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Threat Hunting and Incident Response in a post-compromised environment

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Accepted: November 28th, 2019

Abstract

If you give an attacker 100 days to move freely in your compromised environment, the evidence is reasonably strong that your organization is pretty bad at Security Operations (The future of Security Operations). However, repeatedly sending false positives breach escalation to the forensic team is also problematic. It happens in a lot of large organizations, banks and, government institutions across the globe.

This paper starts with an overview of current significant problems identified in Security Operations and Digital Forensics and Incident Response (DFIR) teams and reasons behind them. Then, we will discuss on the solution that encompasses the MITRE ATT&CK framework (MITRE ATT&CK) along with a robust Cyber Threat Intelligence (CTI). Appropriate data collection sources for data enrichment, including all Cyber Security threat information expressed in the STIX language, will also be covered. Although the solution includes specific commercial and non-commercial products and tools from various vendors and organizations, we are not necessarily in favor of any. The core implementation of the MITRE ATT&CK framework, however, is performed in the IBM Resilient Security Orchestration, Automation, and Response (SOAR) product.

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1. Introduction

Security Operations Center team (SOC) is responsible for detecting any suspicious and malicious cyber activity in an organization. Once such activity is detected, SOC team generates a security incident report that includes any corresponding information, to hand it over to the Computer Emergency Response Team (CERT) or Computer Security Incident Response Team (CSIRT). The latter teams' responsibility is to validate the security incident and coordinate the Incident Response (IR) process. If it turned out to be a false-positive, the team is responsible for marking it and then closing it. SOC, CERT and CSIRT teams are also known as Security Operations (SecOps) with the primary goal as to detect and to respond to Cyber Security threats in defending an organization's networked computer environment including their crown jewels.

If SecOps identifies "the organization has been breached, their work is usually finished since they lack the expertise to comprehend a breach fully. So they hand over the incident to a DFIR team, consists of the most skilled and sought-after experts in the Cyber Security industry. DFIR experts can forensically understand and report on the full scope and complete impact of a data breach. Starting with the date, time, and method of the initial compromise, over privilege escalation" (Current Security Operations and DFIR problems) to lateral movement, and accomplishment of the ultimate attack target. It could be of an exfiltration of confidential data or the manipulation of systems or other types of attacks. For discovering this, DFIR experts use many different methods and tools. Evidences are gathered and preserved, to provide the means for its usability during litigation.

In the next chapter will discuss current problems of SecOps and DFIR teams. We will also cover a third discipline which is relatively new in Cyber defense, namely Threat Hunting. Following this, we will introduce a solution based on the MITRE ATT&CK and STIX frameworks underpinned by a sophisticated CTI. In the last chapter, a concrete implementation of the solution can be seen.

1.1. SecOps analysis and findings

According to a Forrester report (Forrester Now Tech.), the median breach confirmation time in 2017 was 101 days. So basically it took 101 days for SecOps to confirm a breach and hand it off to the DFIR team. However, DFIR teams are currently often annoyed by the input they receive from SecOps that they frequently request them not to forward anything at all.

One of the primary reasons we have found behind this is the success story "We've identified malware and removed it." Most SecOps organizations move directly to the containment, eradication, and recovery phase of the National Institute of Standards and Technology (NIST) framework without proper scoping an attack.

Firstly, if you don't scope a malware scenario out, you don't know anything about the context. As a result, you have no idea at all in which phase the attacker might be. He might be at the very initial stage of the attack, or he might have already compromised your environment and is about to exfiltrate data. You would be blind to the big picture.

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Secondly, if the attacker is an advanced adversary, you can be sure that he's watching your movements. If you begin to remove the threat partially, he might be thinking that you have started a fully-fledged remediation process. And what can be expected from an advanced attacker if he fears to lose his foothold from your compromised environment? If it is, then he is going to start another campaign to strengthen his foothold. That is even worse!

As shown in Figure 1, SecOps needs to improve their capabilities before spending more time and resources in the Detection & Analysis phase. Let me explain later what we mean by this.

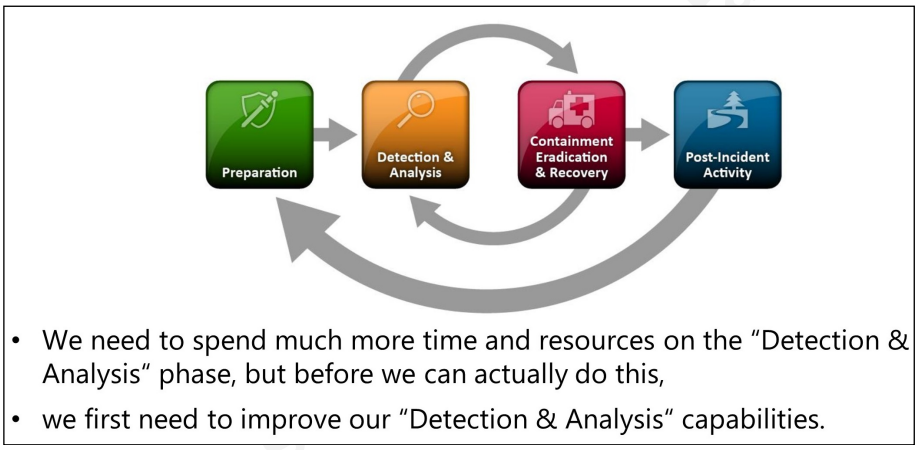

Figure 1: NIST Computer Security Incident Handling Guide

If we wanted to express the major reasons why Security Operations is performing poorly in a single headline, we could say that SecOps is scratching only on the surface. There are use cases that range from trivial to complex ones; however, an approach to classify, to categorize and to organize attack scenarios holistically is still lacking.

Also, when it comes to integrating with a CTI solution, SecOps is mostly concentrating on "Isolated Indicators of Compromise (IoC)" only. By "Isolated IOCs," we mean IP addresses, hash values, domain names, etc. that are neither put into a relationship nor is there provided any additional context as part of the CTI. Firstly, isolated IOCs are of little value if no context is supplied. Then, they are changing too rapidly during an attack so that one cannot entirely rely solely on them. The Verizon DBIR 2016 Report stated that 99% of malware hashes seen for just 58 seconds or less.

A robust and actionable CTI can help organizations in providing detailed context around an IOC. E.g. if your IOC is a known bad IP address, related entities like related IP addresses, domain names, email addresses, hash values, malware, products and tools, a Threat Actor and his used Tactics, Techniques and Procedures (TTPs) – tactical intelligence, a Threat Actor and his motivations – strategic intelligence, intelligence reports, etc. shall be provided. Having these kind of real facts helps in staying focused during the analysis without losing traction.

