabled Users: 270
    - High-Priv Users: 49
    - Ratio: 18.15%

  - Example Domain II:
    - Enabled Users: 1223
    - High-Priv Users: 150
    - Ratio: 12.26%
The Solution: Remove Privileges

- Make more users standard users
  - Grant permissions as granularly as possible, so you do not end up with hundreds of Domain Admins ;)
  - (Regularly) validate necessity for admin privileges
  - Local administrative privileges should only be granted in exceptional cases, as they are harder to manage

- Fix busted applications
  - Legacy software often falsely requires admin privileges
  - Can often be easily fixed (e.g. with Microsoft Application Compatibility Toolkit)
Mistake No. 8: Using Bad Passwords
The Problem: Bad Policies & User Awareness

- Password policies in enterprises are often outdated
  - Do not reflect current threats and technological advances
- Often only user accounts in focus, but not service accounts (e.g. passwords never expire)
- Users often have a wrong idea of secure passwords
  - Hard to remember for humans but easy to guess for computers
- May seem obsolete in the age of Pass-the-Credential attacks
  - Still relevant for an attacker aiming for a privilege escalation
Example I

- If users can they will choose a password, which fulfils the bare minimum

- If they have to change their password too often they try to work around it
  - You most probably can guess the other passwords of this user ;)

Authentication Id : 0 ; 105200145 (00000000:06453a11)
Session : RemoteInteractive from 4
User Name : [Redacted]
Domain : [Redacted]
SID : [Redacted]
msv : [00000003] Primary
  * Username : [Redacted]
  * Domain : [Redacted]
  * NTLM : 620f8ec4fa8c78198eed1986b3c53b9c
  * SHA1 : 9542adc5ed3f0f0b5758a7f97d8963e05354990
  wdigest : 
    * Username : [Redacted]
    * Domain : [Redacted]
    * Password : October

Really?
Example II

- Might seem to be a better password at a first glance
- But:
  - Hard to remember
  - Only 8 characters
  - NTLM hash can be cracked in a few minutes with rainbow tables

Authentication Id : 0 ; 219681182 (00000000:0d18119e)
Session : RemoteInteractive from 20
User Name : [Redacted]
Domain : [Redacted]
SID : [Redacted]
msv : [00000003] Primary
  * Username : [Redacted]
  * Domain : [Redacted]
  * NTLM : 3d8695acdd1747fa3f42e1fe4659a8f0
  * SHA1 : 50ab0e0504673f043e9b1fcdb7e0eb1af9cd0d5e

wdigest :
  * Username: [Redacted]
  * Domain : [Redacted]
  * Password : #Au20G08
The Solution: Update Password Policies

- Length > Complexity
  - Easier to remember
  - Can have a longer lifetime
  - Lockout thresholds can be higher

- All of this increases the acceptance and reduces operational overhead

- For standard users:
  - Use the Default Domain Policy

- For high-privileged & admin accounts:
  - Use Fine-Grained Password Policies

- For Service Accounts:
  - Use Fine-Grained Password Policies
  - Utilize (g)MSAs or implement a manual password reset mechanism

- For local (admin) accounts:
  - Utilize a management solution such as LAPS
  - Do not use GPPs!
### Recommended Password Requirements

<table>
<thead>
<tr>
<th>Type</th>
<th>Min Age</th>
<th>Max Age</th>
<th>Min Length</th>
<th>History</th>
<th>Complexity Requirements</th>
<th>Lockout Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Users</td>
<td>1 day</td>
<td>180 days</td>
<td>12 characters</td>
<td>5 passwords</td>
<td>Yes</td>
<td>15 logon attempts</td>
</tr>
<tr>
<td>Admin Accounts</td>
<td>1 day</td>
<td>90 days</td>
<td>18 characters</td>
<td>10 passwords</td>
<td>Yes</td>
<td>10 logon attempts</td>
</tr>
<tr>
<td>Service Accounts</td>
<td>1 day</td>
<td>180 days</td>
<td>32 characters</td>
<td>20 passwords</td>
<td>Yes</td>
<td>20 logon attempts</td>
</tr>
<tr>
<td>Local Admin Accounts</td>
<td>1 day</td>
<td>30 days</td>
<td>18 characters</td>
<td>20 passwords</td>
<td>Yes</td>
<td>20 logon attempts</td>
</tr>
<tr>
<td>KRBTGT</td>
<td>Regular password resetting procedure every three months</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Mistake No. 9: **Running Outdated Operating Systems**
The Problem: Outdated Operating Systems

- A no-brainer for an attacker - attacking EoL OS
  - (Security) patches no longer released by the vendor
  - Exploits are sometimes even publicly available

- Not a no-brainer, but a problem: outdated but still vendor-supported operating system versions
  - Legacy protocols
  - Insecure authentication mechanisms
  - Lack of modern, state-of-the-art security features
The Solution: Use Modern Operating System Versions

- **Upgrade** to new operating system versions,
- **Substitute** outdated systems,
- **Decommission** End-of-Life systems
  - If not possible: **Isolation for example in an EoL Forest**
    - Overall security level should **not** be lowered
    - Creation of a separated environment for outdated systems
    - See also:

- **Be aware of:** Installation of new operating systems not enough
  - New operating system security features must also be **actively used**
The Solution: Use Modern Operating System Features

- Modern OS provide a lot of credential theft/reuse specific technologies

- Windows 8.1 / Server 2012 R2-specific security features
  - Authentication Policies & Silos
  - LSA Protection
  - Restricted Admin Mode for RDP

