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REFERENCE IMPLEMENTATION REVISION 4 FOR REPRESENTATION OF CYBER ADVERSARY BEHAVIOR IN STRUCTURED THREAT INFORMATION EXCHANGE (STIX) FORMAT

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1. INTRODUCTION

The Johns Hopkins University Applied Physics Laboratory (APL), under sponsorship from the Cybersecurity and Infrastructure Security Agency (CISA), is supporting improvements in the timeliness and effectiveness of cyber defense operations through integration, automation, and standardized information exchange. As part of this support, APL is delivering a reference implementation using machine-readable Structured Threat Information eXpression (STIX) objects to operationalize representations of cyber adversary behaviors on a network.
This report provides an overview of the approach used to generate the current version of the STIX object content, along with guidance for interpreting and applying the data within operational environments.

This document reflects the fourth iteration of the delivered materials. A complete summary of updates made in this version can be found in section 5 of this report.

2. BEHAVIOR SHARING IMPLEMENTATION

APL is supporting the operational use of machine-readable data objects to represent cyber adversary behavior on target networks. This activity builds upon previously completed efforts under the Integrated Adaptive Cyber Defense (IACD) framework and prior work performed for the Cybersecurity and Infrastructure Security Agency (CISA).

Earlier efforts established a format for capturing adversary behavior using custom objects in the STIX 2.1 standard. In this implementation, APL has focused on packaging content into a robust, machine-readable STIX bundle for community sharing. The resulting format enables both human analysts and automated systems to detect observed adversary behavior within victim environments based on standardized, shareable representations.

2.1 Operational Motivation

Previous work under the Integrated Adaptive Cyber Defense (IACD) program highlighted a critical limitation in current Cyber Threat Intelligence (CTI) sharing practices—specifically, the over-reliance on Indicators of Compromise (IOCs). Due to their inherently short lifecycle, IOCs provide only limited windows of actionable use in network defense.

Although Security Orchestration, Automation, and Response (SOAR) capabilities have improved the timely application of IOC-based data, there remains a continued operational need for sharing information that enables proactive defense. This includes behavioral insights that support detection and response to advanced threats across a community of defenders.

2.2 Operational Overview

This document summarizes updates included in Revision 4 of the operational deliverable for representing cyber adversary behavior in STIX format. It extends the content delivered

in Revision 3, which included machine-readable representations of adversary behavior along with corresponding detection and correlation logic for operational use.

Revision 4 incorporates feedback from community stakeholders, enhances integration fidelity, and includes refinements aimed at improving the operational application of Indicators of Behavior (IoB).

2.3 Key Updates in Revision 4

In this update, the structure and object model were adjusted to improve clarity and cross-platform interoperability. Custom object identifiers now use lowercase UUIDs to support consistent parsing and simplify tool integration. Updated STIX content—including playbooks, behaviors, detections, and relationships—has been incorporated to better align with advanced correlation workflows and automation needs. Legacy objects from Revision 3 that presented complexity or redundancy have been removed or replaced with streamlined versions.

The underlying relationship model has also been reorganized to more accurately capture the sequence and logic of observed adversary behaviors. Relationship types such as "detects," "uses," and "occurs-before" were clarified to support graph-based reasoning and improve automation of behavior-based detection and response.

Refinements were also applied to playbooks and automation workflows. Support has been extended for both CACAO and BPMN formats, enabling broader interoperability with orchestration platforms. The additional playbook content delivered in this revision focuses on correlation scoring and alert chaining to facilitate automated detection of behavior patterns, rather than relying on standalone event triggers.

Analytic artifacts were also enhanced. Sigma detection rules were edited for improved clarity and usability. Mappings between detection objects and associated metadata—such as source log details and courses of action—have been aligned to improve traceability and maximize operational value.

2.4 Changes to Object Types

Table 1 provides a summary of the key changes in Revision 4 compared to Revision 3.

Table 1 key changes to STIX Domain Objects (SDOs) in Revision 4

Object Type	Change Summary
x-oca-detection	The data_sources field was removed to reduce redundancy. Metadata about log origins is now managed via linked detector and data source objects.
x-oca-detection	Several updated detections and behaviors provide improved field clarity and updated references to MITRE ATT&CK techniques.
extension-definition	Updates were made to extension definitions were added to support emerging use cases and enable more flexible scoring models.

2.5 Additional Notes

Users transitioning from the Revision 3 bundle should note several key considerations when adopting Revision 4. Many object identifiers from the previous version have been reassigned or updated. As a result, automated ingestion systems should treat the Revision 4 bundle as a distinct dataset, rather than as an in-place update to existing content.

Additionally, certain field-level adjustments—such as the removal of data_sources—may affect systems or parsers that were configured to use the prior schema. Users are encouraged to review schema differences prior to integration to ensure compatibility.

The full STIX bundle for Revision 4 will be made available through the Open Cybersecurity Alliance repository (https://github.com/opencybersecurityalliance/oca-iob/). For reference, the Revision 3 implementation remains accessible at the following link: https://github.com/opencybersecurityalliance/oca-iob/tree/main/apl_reference_implementation_bundle/revision_3

3. ACKNOWLEDGEMENT

The IOB Sub-Project wishes to thank Dr. Vasileios Mavroeidis and his teams at University of Oslo / Cyentific AS for their technical discussions on best practices to represent CACAO playbooks within STIX.

4. CONCLUSION

APL has provided this deliverable and supporting report to promote consistency and interoperability in the representation of adversary behavior using machine-readable formats. This content is intended to support ongoing operational use, facilitate tool integration, and improve coordination across the broader cyber defense community.

Organizations seeking additional information or clarification regarding this material may contact the authors at: Charles.Frick@jhuapl.edu.

5. CHANGELOG

- (Revision 4)
  - Standardized all object identifiers to lowercase UUID format for consistency and parser compatibility
  - Updated playbooks supporting advanced correlation and scoring logic, in both CACAO and BPMN formats
  - Removed deprecated fields: data_sources (from x-oca-detection)
  - Added descriptions to all detections

- Restructured relationships to improve chaining of behavior sequences and strengthen correlation logic
- Improved Sigma rules for clarity and integration across SIEM platforms
- Updated extension definitions to support enhanced metadata and scoring capabilities
- Cleaned up redundant or outdated objects from Revision 3 to streamline the reference bundle

6. APPENDIX A: ACRONYMNS

Acronym	Definition
APL	Johns Hopkins Applied Physics Laboratory
ATT&CK	Adversarial Tactics, Techniques, and Common Knowledge
BPMN	Business Process Modeling Notation
CACAO	Collaborative Automated Course of Action Operations
CISA	Cybersecurity and Infrastructure Security Agency
CTI	Cyber Threat Intelligence
IACD	Integrated Adaptive Cyber Defense
IoB	Indicator of Behavior
IOC	Indicator of Compromise
JSON	JavaScript Object Notation
SCO	STIX Cyber Observable
SDO	STIX Domain Object
SIEM	Security Information and Event Management
SOAR	Security Orchestration, Automation, and Response
SRO	STIX Relationship Object
STIX	Structured Threat Information eXchange
TAXII	Trusted Automated eXchange of Indicator Information
TIP	Threat Intelligence Platform
UUID	Universally Unique Identifier