Checking the local relevance – findings – of IOCs adequately is another crucial step during an analysis. Once CTI provided IOCs have been validated in the local context, it's essential to pull in the corresponding timestamps – first-, last-packet –, source-destination relationships, bytes sent, bytes received, protocols and ports used, duration, domain name, etc. Not only is SecOps currently not looking into these kinds of details. They often even don't have the right technology in place that would provide this level of information.

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IOCs and local findings, along with all their corresponding context, need expression in a meaningful way. For this, a common expression language is required that allows to seamless data sharing between systems and tools, and to visualizes the relationships between them. OpenIOC and STIX are examples of such an expression language. OpenIOC was developed originally by Mandiant which is now owned by Fireeye whereas STIX is developed by OASIS, which is a non-profit consortium that drives the development of open standards. In other words, STIX is Open Source, and the current version is 2. STIX2 is specified in JSON format whereas its predecessors, STIX 1.1 and 1.2, were defined in XML format.

Unfortunately, most Cyber Security vendors have not yet adopted STIX as their preferred output format. Instead, vendors' native JSON format is still commonly used. This leads to heavy data conversion efforts to use STIX in today's environment. However, vendors have realized the importance of such an expression language and are therefore providing additional tools or have STIX2 compatibility on their roadmap.

1.2. DFIR analysis and findings

Major problems that we have encountered in DFIR teams is that, they have to deal with a plethora of tools with uncountable inputs and different output formats that are used manually on command line interfaces.

One of the biggest challenges we have found is the lacking or little integration of the DFIR tool landscape with the organizational infrastructure. Hence, when DFIR teams are conducting a breach analysis, they heavily rely on input from the SecOps and Infrastructure teams related to data collection. This is currently an entirely manual and a time consuming process.

Also, a proper communication and information sharing with the rest of the organization is currently not possible except by means of a ticketing system.

A lot of DFIR teams are also lacking or dealing with poor process driven, standardized procedures for known threat scenarios which prevents them from conducting the breach analysis in a structured and organized way (poor playbooks). Often, enterprises are afraid of funding internal DFIR teams because it's hard to measure their success in a pre-defined timeline. In other words, if a DFIR team is not structured well, there is a high probability that the breach analysis timeline is not predictable. That's why a lot of organizations hire an external DFIR Service Provider that acts as an Incident Response Retainer in case of an emergency.

Forensic tools used by DFIR teams, whether those are commercial products or open source tools, have one thing in common. They are mostly self-contained with no or little integration with 3rd party systems. As to the best of our knowledge, neither does Opentext Encase nor Access Data FTK, two well-known commercial products in the forensic field, have a REST API. The same is true for open source tools like Volatility, Plaso, Log2timeline, etc. This is the main reason we have found why DFIR teams are heavily dependent on the data provisioning from SecOps and Infrastructure teams and unable to communicate and share information to the rest of the organization in a standardized way.

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It's also difficult to provide a process driven procedures standardization since every breach is unique. However, there are still many common investigation routine tasks which need to be processed while triaging a breach.

1.3. Threat Hunting

As the above traditional forensic methods don't allow to respond in a timely manner and at scale, a shift can be observed in the market in the way forensic investigations are conducted today in contrast to "few years ago. Currently, a full-blown deep dive forensic analysis is only done on specific confirmed compromised systems in order to gather additional intelligence. As this doesn't scale across thousands or tens of thousands of endpoints, the new Endpoint Detection and Response (EDR) market has evolved over the last couple of years. Key players like Tanium, Crowdstrike and Carbon Black Response are providing real-time sensors on endpoints in order to quickly gather forensic artifacts via" (Rukhsar Khan, 2019) REST APIs and conduct live response. In our solution we will be leveraging Carbon Black Response for the endpoint sensing and for applying the Threat Hunting technique.

"The idea behind Threat Hunting is to shift from a reactive IR model to a proactive approach. In Security Operations, a detection team hands off an alert" (Operationalizing the MITRE ATT&CK framework for Security Operations, Threat Hunting and DFIR) to a CERT or CSIRT team which reactively kicks off the IR process for validating the incident and responding to it, in case it's a true incident. The goal with Threat Hunting is to proactively engage a team and hunt for known adversaries including their applied TTPs in an organization's networked computing environment. There are multiple different approaches to Threat Hunting. This paper is not intended to introduce the various forms of Threat Hunting.

In our solution we will be starting the hunt engagement by consuming high-quality initial triage results generated by the CERT or CSIRT team for level-1 analysis. These results will already be augmented by a sophisticated CTI which will be further leveraged by the Threat Hunting team in order to remain focused. We will apply different Threat Hunting techniques and support the CERT/CSIRT team in scoping the attack and limiting the capabilities of an intruder. This will mainly be based on live response with Carbon Black Response EDR in order to provide quick results.

2. Solution

Based on the experience within the last decade, dozens of large customers and new emerged market technologies such as Security Information and Event Management (SIEM), EDR, a sophisticated CTI, and advanced tools for computer and network forensics, it is clear that Security Operations, Threat Hunting and DFIR teams need to converge. This is necessary in order to detect and respond to incidents quickly and efficiently, compared to attackers operating their automated attack ecosystems. All three disciplines need to coexist in achieving goals to allow collaboration as well as orchestration, automation and response in single platform. Certainly, See our solution in Figure 2.

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- Secops, Threat Hunting and DFIR need to converge. The preferred tool should be SOAR.
- Security Operations and Threat Hunting need a holistic approach to analyze known Threat Scenarios with better CTI – strategic & tactical – and sophisticated data collection sources – e.g. endpoint sensing, flows, etc.
- DFIR needs to better integrate their forensic tools and procedures with the organizational infrastructure.