- Windows 10 / Server 2016-specific security features
  - Measured Boot and Remote Attestation
  - Virtualization-based Security
    - Device Guard
    - Credential Guard
  - Microsoft Passport
Mistake No. 10: Vulnerable Systems and Applications Everywhere
The Problem: Insufficient Patch Management

- Both operating system and third-party components often not up-to-date
- Regular patches and out-of-band patches both affected
  - Especially critical for OOB patches
- Usually insufficient or even no patch management at all
The Solution: Patch and Vulnerability Management

- Implementation of a proper **patch and vulnerability** management process for maintaining the overall security of a system

- **Implement controlled patching** of operating system components **and** third-party software
  - Ensure an appropriate patching time frame

- **Define update procedures** for security-critical (OOB) out-of-band patches guarantee roll-out in a timely manner
The Solution: Patch and Vulnerability Management

- Operating system patches are released monthly
  - Easy planning
  - Should be rolled out within a week

- Application patches are released irregularly
  - A lot harder to plan for
  - Utilize security advisories and bulletins
  - Should be rolled out within three weeks

- OOB patches must be seen as emergency changes
  - Should be rolled out within 48 hours
Mistake No. 11: No Active Directory-Specific Security Logging & Monitoring
The Problem: No AD-Specific Security Logging & Monitoring

- AD-specific logging & monitoring is often restricted to AD service functionality (e.g. replication)
- Windows security monitoring often deferred to AV functionality (e.g. "AV will detect a compromise...")
- Even if configured, security logs are not analyzed or are only analyzed in case of emergency
- Credential theft & reuse are often very difficult to detect.
The Solution: AD-Specific Security Logging & Monitoring

- Do the basics
  1. Centralized logging & monitoring
  2. Define three Windows audit policies:
     - A baseline policy for all Windows servers
     - A high security policy for high secure systems (Tier 0 & some Tier 1 systems (e.g. SAP), VIPs)
     - A very thorough audit policy in case of assumed compromise and for investigation cases
  3. Acquire or 'hire' AD monitoring know-how and allocate resources and personnel
The Solution: AD-Specific Security Logging & Monitoring

- Implement Admin Tiers with logon & control restrictions and monitor violations
  - Begin with Tier 0
  - Then Tier 1 & VIPs

- Monitor at least:
  - Tier 0 logons (and logon failures)
  - High privileged group membership changes
  - Violations of allowed logon types (e.g. interactive logon of service accounts)
  - Changes of attributes for sensitive AD objects (e.g. AdminSDHolder object)
  - Violations of allowed Kerberos encryption algorithms
  - Large amounts of enumeration errors
  - Some specific kerberos events IDs on DCs (e.g. ID 7 and ID 4769)
  - Yara rules for mimikatz & wce specific usage & strings
Thank you for your time!

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www.ernw.de
www.insinuator.net
Sources

- Link1
  - Ross Anderson, Security Engineering

- Icons
  - https://icons8.com/
Additional Material & Information
Clean Source Principle: Installation

- Ensure that the installation media has not been tampered with
  - Requires validating the software integrity throughout the lifecycle including during acquisition, storage, and transfer until usage

- The source of the software must be validated
  - Physical media directly from the vendor
  - File hash validation
  - Revocation checks for digital signatures

- The software must be stored in a location that is protected from modification
  - especially by internet-connected hosts
  - or personnel trusted at a lower level than the systems where the software system will be installed
Control/Logon Restrictions Example 1 for Admin Tiers

As the user is a tier 1 admin, he cannot control the file share system/the resource (he can only access a share with limited NTFS permissions)

Tier 1 admin must access a Tier 0 file share to store certain files

As required by his role, the Tier 1 admin can logon to a higher-tier resource to access a share and store files (well-defined and strictly monitored)

Note: A similar scenario is the access to the Netlogon share
Control/Logon Restrictions Example 2 for Admin Tiers

Tier 0 admin manages the identity store (Active Directory database). He can define group membership of Tier 0, Tier 1 (and Tier 2) accounts and he can define security settings for Tier 0 and Tier 1 servers (and even Tier 2 computers) in GPOs.

Therefore, the Tier 0 admin must access `dsa.msc` and `gpmc.msc` on a DC (where he logs on).

Thus, as required by his role, the Tier 0 admin can control lower-tier resources, but he never logs on to a lower-tier system.
DMZ AD

- Strictly separate internal AD from DMZ AD
- Do not place even RODC (of internal AD) in the DMZ
- The only Trust allowed between an internal AD and a DMZ AD is an uni-directional Trust outgoing from the DMZ AD
The Problem: AD Borders Neither Well-defined Nor Controlled: AD Extension Into the Cloud

- Many different scenarios possible
  - Application services in Azure (WebApp, SharePoint, SQL, SAP...)
  - Domain Controller(s) in Azure (for Backup-up or authentication reasons)

- Some scenarios require synchronization of credentials to Azure
Azure (Cloud)

- Extension of internal AD via DirSync/ADConnect or member systems in Azure should require a strategic decision.

- A connection via ADFS between on-prem AD and Azure is able to restrict on-prem credentials to on-prem AD.
Exemplary ESAE Forest Implementation

AD(s)

ESAE FOREST

AD
PKI
DNS
Hyper-V
PAM
Shares
WSUS
AV/ Monitor/ Vulnerability
OS (DCs/Member)
Jump
Vault
Storage
Hardware Management
Hypervisor
Firewall
Switches
VPN

TIER 0

App
OS
HW
NW

Switches Firewall

TIER 1

Content Management
Exchange
PKI
Identity & Access Management
Web Apps
DBs

TIER 2

Virtual Clients
Hardware Clients

PAWs
Physically in Tier 2
Logically in Tier 0