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7. APPENDIX B: COMPLETE BEHAVIOR SET STIX BUNDLE


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      "tactic": "Privilege Escalation",
      "technique": "T1134.001 - Access token manipulation - Token impersonation",
      "first_seen": "2022-03-31T13:00:00.000Z",
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      "description": "This detection checks if the src_user field does not contain \"$\" and if the user
field contains \"$\" for event code 4688, indicating an elevation in privileges.",
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      "pid": 0,
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      "command_line": "C:\\Users\\jsmith.CBIS\\AppData\\Local\\PrintSpoofer64.exe",
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      "command_line": "C:\\Users\\jsmith.CBIS\\AppData\\Local\\Beacon.exe",
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      "description": "A DCSync may have occurred, allowing an adversary access to the Domain Controller's
credentials. The adversary may obtain password hashes via Kerberoasting and attempt to crack them.",
      "behavior_class": "anomalous",
      "tactic": "Credential Access",
      "technique": "T1003.006 - OS Credential dumping - DCSync",
      "first_seen": "2022-03-31T13:00:00.000Z",
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      "name": "DC Sync Detection",
      "description": "This detection checks if zeek network events contain \"drsuapi::DRSGetNCChanges\".",
      "analytic": {
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      "description": "Network traffic matching a pattern which may indicate lateral movement done by an
adversary.",
      "behavior_class": "anomalous",
      "tactic": "Lateral Movement",
      "technique": "T1558.001 - Steal Or Forge Kerberos Tickets - Golden Ticket",
      "first_seen": "2022-03-31T13:00:00.000Z",
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          "version": "10"
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      "created": "2022-03-31T13:00:00.000Z",
      "modified": "2025-06-06T17:08:00.000Z",
      "name": "Lateral Movement Detection",
      "description": "This detection checks for Golden Ticket Kerberos alerts from a 3rd Party Tool.",
      "analytic": {
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      "value": "data-server-domain",
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    "dst_ref": "domain-name--8713b93b-186e-524d-9224-db3b8f9fb9ef",
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      "smb"
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    "description": "Adversary exfiltrates data from the target network.",
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    "tactic": "Exfiltration",
    "technique": "T1041 - Exfiltration over C2 Channel",
    "first_seen": "2022-03-31T13:00:00.000Z",
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      "name": "Data Exfiltration Detection",
      "description": "This detection monitors a known file share directory with sensitive information and
checks if its name, the string \"Sensitive Data\", appears in Zeek's files log.",
      "analytic": {
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        "rule":
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    "x_mitre_attack_spec_version": "2.1.0",
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    "modified": "2022-03-31T13:00:00.000Z",
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      "created": "2022-03-31T13:00:00.000Z",
      "modified": "2025-06-18T12:00:00.000Z",
      "name": "x-oca-behavior Extension Definition",
      "description": "Behavior objects define adversary behaviors associated with higher level MITRE
ATT&CK tactics and techniques. The Attack Pattern SDO may have multiple behaviors associated with it. For
example, a spearphishing attack may employ multiple behaviors (usage of email attachments, process
modifying a registry key, network patterns, etc.).",
      "schema": "https://raw.githubusercontent.com/opencybersecurityalliance/stix-
extensions/main/2.x/schemas/x-oca-behavior.json",
      "version": "1.0.1",
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      "description": "Detector objects define tools, software, products, etc. that are capable of
performing detection. They should likely be related to one or more Detection obects.",
      "schema": "https://raw.githubusercontent.com/opencybersecurityalliance/stix-
extensions/main/2.x/schemas/x-oca-detector.json",
      "version": "1.0.1",
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      "description": "Detections contain logic to detect an adversary behavior.",
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      "version": "1.0.1",
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      "modified": "2025-06-18T12:00:00.000Z",
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      "description": "This extended process object contains fields from Windows Security Event 4688 (new
process created) for additional context.",
      "schema": "https://raw.githubusercontent.com/opencybersecurityalliance/stix-
extensions/main/2.x/schemas/extended-process.json",
      "version": "1.0.1",
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      "target_ref": "x-oca-behavior--edc99806-f8e9-4ee3-b2d4-1234567890aa"
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      "spec_version": "2.1",
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          "extension_type": "property-extension"
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      "is_hidden": false,
      "pid": 0,
      "cwd": "C:\\Program Files\\Microsoft Office\\Office14\\",
      "command_line": "C:\\Program Files\\Microsoft Office\\Office14\\OUTLOOK.EXE",
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          "name": "OUTLOOK.EXE",
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      "command_line": "C:\\User\\jsmith.CBIS\\AppData\\Local\\Google\\Chrome\\Application\\chrome.exe --
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      "parent_ref": "process--862e625d-48bb-489e-8d4e-f7d8cd2fcaaa",
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          "name": "chrome.exe",
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      "is_hidden": false,
      "pid": 0,
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      "command_line": "'C:\\Program Files\\Microsoft Office\\Office14\\WINWORD.EXE' /n
'C:\\Users\\jsmith.CBIS\\Downloads\\test.docm'",
      "parent_ref": "process--862e625d-48bb-489e-8d4e-f7d8cd2fcbbb",
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          "win_event_code": 4688
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      "pid": 0,
      "cwd": "C:\\Program Files\\Microsoft Office\\Office14\\",
      "command_line": "C:\\Users\\JSMITH.CBIS\\AppData\\Local\\Temp\\rad99952.tmp.exe",
      "parent_ref": "process--862e625d-48bb-489e-8d4e-f7d8cd2fcccc",
      "extensions": {
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          "extension_type": "property-extension",
          "operation_type": "created",
          "name": "C:\\Users\\JSMITH.CBIS\\AppData\\Local\\Temp\\rad99952.tmp.exe",
          "win_event_code": 4688
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      "name": "Process 1 - SpearPhish",
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\"Creator_Process_Name\" contains a string associated with common email clients and \"New_Process_Name\"
contains a string associated with common web browsers.",
      "analytic": {
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        }
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      "spec_version": "2.1",
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      "created_by_ref": "identity--b085a68a-bf48-4316-9667-37af78cba894",
      "created": "2022-03-31T13:00:00.000Z",
      "modified": "2025-06-06T17:08:00.000Z",
      "name": "Process 2 - SpearPhish",
      "description": "This detection checks for process creation events with EventCode 4688 where
\"Creator_Process_Name\" contains a string associated with common web browsers, \"New_Process_Name\"
contains a string associated with common MS Office products, and \"Process_Command_Line\" contains a
string associated with common MS Office files.",
      "analytic": {
        "rule":
"YXV0aG9yOiBPQ0EKZGF0ZTogMjAyMS0wNi0wNwptb2RpZmllZDogMjAyNS0wNi0xNgp0aXRsZTogU3BlYXJwaGlzaCAtIEJyb3dzZXIgR
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      "modified": "2025-06-06T17:08:00.000Z",
      "name": "Process - Execution",
      "description": "This detection checks for process creation events with EventCode 4688 where
\"Creator_Process_Name\" contains a string associated with common MS Office products and
\"New_Process_Name\" ends a string associated with \".exe\" or \".dll\". The event is ignored if
\"New_Process_Name\" contains splwow64, which is a Windows process.",
      "analytic": {
        "rule":
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APPLIED PHYSICS LABORATORY

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JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