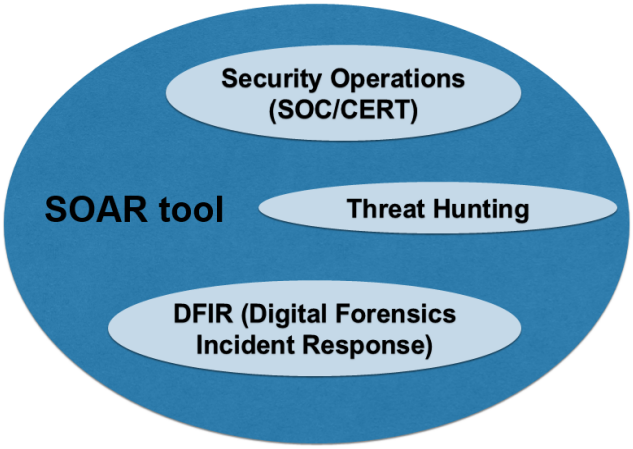

Figure 2: Solution – Claim

It should be noted that a SOAR platform is purpose-built for IR in Security Operations. However, we believe that many features are also well suited for supporting Threat Hunting and DFIR teams. To name a few, workflows, playbooks and orchestration techniques can help the latter teams in order to stay focused and provide quick results. Taking ownership of routine tasks through automation techniques a SOAR platform can further help these teams to free up valuable resources for the more sophisticated and manual tasks required during a Threat Hunting engagement or forensic investigation. Both teams will additionally require to leverage an EDR solution especially for data collection from the endpoint. DFIR teams also need to use a lot of additional forensic tools which can often be integrated with the SOAR platform.

In order to qualify Cyber Security threats and drastically reduce the median breach confirmation time, Security Operations and Threat Hunting teams need "holistic approach to analyze known threat scenarios. Also, they need to start an investigation on the right foot. This is why they need a better CTI that is providing comprehensive strategic and tactical intelligence and giving them context around their IOCs. In addition to this, sophisticated data collection sources need to be implemented. E.g. endpoint sensing and flows are absolutely essential as they provide the means to understand the IOCs in context of their local relevance" (Solution draft). All in all, the goal for SecOps should be to provide high quality results that are consumable by a Threat Hunting and DFIR team.

A Threat Hunting team should support a SecOps team in further scoping an attack by conducting individual TTP analysis and developing additional intelligence. Very importantly, a Threat Hunting team should also be able to identify an ongoing attack and advise the SecOps team how to restrict the capabilities of the attacker. DFIR needs to better integrate their forensic tools and procedures – playbooks and workflows – with the organizational infrastructure.

All of these are part of our solutions, however before we go into the details, we need to introduce the MITRE ATT&CK framework, some useful MITRE resources, sophisticated CTI of the providers Recorded Future and STIX.

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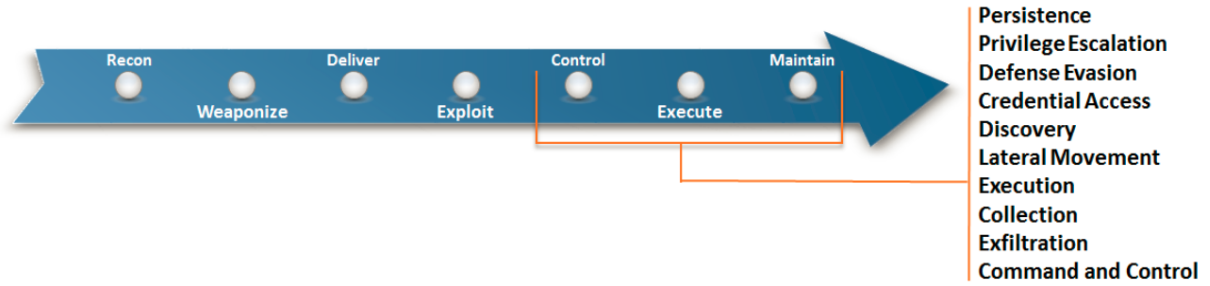
Figure 3 is showing the MITRE ATT&CK framework (MITRE ATT&CK). MITRE institute spent many years in analyzing the global high-profile breaches and categorizing them into individual TTPs. Currently, there are 11 tactics of the ATT&CK Matrix for Enterprise, starting off with Initial Access up to Command and Control, down to individual techniques. Every technique describes adversarial procedures and methods. You can also see on the right top corner, on how the ATT&CK Matrix for Enterprise maps to the Cyber Kill Chain. It fits into the last three phases and therefore a post-compromise matrix. A Pre-ATT&CK Matrix available that maps to the pre-compromise phases of the Cyber Kill Chain.



ATT&CK Matrix for Enterprise

The full ATT&CK Matrix below includes techniques spanning Windows, Mac, and Linux platforms and can be used to navigate through the knowledge base.

Initial Access	Execution	Persistence	Privilege Escalation	Defense Evasion	Credential Access	Discovery	Lateral Movement	Collection	Exfiltration	Command and Control
Drive-by Compromise	AppleScript	.bash_profile and .bashrc	Access Token Manipulation	Access Token Manipulation	Account Manipulation	Account Discovery	AppleScript	Audio Capture	Automated Exfiltration	Commonly Used Port
Exploit Public-Facing Application	CMSTP	Accessibility Features	Accessibility Features	BITS Jobs	Bash History	Application Window Discovery	Application Deployment Software	Automated Collection	Data Compressed	Communication Through Removable Media
Hardware Additions	Command-Line Interface	AppCert DLLs	AppCert DLLs	Binary Padding	Brute Force	Browser Bookmark Discovery	Distributed Component Object Model	Clipboard Data	Data Encrypted	Connection Proxy
Replication Through Removable Media	Control Panel Items	AppInit DLLs	AppInit DLLs	Bypass User Account Control	Credential Dumping	File and Directory Discovery	Exploitation of Remote Services	Data Staged	Data Transfer Size Limits	Custom Command and Control Protocol
Spearphishing Attachment	Dynamic Data Exchange	Application Shimming	Application Shimming	CMSTP	Credentials in Files	Network Service Scanning	Logon Scripts	Data from Information Repositories	Exfiltration Over Alternative Protocol	Custom Cryptographic Protocol
Spearphishing Link	Execution through API	Authentication Package	Bypass User Account Control	Clear Command History	Credentials in Registry	Network Share Discovery	Pass the Hash	Data from Local System	Exfiltration Over Command and Control Channel	Data Encoding
Spearphishing via Service	Execution through Module Load	BITS Jobs	DLL Search Order Hijacking	Code Signing	Exploitation for Credential Access	Password Policy Discovery	Pass the Ticket	Data from Network Shared Drive	Exfiltration Over Other Network Medium	Data Obfuscation
Supply Chain Compromise	Exploitation for Client Execution	Bootkit	Dylib Hijacking	Component Firmware	Forced Authentication	Peripheral Device Discovery	Remote Desktop Protocol	Data from Removable Media	Exfiltration Over Physical Medium	Domain Fronting
Trusted Relationship	Graphical User Interface	Browser Extensions	Exploitation for Privilege Escalation	Component Object Model Hijacking	Hooking	Permission Groups Discovery	Remote File Copy	Email Collection	Scheduled Transfer	Fallback Channels
Valid Accounts	InstallUtil	Change Default File Association	Extra Window Memory Injection	Control Panel Items	Input Capture	Process Discovery	Remote Services	Input Capture		Multi-Stage Channels
	LSASS Driver	Component Firmware	File System Permissions	DCShadow	Input Prompt	Query Registry	Replication Through	Man in the Browser		Multi-hop Proxy