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APPLIED PHYSICS LABORATORY

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JOHNS HOPKINS
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          "url": "https://attack.mitre.org/datasources/DS0024",
          "external_id": "DS0024"
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          "description": "Microsoft. (2018, May 31). Registry. Retrieved September 29, 2021.",
          "url": "https://docs.microsoft.com/en-us/windows/win32/sysinfo/registry"
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Microsoft Registry)",
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Processes have memory space for process executables, loaded modules (DLLs or shared libraries), and
allocated memory regions containing everything from user input to application-specific data
structures(Citation: Microsoft Processes and Threads)",
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          "external_id": "DS0009"
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          "description": "Microsoft. (2018, May 31). Processes and Threads. Retrieved September 28,
2021.",
          "url": "https://docs.microsoft.com/en-us/windows/win32/procthread/processes-and-threads"
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          "external_id": "DS0033"
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          "description": "Microsoft. (2018, July 9). Network File System overview. Retrieved September 28,
2021.",
          "url": "https://docs.microsoft.com/en-us/windows-server/storage/nfs/nfs-overview"
        }
      ],
      "modified": "2022-03-30T14:26:51.806Z",
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Microsoft NFS Overview)",
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      "x_mitre_attack_spec_version": "2.1.0",
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"relationship--f7b01cee-b68c-4f5d-bd2f-392041311144",
"relationship--e4c6cae2-53e6-4855-b795-5cdb4f62f3a3",
"relationship--5adfcaba-a562-4bc3-a03b-7aa5fa3effe3",
"windows-registry-key--c5a4244e-22d5-5797-8f78-c5fc3d1c0bde",
"x-mitre-data-component--181a9f8c-c780-4f1f-91a8-edb770e904ba",
"x-mitre-data-component--3772e279-27d6-477a-9fe3-c6beb363594c",
"x-mitre-data-component--3d20385b-24ef-40e1-9f56-f39750379077",
"x-mitre-data-component--a7f22107-02e5-4982-9067-6625d4a1765a",
"x-mitre-data-component--da85d358-741a-410d-9433-20d6269a6170",
"x-mitre-data-component--f5468e67-51c7-4756-9b4f-65707708e7fa",
"x-mitre-data-source--0f42a24c-e035-4f93-a91c-5f7076bd8da0",
"x-mitre-data-source--ba27545a-9c32-47ea-ba6a-cce50f1b326e",
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        "x-mitre-data-source--c000cd5c-bbb3-4606-af6f-6c6d9de0bbe3",
        "x-mitre-data-source--e8b8ede7-337b-4c0c-8c32-5c7872c1ee22",
        "x-oca-behavior--de81ef18-55e6-4754-a761-6b929bf22395",
        "x-oca-behavior--edc99806-f8e9-4ee3-b2d4-1234567890aa",
        "x-oca-behavior--edc99806-f8e9-4ee3-b2d4-1234567890ab",
        "x-oca-behavior--edc99806-f8e9-4ee3-b2d4-1234567890bb",
        "x-oca-behavior--edc99806-f8e9-4ee3-b2d4-1234567890bc",
        "x-oca-behavior--edc99806-f8e9-4ee3-b2d4-1234567890cc",
        "x-oca-behavior--edc99806-f8e9-4ee3-b2d4-1234567890dd",
        "x-oca-behavior--edc99806-f8e9-4ee3-b2d4-1234567890ee",
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        "x-oca-detection--40a941cc-42df-4b2e-b607-6d74168084b9",
        "x-oca-detection--458c02c9-3635-42e4-8873-6785e00517e7",
        "x-oca-detection--58834c29-4ceb-42a1-a218-336103021000",
        "x-oca-detection--58834c29-4ceb-42a1-a218-336103021111",
        "x-oca-detection--58834c29-4ceb-42a1-a218-336103021222",
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        "x-oca-detection--66aa9c25-8b56-4121-8630-dbe457393b27",
        "x-oca-detection--f27cb358-d747-47ba-a6c4-e5b8debab157",
        "grouping--e2816452-0165-433b-a4cd-18da4315441d",
        "x-oca-detector--67330653-ac02-46c8-b9c2-25b837a2ed6d",
        "x-oca-detector--9441073d-119b-4ec9-aa08-8bdb1703ed56",
        "x-oca-detector--f9ccdd3d-2217-45fd-8e65-055da8e66c3e",
        "x-oca-playbook--32f52089-9943-4231-bba3-5c02ba654755",
        "x-oca-playbook--720e5e68-3959-4ee0-99de-87a4eaa39f44",
        "x-oca-playbook--9880df48-09a7-4e99-8070-0db8f4c946d0",
        "x-oca-playbook--ae16a784-bac9-4334-a09f-7cb63053a6d7",
        "x-oca-playbook--cab95b33-7770-4891-94f2-f2c640f2408a",
        "x-oca-playbook--8fc70cce-8293-4076-ad9b-e8bc4fd12845",
        "note--e7136d2a-77d8-49e2-891a-529159c9cd81",
        "note--e9850a74-a2bd-4535-80fc-ed9ea086862a"
      ]
    },
    {
      "modified": "2023-10-16T09:08:22.319Z",
      "name": "Registry Run Keys / Startup Folder",
      "description": "Adversaries may achieve persistence by adding a program to a startup folder or
referencing it with a Registry run key. Adding an entry to the \"run keys\" in the Registry or startup
folder will cause the program referenced to be executed when a user logs in.(Citation: Microsoft Run Key)
These programs will be executed under the context of the user and will have the account's associated
permissions level.\n\nThe following run keys are created by default on Windows systems:\n\n*
<code>HKEY_CURRENT_USER\\Software\\Microsoft\\Windows\\CurrentVersion\\Run</code>\n*
<code>HKEY_CURRENT_USER\\Software\\Microsoft\\Windows\\CurrentVersion\\RunOnce</code>\n*
<code>HKEY_LOCAL_MACHINE\\Software\\Microsoft\\Windows\\CurrentVersion\\Run</code>\n*
<code>HKEY_LOCAL_MACHINE\\Software\\Microsoft\\Windows\\CurrentVersion\\RunOnce</code>\n\nRun keys may
exist under multiple hives.(Citation: Microsoft Wow6432Node 2018)(Citation: Malwarebytes Wow6432Node 2016)
The <code>HKEY_LOCAL_MACHINE\\Software\\Microsoft\\Windows\\CurrentVersion\\RunOnceEx</code> is also
available but is not created by default on Windows Vista and newer. Registry run key entries can reference
programs directly or list them as a dependency.(Citation: Microsoft Run Key) For example, it is possible
to load a DLL at logon using a \"Depend\" key with RunOnceEx: <code>reg add
HKLM\\SOFTWARE\\Microsoft\\Windows\\CurrentVersion\\RunOnceEx\\0001\\Depend /v 1 /d
\"C:\\temp\\evil[.]dll\"</code> (Citation: Oddvar Moe RunOnceEx Mar 2018)\n\nPlacing a program within a
startup folder will also cause that program to execute when a user logs in. There is a startup folder
location for individual user accounts as well as a system-wide startup folder that will be checked
regardless of which user account logs in. The startup folder path for the current user is
<code>C:\\Users\\\\[Username]\\AppData\\Roaming\\Microsoft\\Windows\\Start Menu\\Programs\\Startup</code>.
The startup folder path for all users is <code>C:\\ProgramData\\Microsoft\\Windows\\Start
Menu\\Programs\\StartUp</code>.\n\nThe following Registry keys can be used to set startup folder items for
persistence:\n\n* <code>HKEY_CURRENT_USER\\Software\\Microsoft\\Windows\\CurrentVersion\\Explorer\\User
Shell Folders</code>\n*
<code>HKEY_CURRENT_USER\\Software\\Microsoft\\Windows\\CurrentVersion\\Explorer\\Shell Folders</code>\n*
<code>HKEY_LOCAL_MACHINE\\SOFTWARE\\Microsoft\\Windows\\CurrentVersion\\Explorer\\Shell Folders</code>\n*
<code>HKEY_LOCAL_MACHINE\\SOFTWARE\\Microsoft\\Windows\\CurrentVersion\\Explorer\\User Shell
Folders</code>\n\nThe following Registry keys can control automatic startup of services during boot:\n\n*
<code>HKEY_LOCAL_MACHINE\\Software\\Microsoft\\Windows\\CurrentVersion\\RunServicesOnce</code>\n*
<code>HKEY_CURRENT_USER\\Software\\Microsoft\\Windows\\CurrentVersion\\RunServicesOnce</code>\n*
<code>HKEY_LOCAL_MACHINE\\Software\\Microsoft\\Windows\\CurrentVersion\\RunServices</code>\n*
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<code>HKEY_CURRENT_USER\\Software\\Microsoft\\Windows\\CurrentVersion\\RunServices</code>\n\nUsing policy
settings to specify startup programs creates corresponding values in either of two Registry keys:\n\n*
<code>HKEY_LOCAL_MACHINE\\Software\\Microsoft\\Windows\\CurrentVersion\\Policies\\Explorer\\Run</code>\n*
<code>HKEY_CURRENT_USER\\Software\\Microsoft\\Windows\\CurrentVersion\\Policies\\Explorer\\Run</code>\n\nP
rograms listed in the load value of the registry key <code>HKEY_CURRENT_USER\\Software\\Microsoft\\Windows
NT\\CurrentVersion\\Windows</code> run automatically for the currently logged-on user.\n\nBy default, the
multistring <code>BootExecute</code> value of the registry key
<code>HKEY_LOCAL_MACHINE\\System\\CurrentControlSet\\Control\\Session Manager</code> is set to
<code>autocheck autochk *</code>. This value causes Windows, at startup, to check the file-system
integrity of the hard disks if the system has been shut down abnormally. Adversaries can add other
programs or processes to this registry value which will automatically launch at boot.\n\nAdversaries can
use these configuration locations to execute malware, such as remote access tools, to maintain persistence
through system reboots. Adversaries may also use [Masquerading](https://attack.mitre.org/techniques/T1036)
to make the Registry entries look as if they are associated with legitimate programs.",
      "kill_chain_phases": [
        {
          "kill_chain_name": "mitre-attack",
          "phase_name": "persistence"
        },
        {
          "kill_chain_name": "mitre-attack",
          "phase_name": "privilege-escalation"
        }
      ],
      "x_mitre_contributors": [
        "Oddvar Moe, @oddvarmoe",
        "Dray Agha, @Purp1eW0lf, Huntress Labs",
        "Harun K\u00fc\u00dfner"
      ],
      "x_mitre_deprecated": false,
      "x_mitre_detection": "Monitor Registry for changes to run keys that do not correlate with known
software, patch cycles, etc. Monitor the start folder for additions or changes. Tools such as Sysinternals
Autoruns may also be used to detect system changes that could be attempts at persistence, including
listing the run keys' Registry locations and startup folders. (Citation: TechNet Autoruns) Suspicious
program execution as startup programs may show up as outlier processes that have not been seen before when
compared against historical data.\n\nChanges to these locations typically happen under normal conditions
when legitimate software is installed. To increase confidence of malicious activity, data and events
should not be viewed in isolation, but as part of a chain of behavior that could lead to other activities,
such as network connections made for Command and Control, learning details about the environment through
Discovery, and Lateral Movement.",
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      "x_mitre_is_subtechnique": true,
      "x_mitre_platforms": [
        "Windows"
      ],
      "x_mitre_version": "2.0",
      "x_mitre_data_sources": [
        "Command: Command Execution",
        "File: File Modification",
        "Process: Process Creation",
        "Windows Registry: Windows Registry Key Creation",
        "Windows Registry: Windows Registry Key Modification"
      ],
      "x_mitre_permissions_required": [
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        "User"
      ],
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      "id": "attack-pattern--9efb1ea7-c37b-4595-9640-b7680cd84279",
      "created": "2020-01-23T22:02:48.566Z",
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      "revoked": false,
      "external_references": [
        {
          "source_name": "mitre-attack",
          "url": "https://attack.mitre.org/techniques/T1547/001",
```