Figure 3: Holistic approach – MITRE ATT&CK framework

The MITRE ATT&CK framework is a TTP-based, behavioral threat model. The goal is to detect and mitigate adversarial behaviors based on the individual TTPs as opposed to IOC-based detection and mitigation. As we learned before, IOCs are changing too rapidly but behaviors of an attack scenario can't change entirely. That's why MITRE ATT&CK is entirely concentrating on detection behaviors. This does not mean that we will not be looking at IOCs at all. We will start the investigation based on known IOCs that are relevant for our environment but after some initial triage tasks we will shortly switch to the behavioral model.

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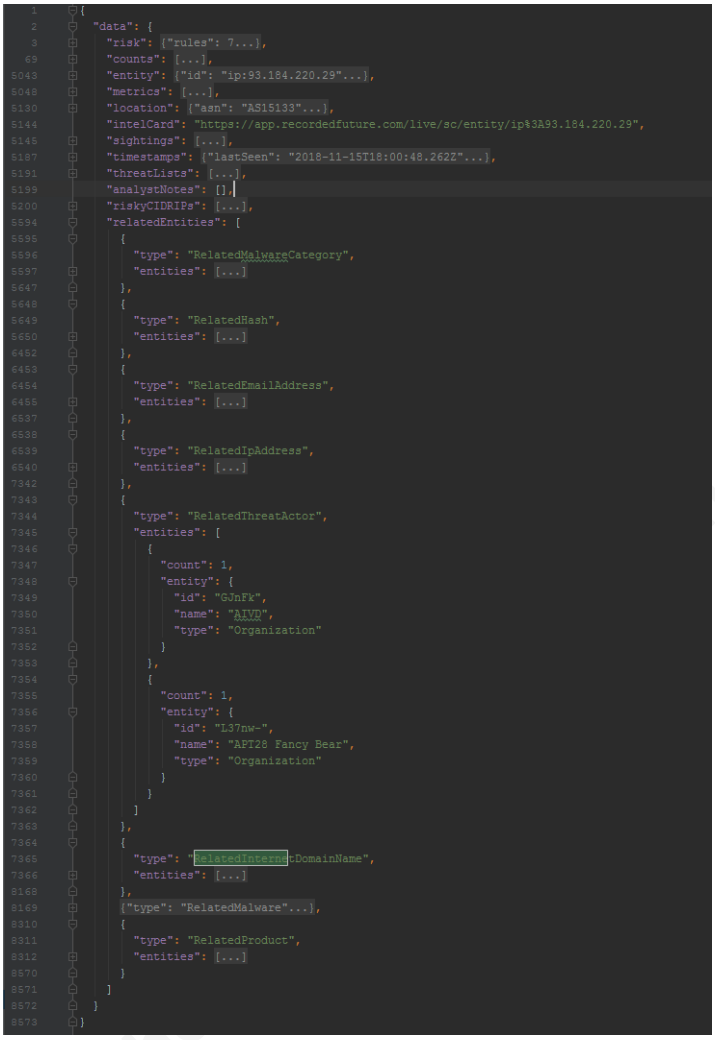

- A robust threat intelligence capability can:
  1. Provide real facts
  2. Inform an organization on the ATT&CK tactics and techniques on which to focus.
- Beginning the analysis on the right foot is crucial. Else you quickly lose focus and waste all your time.

Figure 4: Cyber Threat Intelligence – Recorded Future

So, for beginning the analysis on the right foot it is crucial to have an excellent and robust CTI in place that provides real facts and "informs an organization on the ATT&CK tactics and techniques on which to focus" (MITRE MTR170202). In our solution we are leveraging CTI from Recorded Future. See Figure 4.

This CTI is related to an IP address entity of the value 93.184.220.29. The term entity is equivalent to the term indicator which means that this is the IOC we are starting our investigation with. As you can see further down in the CTI there are multiple related entities to this indicator like related hashes, related email addresses, related IP addresses and most importantly for now a related Threat Actor – APT 28, a well-known Russian Threat Group – which we have learned should be part of a robust and actionable CTI. Based on the provided Threat Actor our next step is to map the CTI out to the MITRE ATT&CK Matrix. In our example we have two related Threat Actors, namely AIVD and APT28. Since MITRE is providing known Threat Actors and their used TTPs as part of the ATT&CK framework, you can simply map out TTPs based on the Threat Actor name.

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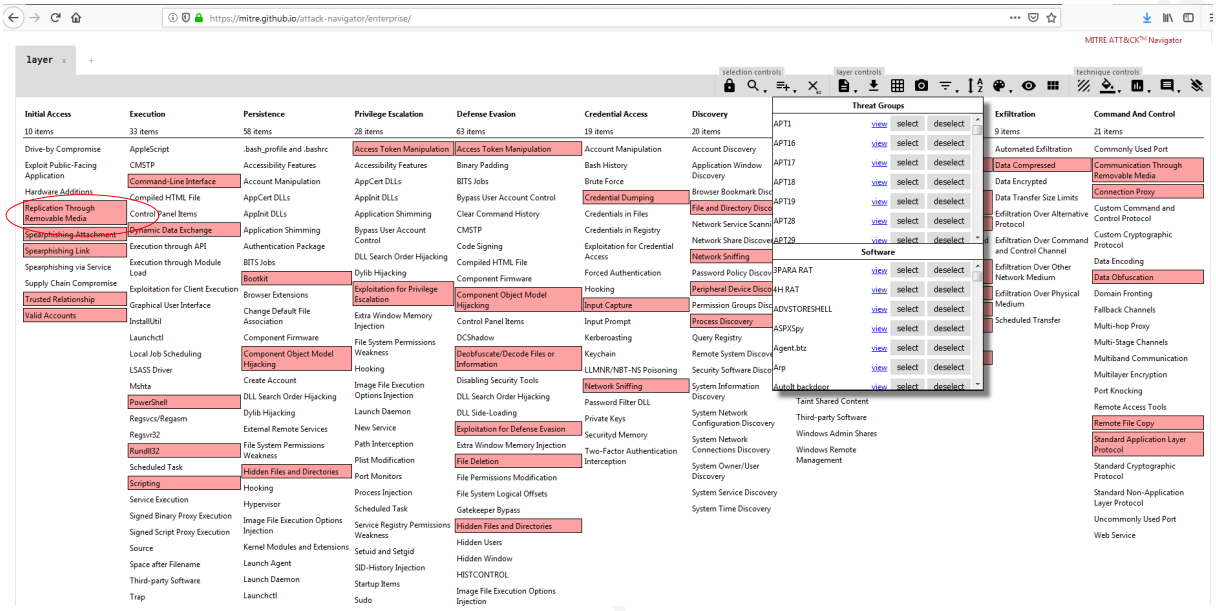