```
          "external_id": "T1547.001"
        },
        {
          "source_name": "Malwarebytes Wow6432Node 2016",
          "description": "Arntz, P. (2016, March 30). Hiding in Plain Sight. Retrieved August 3, 2020.",
          "url": "https://blog.malwarebytes.com/cybercrime/2013/10/hiding-in-plain-sight/"
        },
        {
          "source_name": "Microsoft Wow6432Node 2018",
          "description": "Microsoft. (2018, May 31). 32-bit and 64-bit Application Data in the Registry.
Retrieved August 3, 2020.",
          "url": "https://docs.microsoft.com/en-us/windows/win32/sysinfo/32-bit-and-64-bit-application-
data-in-the-registry"
        },
        {
          "source_name": "Microsoft Run Key",
          "description": "Microsoft. (n.d.). Run and RunOnce Registry Keys. Retrieved November 12, 2014.",
          "url": "http://msdn.microsoft.com/en-us/library/aa376977"
        },
        {
          "source_name": "Oddvar Moe RunOnceEx Mar 2018",
          "description": "Moe, O. (2018, March 21). Persistence using RunOnceEx - Hidden from
Autoruns.exe. Retrieved June 29, 2018.",
          "url": "https://oddvar.moe/2018/03/21/persistence-using-runonceex-hidden-from-autoruns-exe/"
        },
        {
          "source_name": "TechNet Autoruns",
          "description": "Russinovich, M. (2016, January 4). Autoruns for Windows v13.51. Retrieved June
6, 2016.",
          "url": "https://technet.microsoft.com/en-us/sysinternals/bb963902"
        }
      ],
      "object_marking_refs": [
        "marking-definition--fa42a846-8d90-4e51-bc29-71d5b4802168"
      ],
      "x_mitre_attack_spec_version": "3.2.0",
      "x_mitre_modified_by_ref": "identity--c78cb6e5-0c4b-4611-8297-d1b8b55e40b5",
      "spec_version": "2.1"
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    {
      "modified": "2023-09-29T21:08:45.174Z",
      "name": "Token Impersonation/Theft",
      "description": "Adversaries may duplicate then impersonate another user's existing token to escalate
privileges and bypass access controls. For example, an adversary can duplicate an existing token using
`DuplicateToken` or `DuplicateTokenEx`. The token can then be used with `ImpersonateLoggedOnUser` to allow
the calling thread to impersonate a logged on user's security context, or with `SetThreadToken` to assign
the impersonated token to a thread.\n\nAn adversary may perform [Token
Impersonation/Theft](https://attack.mitre.org/techniques/T1134/001) when they have a specific, existing
process they want to assign the duplicated token to. For example, this may be useful for when the target
user has a non-network logon session on the system.\n\nWhen an adversary would instead use a duplicated
token to create a new process rather than attaching to an existing process, they can additionally [Create
Process with Token](https://attack.mitre.org/techniques/T1134/002) using `CreateProcessWithTokenW` or
`CreateProcessAsUserW`. [Token Impersonation/Theft](https://attack.mitre.org/techniques/T1134/001) is also
distinct from [Make and Impersonate Token](https://attack.mitre.org/techniques/T1134/003) in that it
refers to duplicating an existing token, rather than creating a new one.",
      "kill_chain_phases": [
        {
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          "phase_name": "defense-evasion"
        },
        {
          "kill_chain_name": "mitre-attack",
          "phase_name": "privilege-escalation"
        }
      ],
      "x_mitre_contributors": [
        "Jonny Johnson"
      ],
```

```
      "x_mitre_deprecated": false,
      "x_mitre_detection": "If an adversary is using a standard command-line shell, analysts can detect
token manipulation by auditing command-line activity. Specifically, analysts should look for use of the
<code>runas</code> command. Detailed command-line logging is not enabled by default in Windows.(Citation:
Microsoft Command-line Logging)\n\nAnalysts can also monitor for use of Windows APIs such as
<code>DuplicateToken(Ex)</code>, <code> ImpersonateLoggedOnUser </code>, and <code> SetThreadToken </code>
and correlate activity with other suspicious behavior to reduce false positives that may be due to normal
benign use by users and administrators.",
      "x_mitre_domains": [
        "enterprise-attack"
      ],
      "x_mitre_is_subtechnique": true,
      "x_mitre_platforms": [
        "Windows"
      ],
      "x_mitre_version": "1.2",
      "x_mitre_data_sources": [
        "Command: Command Execution",
        "Process: OS API Execution"
      ],
      "x_mitre_defense_bypassed": [
        "Windows User Account Control",
        "System access controls",
        "File system access controls"
      ],
      "type": "attack-pattern",
      "id": "attack-pattern--86850eff-2729-40c3-b85e-c4af26da4a2d",
      "created": "2020-02-18T16:39:06.289Z",
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      "revoked": false,
      "external_references": [
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          "url": "https://attack.mitre.org/techniques/T1134/001",
          "external_id": "T1134.001"
        },
        {
          "source_name": "Microsoft Command-line Logging",
          "description": "Mathers, B. (2017, March 7). Command line process auditing. Retrieved April 21,
2017.",
          "url": "https://technet.microsoft.com/en-us/windows-server-docs/identity/ad-ds/manage/component-
updates/command-line-process-auditing"
        }
      ],
      "object_marking_refs": [
        "marking-definition--fa42a846-8d90-4e51-bc29-71d5b4802168"
      ],
      "x_mitre_attack_spec_version": "3.2.0",
      "x_mitre_modified_by_ref": "identity--c78cb6e5-0c4b-4611-8297-d1b8b55e40b5",
      "spec_version": "2.1"
    },
    {
      "modified": "2023-05-09T14:00:00.188Z",
      "name": "Exfiltration Over C2 Channel",
      "description": "Adversaries may steal data by exfiltrating it over an existing command and control
channel. Stolen data is encoded into the normal communications channel using the same protocol as command
and control communications.",
      "kill_chain_phases": [
        {
          "kill_chain_name": "mitre-attack",
          "phase_name": "exfiltration"
        }
      ],
      "x_mitre_contributors": [
        "William Cain"
      ],
      "x_mitre_deprecated": false,
```

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      "x_mitre_detection": "Analyze network data for uncommon data flows (e.g., a client sending
significantly more data than it receives from a server). Processes utilizing the network that do not
normally have network communication or have never been seen before are suspicious. Analyze packet contents
to detect communications that do not follow the expected protocol behavior for the port that is being
used. (Citation: University of Birmingham C2)",
      "x_mitre_domains": [
        "enterprise-attack"
      ],
      "x_mitre_is_subtechnique": false,
      "x_mitre_platforms": [
        "Linux",
        "macOS",
        "Windows"
      ],
      "x_mitre_version": "2.2",
      "x_mitre_data_sources": [
        "Command: Command Execution",
        "File: File Access",
        "Network Traffic: Network Connection Creation",
        "Network Traffic: Network Traffic Content",
        "Network Traffic: Network Traffic Flow"
      ],
      "x_mitre_network_requirements": false,
      "type": "attack-pattern",
      "id": "attack-pattern--92d7da27-2d91-488e-a00c-059dc162766d",
      "created": "2017-05-31T21:30:41.804Z",
      "created_by_ref": "identity--c78cb6e5-0c4b-4611-8297-d1b8b55e40b5",
      "revoked": false,
      "external_references": [
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          "url": "https://attack.mitre.org/techniques/T1041",
          "external_id": "T1041"
        },
        {
          "source_name": "University of Birmingham C2",
          "description": "Gardiner, J.,  Cova, M., Nagaraja, S. (2014, February). Command & Control
Understanding, Denying and Detecting. Retrieved April 20, 2016.",
          "url": "https://arxiv.org/ftp/arxiv/papers/1408/1408.1136.pdf"
        }
      ],
      "object_marking_refs": [
        "marking-definition--fa42a846-8d90-4e51-bc29-71d5b4802168"
      ],
      "x_mitre_attack_spec_version": "3.1.0",
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      "spec_version": "2.1"
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      "modified": "2023-09-06T14:08:51.616Z",
      "name": "Spearphishing Link",
      "description": "Adversaries may send spearphishing emails with a malicious link in an attempt to
gain access to victim systems. Spearphishing with a link is a specific variant of spearphishing. It is
different from other forms of spearphishing in that it employs the use of links to download malware
contained in email, instead of attaching malicious files to the email itself, to avoid defenses that may
inspect email attachments. Spearphishing may also involve social engineering techniques, such as posing as
a trusted source.\n\nAll forms of spearphishing are electronically delivered social engineering targeted
at a specific individual, company, or industry. In this case, the malicious emails contain links.
Generally, the links will be accompanied by social engineering text and require the user to actively click
or copy and paste a URL into a browser, leveraging [User
Execution](https://attack.mitre.org/techniques/T1204). The visited website may compromise the web browser
using an exploit, or the user will be prompted to download applications, documents, zip files, or even
executables depending on the pretext for the email in the first place.\n\nAdversaries may also include
links that are intended to interact directly with an email reader, including embedded images intended to
exploit the end system directly. Additionally, adversaries may use seemingly benign links that abuse
special characters to mimic legitimate websites (known as an \"IDN homograph attack\").(Citation: CISA IDN
ST05-016) URLs may also be obfuscated by taking advantage of quirks in the URL schema, such as the
acceptance of integer- or hexadecimal-based hostname formats and the automatic discarding of text before
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an \u201c@\u201d symbol: for example, `hxxp://google.com@1157586937`.(Citation: Mandiant URL Obfuscation 2023)\n\nAdversaries may also utilize links to perform consent phishing, typically with OAuth 2.0 request URLs that when accepted by the user provide permissions/access for malicious applications, allowing adversaries to [Steal Application Access Token](https://attack.mitre.org/techniques/T1528)s.(Citation: Trend Micro Pawn Storm OAuth 2017) These stolen access tokens allow the adversary to perform various actions on behalf of the user via API calls. (Citation: Microsoft OAuth 2.0 Consent Phishing 2021)",
      "kill_chain_phases": [
        {
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          "phase_name": "initial-access"
        }
      ],
      "x_mitre_contributors": [
        "Philip Winther",
        "Shailesh Tiwary (Indian Army)",
        "Mark Wee",
        "Jeff Sakowicz, Microsoft Identity Developer Platform Services (IDPM Services)",
        "Saisha Agrawal, Microsoft Threat Intelligent Center (MSTIC)",
        "Kobi Haimovich, CardinalOps",
        "Menachem Goldstein"
      ],
      "x_mitre_deprecated": false,