Figure 5: ATT&CK Navigator for Enterprise
(Source: https://mitre.github.io/attack-navigator/enterprise)

Figure 5 introduces a free tool from MITRE, the ATT&CK Navigator, that visualizes all the TTPs of one of the ATT&CK matrices, depending on which matrix you have loaded. In our example we have loaded the ATT&CK Matrix for Enterprise. This tool allows us to select a Threat Actor. Since our CTI indicates APT28 as a related Threat Actor and this specific Threat Actor is available in the ATT&CK framework, we can simply select it and the ATT&CK Navigator highlights all the related TTPs. This allows us to learn how the Threat Group is operating. If we right-klick on a TTP we can select to view the corresponding technique details. This opens a new browser tab which is linked back to the MITRE website. Every TTP has a unique id, some high-level information on the corresponding procedures and methods, examples out of the wild, detection and mitigation advise and a whole universe of further detailed references to known global high-profile breach reports. We call this the human readable version of the ATT&CK framework.

In our solution we are splitting the TTP provided information into multiple stages, namely *Stage 1 Analysis*, *Stage 2 Analysis* and *Stage 3 Analysis*. We will later describe what we exactly mean by this.

In contrast to the human readable version of the ATT&CK Matrix the entire framework is also available in machine code, more precisely in STIX2 format. As mentioned earlier, STIX2 is a specific JSON formatting. Based on Figure 6 and Figure 7 let's see what STIX2 is about.

STIX is a great language that can express and describe a Cyber Security threat or incident by breaking down its complex and obfuscated elements into individual structured objects and put those objects into a relationship. You can then visualize the relationships in a graph.

STIX2 defines twelve STIX Domain Objects (SDOs), namely Attack Pattern, Campaign, Course of Action, Identity, Indicator, Intrusion Set, Malware, Observed Data, Report, Threat Actor, Tool and Vulnerability. In addition to these, two additional STIX Relationship Objects (SROs) are defined which can put the SDOs in a specific kind of relationship. SRO names are Relationship and Sighting. Following is an enumeration of all the domain objects provided by MITRE ATT&CK as part of their framework:

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1. MITRE TTPs = Attack Pattern SDO
2. MITRE Mitigation = Course of Action SDO
3. MITRE Intrusion Set = Intrusion Set SDO
4. MITRE Malware = Malware SDO
5. MITRE Tool = Tool SDO
6. MITRE Identity = Identity SDO
7. MITRE Relationship = Relationship SRO

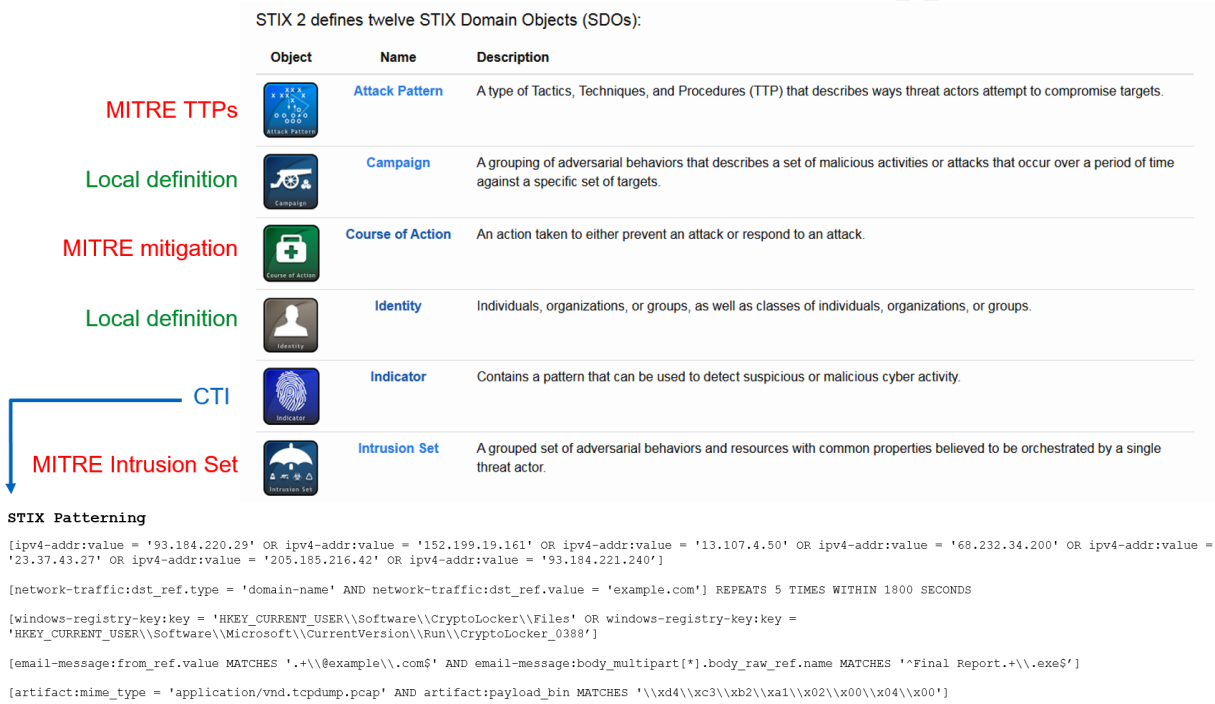

Figure 6: Structured Threat Information Expression (STIX)
(Source: https://oasis-open.github.io/cti-documentation/stix/intro)

An Attack Pattern SDO describes the TTPs a Threat Actor is using in order to compromise a target. A Course of Action SDO gives instructions on how to respond to the attack. An Intrusion Set SDO provides all the context around a Threat Actor or Threat Group, their motives, the way they are operating, etc. A Malware SDO expresses a malware variant that is used to compromise a target. A Tool SDO describes a tool that can be utilized in order to compromise a system. An Identity SDO simply describes an individual, an organization or a group. A Relationship SRO creates relationships of a specific type between SDOs in order to express that relationship. E.g. an Identity Set is using specific malware, a Course of Action mitigates an Attack Pattern, an Identity is targeted by a tool, etc.