      "x_mitre_detection": "URL inspection within email (including expanding shortened links) can help detect links leading to known malicious sites as well as links redirecting to adversary infrastructure based by upon suspicious OAuth patterns with unusual TLDs.(Citation: Microsoft OAuth 2.0 Consent Phishing 2021). Detonation chambers can be used to detect these links and either automatically go to these sites to determine if they're potentially malicious, or wait and capture the content if a user visits the link.\n\nFiltering based on DKIM+SPF or header analysis can help detect when the email sender is spoofed.(Citation: Microsoft Anti Spoofing)(Citation: ACSC Email Spoofing)\n\nBecause this technique usually involves user interaction on the endpoint, many of the possible detections take place once [User Execution](https://attack.mitre.org/techniques/T1204) occurs.",
      "x_mitre_domains": [
        "enterprise-attack"
      ],
      "x_mitre_is_subtechnique": true,
      "x_mitre_platforms": [
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        "macOS",
        "Windows",
        "Office 365",
        "SaaS",
        "Google Workspace"
      ],
      "x_mitre_version": "2.5",
      "x_mitre_data_sources": [
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        "Application Log: Application Log Content",
        "Network Traffic: Network Traffic Content"
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          "external_id": "T1566.002"
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          "description": "Australian Cyber Security Centre. (2012, December). Mitigating Spoofed Emails Using Sender Policy Framework. Retrieved October 19, 2020.",
          "url": "https://www.cyber.gov.au/sites/default/files/2019-03/spoof_email_sender_policy_framework.pdf"
        },
        {

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          "source_name": "CISA IDN ST05-016",
          "description": "CISA. (2019, September 27). Security Tip (ST05-016): Understanding
Internationalized Domain Names. Retrieved October 20, 2020.",
          "url": "https://us-cert.cisa.gov/ncas/tips/ST05-016"
        },
        {
          "source_name": "Trend Micro Pawn Storm OAuth 2017",
          "description": "Hacquebord, F.. (2017, April 25). Pawn Storm Abuses Open Authentication in
Advanced Social Engineering Attacks. Retrieved October 4, 2019.",
          "url": "https://blog.trendmicro.com/trendlabs-security-intelligence/pawn-storm-abuses-open-
authentication-advanced-social-engineering-attacks"
        },
        {
          "source_name": "Microsoft OAuth 2.0 Consent Phishing 2021",
          "description": "Microsoft 365 Defender Threat Intelligence Team. (2021, June 14). Microsoft
delivers comprehensive solution to battle rise in consent phishing emails. Retrieved December 13, 2021.",
          "url": "https://www.microsoft.com/security/blog/2021/07/14/microsoft-delivers-comprehensive-
solution-to-battle-rise-in-consent-phishing-emails/"
        },
        {
          "source_name": "Microsoft Anti Spoofing",
          "description": "Microsoft. (2020, October 13). Anti-spoofing protection in EOP. Retrieved
October 19, 2020.",
          "url": "https://docs.microsoft.com/en-us/microsoft-365/security/office-365-security/anti-
spoofing-protection?view=o365-worldwide"
        },
        {
          "source_name": "Mandiant URL Obfuscation 2023",
          "description": "Nick Simonian. (2023, May 22). Don't @ Me: URL Obfuscation Through Schema Abuse.
Retrieved August 4, 2023.",
          "url": "https://www.mandiant.com/resources/blog/url-obfuscation-schema-abuse"
        }
      ],
      "object_marking_refs": [
        "marking-definition--fa42a846-8d90-4e51-bc29-71d5b4802168"
      ],
      "x_mitre_attack_spec_version": "3.1.0",
      "x_mitre_modified_by_ref": "identity--c78cb6e5-0c4b-4611-8297-d1b8b55e40b5",
      "spec_version": "2.1"
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      "name": "Web Protocols",
      "description": "Adversaries may communicate using application layer protocols associated with web
traffic to avoid detection/network filtering by blending in with existing traffic. Commands to the remote
system, and often the results of those commands, will be embedded within the protocol traffic between the
client and server. \n\nProtocols such as HTTP/S(Citation: CrowdStrike Putter Panda) and
WebSocket(Citation: Brazking-Websockets) that carry web traffic may be very common in environments. HTTP/S
packets have many fields and headers in which data can be concealed. An adversary may abuse these
protocols to communicate with systems under their control within a victim network while also mimicking
normal, expected traffic. ",
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          "phase_name": "command-and-control"
        }
      ],
      "x_mitre_contributors": [
        "TruKno"
      ],
      "x_mitre_deprecated": false,
      "x_mitre_detection": "Analyze network data for uncommon data flows (e.g., a client sending
significantly more data than it receives from a server). Processes utilizing the network that do not
normally have network communication or have never been seen before are suspicious. Analyze packet contents
to detect application layer protocols that do not follow the expected protocol standards regarding syntax,
structure, or any other variable adversaries could leverage to conceal data.(Citation: University of
Birmingham C2)\n\nMonitor for web traffic to/from known-bad or suspicious domains. ",
      "x_mitre_domains": [
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        "enterprise-attack"
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        "Windows"
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        "Network Traffic: Network Traffic Flow"
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      "created": "2020-03-15T16:13:46.151Z",
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      "revoked": false,
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          "url": "https://attack.mitre.org/techniques/T1071/001",
          "external_id": "T1071.001"
        },
        {
          "source_name": "CrowdStrike Putter Panda",
          "description": "Crowdstrike Global Intelligence Team. (2014, June 9). CrowdStrike Intelligence
Report: Putter Panda. Retrieved January 22, 2016.",
          "url": "http://cdn0.vox-cdn.com/assets/4589853/crowdstrike-intelligence-report-putter-
panda.original.pdf"
        },
        {
          "source_name": "University of Birmingham C2",
          "description": "Gardiner, J.,  Cova, M., Nagaraja, S. (2014, February). Command & Control
Understanding, Denying and Detecting. Retrieved April 20, 2016.",
          "url": "https://arxiv.org/ftp/arxiv/papers/1408/1408.1136.pdf"
        },
        {
          "source_name": "Brazking-Websockets",
          "description": "Shahar Tavor. (n.d.). BrazKing Android Malware Upgraded and Targeting Brazilian
Banks. Retrieved March 24, 2023.",
          "url": "https://securityintelligence.com/posts/brazking-android-malware-upgraded-targeting-
brazilian-banks/"
        }
      ],
      "object_marking_refs": [
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      ],
      "x_mitre_attack_spec_version": "3.2.0",
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      "spec_version": "2.1"
    },
    {
      "modified": "2023-05-09T14:00:00.188Z",
      "name": "PowerShell",
      "description": "Adversaries may abuse PowerShell commands and scripts for execution. PowerShell is a
powerful interactive command-line interface and scripting environment included in the Windows operating
system.(Citation: TechNet PowerShell) Adversaries can use PowerShell to perform a number of actions,
including discovery of information and execution of code. Examples include the <code>Start-Process</code>
cmdlet which can be used to run an executable and the <code>Invoke-Command</code> cmdlet which runs a
command locally or on a remote computer (though administrator permissions are required to use PowerShell
to connect to remote systems).\n\nPowerShell may also be used to download and run executables from the
Internet, which can be executed from disk or in memory without touching disk.\n\nA number of PowerShell-
based offensive testing tools are available, including [Empire](https://attack.mitre.org/software/S0363),
[PowerSploit](https://attack.mitre.org/software/S0194), [PoshC2](https://attack.mitre.org/software/S0378),
and PSAttack.(Citation: Github PSAttack)\n\nPowerShell commands/scripts can also be executed without
directly invoking the <code>powershell.exe</code> binary through interfaces to PowerShell's underlying
<code>System.Management.Automation</code> assembly DLL exposed through the .NET framework and Windows
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Common Language Interface (CLI).(Citation: Sixdub PowerPick Jan 2016)(Citation: SilentBreak Offensive PS
Dec 2015)(Citation: Microsoft PSfromCsharp APR 2014)",
      "kill_chain_phases": [
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          "phase_name": "execution"
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      "x_mitre_contributors": [
        "Mayuresh Dani, Qualys",
        "Praetorian",
        "Ross Brittain"
      ],
      "x_mitre_deprecated": false,
      "x_mitre_detection": "If proper execution policy is set, adversaries will likely be able to define
their own execution policy if they obtain administrator or system access, either through the Registry or
at the command line. This change in policy on a system may be a way to detect malicious use of PowerShell.
If PowerShell is not used in an environment, then simply looking for PowerShell execution may detect
malicious activity.\n\nMonitor for loading and/or execution of artifacts associated with PowerShell
specific assemblies, such as System.Management.Automation.dll (especially to unusual process
names/locations).(Citation: Sixdub PowerPick Jan 2016)(Citation: SilentBreak Offensive PS Dec 2015)\n\nIt
is also beneficial to turn on PowerShell logging to gain increased fidelity in what occurs during
execution (which is applied to .NET invocations). (Citation: Malware Archaeology PowerShell Cheat Sheet)
PowerShell 5.0 introduced enhanced logging capabilities, and some of those features have since been added
to PowerShell 4.0. Earlier versions of PowerShell do not have many logging features.(Citation: FireEye
PowerShell Logging 2016) An organization can gather PowerShell execution details in a data analytic
platform to supplement it with other data.\n\nConsider monitoring for Windows event ID (EID) 400, which
shows the version of PowerShell executing in the <code>EngineVersion</code> field (which may also be
relevant to detecting a potential [Downgrade Attack](https://attack.mitre.org/techniques/T1562/010)) as
well as if PowerShell is running locally or remotely in the <code>HostName</code> field. Furthermore, EID
400 may indicate the start time and EID 403 indicates the end time of a PowerShell session.(Citation:
inv_ps_attacks)",
      "x_mitre_domains": [
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        "Process: Process Creation",
        "Process: Process Metadata",
        "Command: Command Execution",
        "Module: Module Load"
      ],
      "x_mitre_remote_support": true,
      "type": "attack-pattern",
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      "created": "2020-03-09T13:48:55.078Z",
      "created_by_ref": "identity--c78cb6e5-0c4b-4611-8297-d1b8b55e40b5",
      "revoked": false,
      "external_references": [
        {
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          "url": "https://attack.mitre.org/techniques/T1059/001",
          "external_id": "T1059.001"
        },
        {
          "source_name": "Microsoft PSfromCsharp APR 2014",
          "description": "Babinec, K. (2014, April 28). Executing PowerShell scripts from C#. Retrieved
April 22, 2019.",
          "url": "https://blogs.msdn.microsoft.com/kebab/2014/04/28/executing-powershell-scripts-from-c/"
        },
        {
          "source_name": "SilentBreak Offensive PS Dec 2015",
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          "description": "Christensen, L.. (2015, December 28). The Evolution of Offensive PowerShell
Invocation. Retrieved December 8, 2018.",
          "url": "https://web.archive.org/web/20190508170150/https://silentbreaksecurity.com/powershell-
jobs-without-powershell-exe/"
        },
        {
          "source_name": "FireEye PowerShell Logging 2016",
          "description": "Dunwoody, M. (2016, February 11). GREATER VISIBILITY THROUGH POWERSHELL LOGGING.
Retrieved February 16, 2016.",
          "url": "https://www.fireeye.com/blog/threat-research/2016/02/greater_visibilityt.html"
        },
        {
          "source_name": "Github PSAttack",
          "description": "Haight, J. (2016, April 21). PS>Attack. Retrieved June 1, 2016.",
          "url": "https://github.com/jaredhaight/PSAttack"
        },
        {
          "source_name": "inv_ps_attacks",
          "description": "Hastings, M. (2014, July 16). Investigating PowerShell Attacks. Retrieved
December 1, 2021.",
          "url": "https://powershellmagazine.com/2014/07/16/investigating-powershell-attacks/"
        },
        {
          "source_name": "Malware Archaeology PowerShell Cheat Sheet",
          "description": "Malware Archaeology. (2016, June). WINDOWS POWERSHELL LOGGING CHEAT SHEET - Win
7/Win 2008 or later. Retrieved June 24, 2016.",
          "url": "http://www.malwarearchaeology.com/s/Windows-PowerShell-Logging-Cheat-Sheet-ver-June-
2016-v2.pdf"
        },
        {
          "source_name": "TechNet PowerShell",
          "description": "Microsoft. (n.d.). Windows PowerShell Scripting. Retrieved April 28, 2016.",
          "url": "https://technet.microsoft.com/en-us/scriptcenter/dd742419.aspx"
        },
        {
          "source_name": "Sixdub PowerPick Jan 2016",
          "description": "Warner, J.. (2015, January 6). Inexorable PowerShell \u2013 A Red Teamer\u2019s
Tale of Overcoming Simple AppLocker Policies. Retrieved December 8, 2018.",
          "url": "https://web.archive.org/web/20160327101330/http://www.sixdub.net/?p=367"
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      "object_marking_refs": [
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        "Vincent Le Toux"
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          "description": "Microsoft. (2017, December 1). MS-DRSR Directory Replication Service (DRS)
Remote Protocol. Retrieved December 4, 2017.",
          "source_name": "Microsoft DRSR Dec 2017"
        },
        {
          "url": "https://msdn.microsoft.com/library/dd207691.aspx",
          "description": "Microsoft. (n.d.). IDL_DRSGetNCChanges (Opnum 3). Retrieved December 4, 2017.",
          "source_name": "Microsoft GetNCCChanges"
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          "url": "https://wiki.samba.org/index.php/DRSUAPI",
          "description": "SambaWiki. (n.d.). DRSUAPI. Retrieved December 4, 2017.",
          "source_name": "Samba DRSUAPI"
        },
        {
          "url": "https://source.winehq.org/WineAPI/samlib.html",
          "description": "Wine API. (n.d.). samlib.dll. Retrieved December 4, 2017.",
          "source_name": "Wine API samlib.dll"
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          "url": "https://adsecurity.org/?p=1729",
          "description": "Metcalf, S. (2015, September 25). Mimikatz DCSync Usage, Exploitation, and
Detection. Retrieved August 7, 2017.",
          "source_name": "ADSecurity Mimikatz DCSync"
        },
        {
          "url": "http://www.harmj0y.net/blog/redteaming/mimikatz-and-dcsync-and-extrasids-oh-my/",
          "description": "Schroeder, W. (2015, September 22). Mimikatz and DCSync and ExtraSids, Oh My.
Retrieved August 7, 2017.",
          "source_name": "Harmj0y Mimikatz and DCSync"
        },
        {
          "url": "https://blog.stealthbits.com/manipulating-user-passwords-with-mimikatz-SetNTLM-
ChangeNTLM",
          "description": "Warren, J. (2017, July 11). Manipulating User Passwords with Mimikatz. Retrieved
December 4, 2017.",
          "source_name": "InsiderThreat ChangeNTLM July 2017"
        },
        {
          "url": "https://github.com/gentilkiwi/mimikatz/wiki/module-~-lsadump",
          "description": "Deply, B., Le Toux, V. (2016, June 5). module ~ lsadump. Retrieved August 7,
2017.",
          "source_name": "GitHub Mimikatz lsadump Module"
        },
        {
          "url": "https://msdn.microsoft.com/library/cc237008.aspx",
          "description": "Microsoft. (2017, December 1). MS-NRPC - Netlogon Remote Protocol. Retrieved
December 6, 2017.",
          "source_name": "Microsoft NRPC Dec 2017"