Other SDOs or the Sighting SRO which are not provided by MITRE ATT&CK need to get derived from other sources. E.g. the Indicator SDO can come from a CTI feed. Contextual objects like Report SDOs, Threat Actor SDOs and Tool SDOs can also be delivered as part of a robust and actionable CTI.

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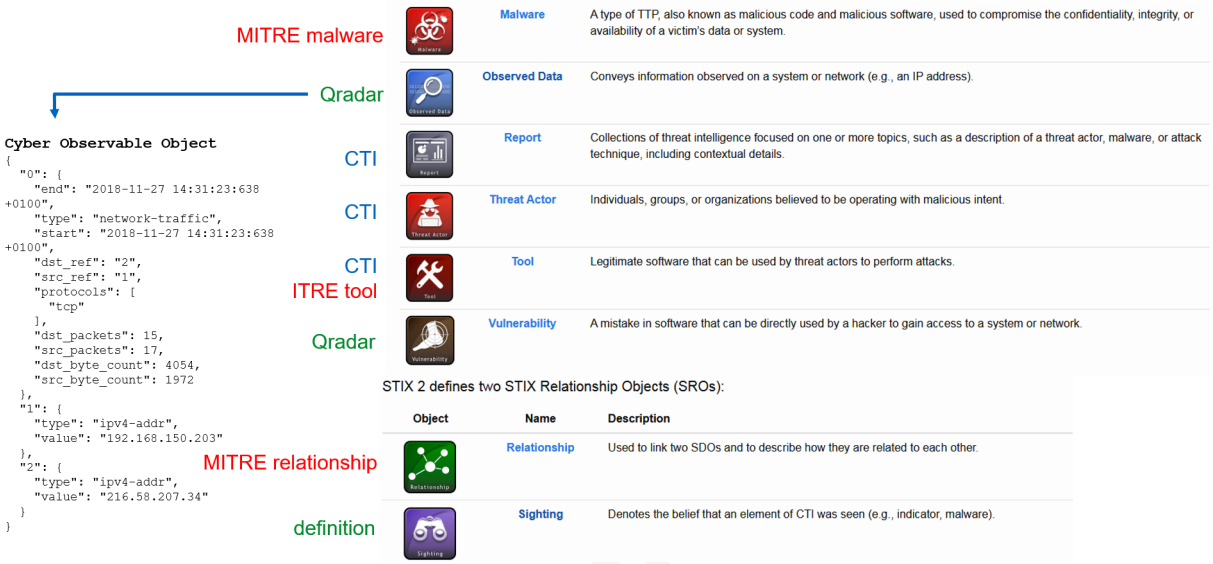

Figure 7: Structured Threat Information Expression (STIX) continued
(Source: https://oasis-open.github.io/cti-documentation/stix/intro)

Observed Data and Vulnerability SDOs can be created from data collected from an internal Cyber Security defense system like a SIEM, Vulnerability Management system, EDR system, etc. that has matched against a CTI provided indicator in order to express the local relevance. Putting an Indicator SDO into a relationship with an Observed Data SDO is done by the special Sighting SRO.

When operationalizing MITRE ATT&CK and STIX a defending organization can develop SDOs and SROs by leveraging the STIX2 Python APIs (Oasis Open) which are available for free. Let's take a closer look at the Indicator SDO. In order to express a suspicious or malicious IOC with all its context a CTI provider can use STIX patterning which is defined in its own document (Oasis Open). As seen in Figure 6, STIX patterning allows you to narrow down suspicious or malicious behavior very granularly. In Figure 7 you can further see how the local relevance of an IOC expressed by an Indicator SDO is defined by a Cyber Observable Object (Oasis Open) that is part of the Observed Data SDO. Cyber Observable Objects can be far more comprehensive in order to specify any kind of local findings.

In Figure 8 you can further see SDOs put into relationships. A small example in the right top corner is showing how an indicator indicates a Campaign which is in turn attributed-to a Threat Actor and targets a Vulnerability. A graph could look like the one in the middle of this illustration if more context is available.

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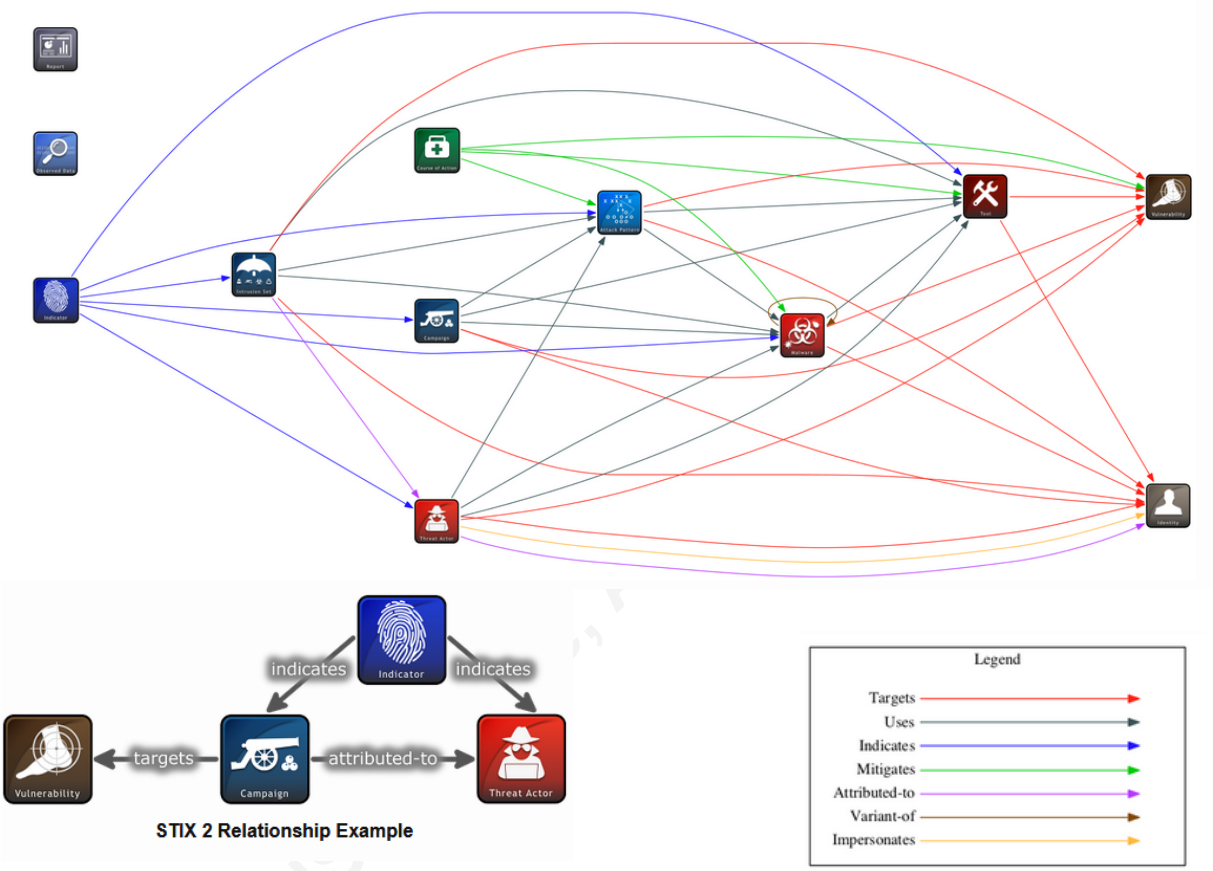

Figure 8: Structured Threat Information Expression – Relationship types
(Source: https://oasis-open.github.io/cti-documentation/stix/intro)

3. Implementation

This section details on how we implemented our solution. "As mentioned earlier, our core implementation of the MITRE ATT&CK framework is performed in the IBM Resilient SOAR platform" (Implementation – Overview – steps 0-6). In order to converge Security Operations, Threat Hunting and DFIR in this single platform we have defined three stages, namely *Stage 1 Analysis*, *Stage 2 Analysis* and *Stage 3 Analysis*. *Stage 1 Analysis* corresponds to a SecOps Level-1 IR team, *Stage 2 Analysis* to a Threat Hunting team and *Stage 3 Analysis* applies to a DFIR team. See Figure 9.

Only the items that we have colored red are the ones that we have integrated with IBM Resilient as part of this writeup. These are Recorded Future Threat Intelligence, IBM QRadar SIEM with Wincollect and Sysmon for the endpoint sensing, IBM QRadar Network Insights (QNI) for creating network flows (Internet Protocol Flow Information Export (IPFIX)), A10 SSL interception proxy for intercepting and decrypting SSL traffic, Carbon Black Response as the EDR and Volatility for deep dive forensics. Except for Volatility all our integrations are based on REST APIs. For better understanding our implementation we have given some items of the Stage 1 Analysis unique step numbers. These are the steps that we will demonstrate on the following diagrams. Other system and tool integrations will follow later.

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Stage1 Analysis – L1 (Secops):

- Recorded Future Threat Intelligence (steps 0.2, 5)
- SIEM Qradar events – Wincollect - Sysmon (steps 2-6)
- QNI Flows (steps 7-10)
- A10 SSL interception proxy

Stage2 Analysis – L2 (Threat Hunting):

- CB Response

Stage3 Analysis – L3 (DFIR):

- Volatility
- Plaso, Log2timeline, etc.
- Qradar Incident Forensics, PCAP
- Google Rekall Agent Server
- Cuckoo Sandbox

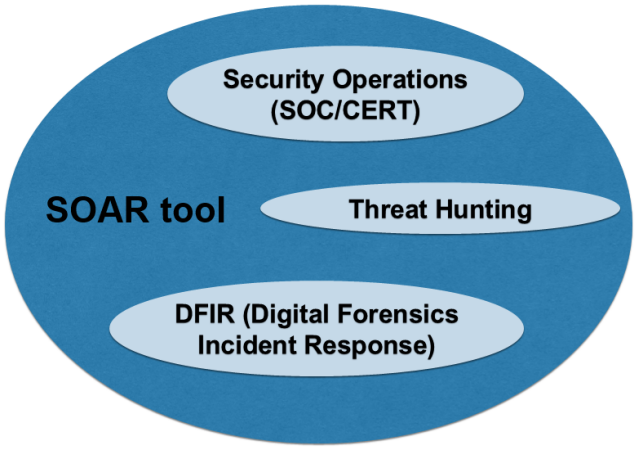

Figure 9: Solution continued

3.1. Stage 1 Analysis – L1 SecOps

3.1.1. Find Recorded Future matched destination IPs and load CTI – steps 0-6

Figure 10 on the next page is visualizing how we are initially detecting destination IP addresses that have matched against the Recorded Future (RF) CTI and what actions we are taking in order to get context. As a prerequisite for this solution to work properly we are first loading the complete MITRE ATT&CK Matrix for Enterprise into a Postgres database named test. To accomplish this, we have written a script that leverages the MITRE TAXII server (step 0.1). Secondly, we are integrating QRadar with Recorded Future by taking advantage of the available Recorded Future app. This app can be configured in a way that it loads RF provided Risklists into QRadar Reference Sets (step 0.2). By defining an RF risk score we were able to limit the number of objects – IP addresses, hash values, domain names, etc. – that are loading into these reference sets. E.g. we configured 65 which corresponds to a high-risk score. We also specified a time interval for updating the reference sets hourly.

Within QRadar we have created rules that point to the reference sets. If any local-to- remote network traffic that matches against an IP address object in a reference set has been identified, the rule fires an alarm which is called offense in the QRadar terminology. An offense contains all the related event[1] and flow data that has been recorded according to the configured rule specification. An offense also includes a list of source and destination IP addresses that have been identified as part of the offense. We are escalating this offense automatically into Resilient which is represented as a new incident (step 1).