        },
        {
          "url": "https://msdn.microsoft.com/library/cc245496.aspx",
          "description": "Microsoft. (n.d.). MS-SAMR Security Account Manager (SAM) Remote Protocol
(Client-to-Server) - Transport. Retrieved December 4, 2017.",
          "source_name": "Microsoft SAMR"
        },
        {
          "url": "https://adsecurity.org/?p=1729",
          "description": "Metcalf, S. (2015, September 25). Mimikatz DCSync Usage, Exploitation, and
Detection. Retrieved December 4, 2017.",
          "source_name": "AdSecurity DCSync Sept 2015"
        },
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        {
          "url": "http://www.harmj0y.net/blog/redteaming/mimikatz-and-dcsync-and-extrasids-oh-my/",
          "description": "Schroeder, W. (2015, September 22). Mimikatz and DCSync and ExtraSids, Oh My.
Retrieved December 4, 2017.",
          "source_name": "Harmj0y DCSync Sept 2015"
        }
      ],
      "modified": "2022-04-25T14:00:00.188Z",
      "name": "DCSync",
      "description": "Adversaries may attempt to access credentials and other sensitive information by
abusing a Windows Domain Controller's application programming interface (API)(Citation: Microsoft DRSR Dec
2017) (Citation: Microsoft GetNCCChanges) (Citation: Samba DRSUAPI) (Citation: Wine API samlib.dll) to
simulate the replication process from a remote domain controller using a technique called
DCSync.\n\nMembers of the Administrators, Domain Admins, and Enterprise Admin groups or computer accounts
on the domain controller are able to run DCSync to pull password data(Citation: ADSecurity Mimikatz
DCSync) from Active Directory, which may include current and historical hashes of potentially useful
accounts such as KRBTGT and Administrators. The hashes can then in turn be used to create a [Golden
Ticket](https://attack.mitre.org/techniques/T1558/001) for use in [Pass the
Ticket](https://attack.mitre.org/techniques/T1550/003)(Citation: Harmj0y Mimikatz and DCSync) or change an
account's password as noted in [Account
Manipulation](https://attack.mitre.org/techniques/T1098).(Citation: InsiderThreat ChangeNTLM July
2017)\n\nDCSync functionality has been included in the \"lsadump\" module in
[Mimikatz](https://attack.mitre.org/software/S0002).(Citation: GitHub Mimikatz lsadump Module) Lsadump
also includes NetSync, which performs DCSync over a legacy replication protocol.(Citation: Microsoft NRPC
Dec 2017)",
      "kill_chain_phases": [
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          "phase_name": "credential-access"
        }
      ],
      "x_mitre_detection": "Monitor domain controller logs for replication requests and other unscheduled
activity possibly associated with DCSync.(Citation: Microsoft DRSR Dec 2017) (Citation: Microsoft
GetNCCChanges) (Citation: Samba DRSUAPI) Also monitor for network protocols(Citation: Microsoft DRSR Dec
2017) (Citation: Microsoft NRPC Dec 2017) and other replication requests(Citation: Microsoft SAMR) from
IPs not associated with known domain controllers.(Citation: AdSecurity DCSync Sept 2015)\n\nNote: Domain
controllers may not log replication requests originating from the default domain controller
account.(Citation: Harmj0y DCSync Sept 2015)",
      "x_mitre_is_subtechnique": true,
      "x_mitre_version": "1.0",
      "x_mitre_modified_by_ref": "identity--c78cb6e5-0c4b-4611-8297-d1b8b55e40b5",
      "x_mitre_data_sources": [
        "Active Directory: Active Directory Object Access",
        "Network Traffic: Network Traffic Content",
        "Network Traffic: Network Traffic Flow"
      ],
      "x_mitre_permissions_required": [
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      ],
      "spec_version": "2.1",
      "x_mitre_attack_spec_version": "2.1.0"
    },
    {
      "modified": "2023-10-31T14:00:00.188Z",
      "name": "Pass the Ticket",
      "description": "Adversaries may \u201cpass the ticket\u201d using stolen Kerberos tickets to move
laterally within an environment, bypassing normal system access controls. Pass the ticket (PtT) is a
method of authenticating to a system using Kerberos tickets without having access to an account's
password. Kerberos authentication can be used as the first step to lateral movement to a remote
system.\n\nWhen preforming PtT, valid Kerberos tickets for [Valid
Accounts](https://attack.mitre.org/techniques/T1078) are captured by [OS Credential
Dumping](https://attack.mitre.org/techniques/T1003). A user's service tickets or ticket granting ticket
(TGT) may be obtained, depending on the level of access. A service ticket allows for access to a
particular resource, whereas a TGT can be used to request service tickets from the Ticket Granting Service
(TGS) to access any resource the user has privileges to access.(Citation: ADSecurity AD Kerberos
Attacks)(Citation: GentilKiwi Pass the Ticket)\n\nA [Silver
Ticket](https://attack.mitre.org/techniques/T1558/002) can be obtained for services that use Kerberos as
an authentication mechanism and are used to generate tickets to access that particular resource and the
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system that hosts the resource (e.g., SharePoint).(Citation: ADSecurity AD Kerberos Attacks)\n\nA [Golden Ticket](https://attack.mitre.org/techniques/T1558/001) can be obtained for the domain using the Key Distribution Service account KRBTGT account NTLM hash, which enables generation of TGTs for any account in Active Directory.(Citation: Campbell 2014)\n\nAdversaries may also create a valid Kerberos ticket using other user information, such as stolen password hashes or AES keys. For example, \"overpassing the hash\" involves using a NTLM password hash to authenticate as a user (i.e. [Pass the Hash](https://attack.mitre.org/techniques/T1550/002)) while also using the password hash to create a valid Kerberos ticket.(Citation: Stealthbits Overpass-the-Hash)",
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        },
        {
          "kill_chain_name": "mitre-attack",
          "phase_name": "lateral-movement"
        }
      ],
      "x_mitre_contributors": [
        "Vincent Le Toux",
        "Ryan Becwar"
      ],
      "x_mitre_detection": "Audit all Kerberos authentication and credential use events and review for discrepancies. Unusual remote authentication events that correlate with other suspicious activity (such as writing and executing binaries) may indicate malicious activity.\n\nEvent ID 4769 is generated on the Domain Controller when using a golden ticket after the KRBTGT password has been reset twice, as mentioned in the mitigation section. The status code 0x1F indicates the action has failed due to \"Integrity check on decrypted field failed\" and indicates misuse by a previously invalidated golden ticket.(Citation: CERT-EU Golden Ticket Protection)",
      "x_mitre_domains": [
        "enterprise-attack"
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      "x_mitre_modified_by_ref": "identity--c78cb6e5-0c4b-4611-8297-d1b8b55e40b5",
      "x_mitre_platforms": [
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        "Logon Session: Logon Session Creation",
        "Active Directory: Active Directory Credential Request"
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      "x_mitre_defense_bypassed": [
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      "x_mitre_system_requirements": [
        "Kerberos authentication enabled"
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      "created": "2020-01-30T17:03:43.072Z",
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          "url": "https://attack.mitre.org/techniques/T1550/003",
          "external_id": "T1550.003"
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        {
          "source_name": "ADSecurity AD Kerberos Attacks",
          "description": "Metcalf, S. (2014, November 22). Mimikatz and Active Directory Kerberos Attacks. Retrieved June 2, 2016.",
          "url": "https://adsecurity.org/?p=556"
        },
        {
          "source_name": "GentilKiwi Pass the Ticket",
          "description": "Deply, B. (2014, January 13). Pass the ticket. Retrieved June 2, 2016.",

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