[1] Event data is equivalent to log data in the QRadar nomenclature

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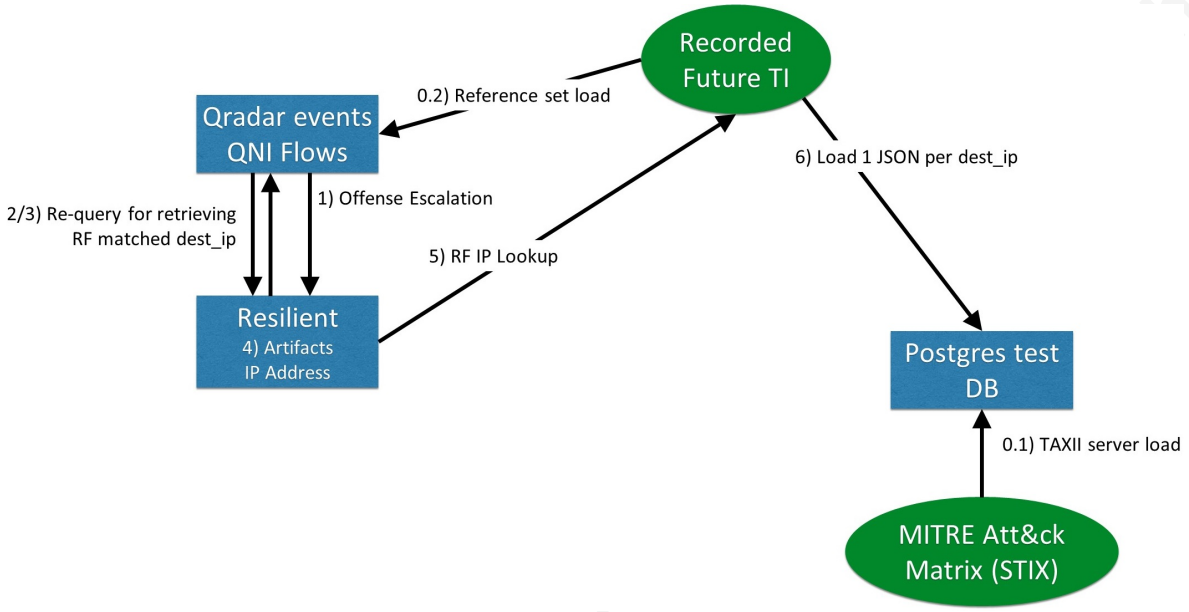

Figure 10: Steps 0-6 – Functions diagram on Steps 0-6 – Functions diagram

The offense escalation process is only taking high-level information from the QRadar offense into the Resilient incident. If the analyst needs to enrich the original incident by additional information, he can simply take advantage of Resilient's automation feature that re-queries the QRadar Ariel[2] database and loads the additional information into the incident.

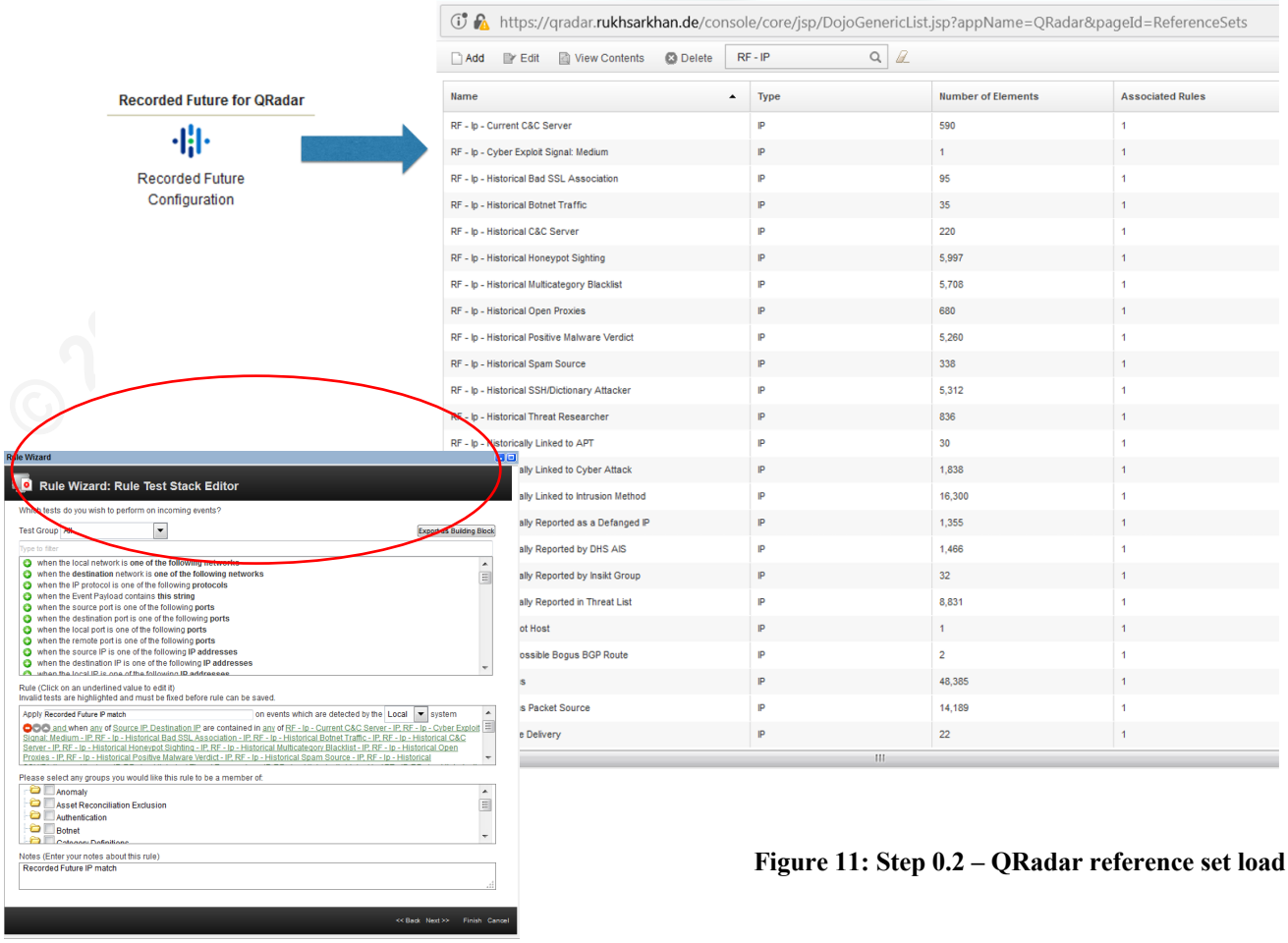

Figure 11: Step 0.2 – QRadar reference set load

[2] Ariel is the name of the QRadar log/event database

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From the list of all the suspicious destination IP addresses that have been detected by QRadar as part of an offense we want to load the RF matched destination IP addresses into the Resilient incident. For this we are re-querying QRadar from within Resilient (steps 2-3) and loading the retrieved RF matched destination IP addresses into the incident's Artifacts (step 4) tab. An artifact in the Resilient context is an IOC. We have configured to trigger another automation that accomplishes an IP lookup for every newly created RF matched IP address artifact (step 5) in order to load the detailed CTI with all the IOC context in our test database (step 6).

Figure 11 is visualizing the loading of objects by the RF app provided risklists into QRadar reference sets. Reference sets have a Name, Type, Number of Elements and Associated Rules column. The associated rule is also shown on the right side of this illustration.

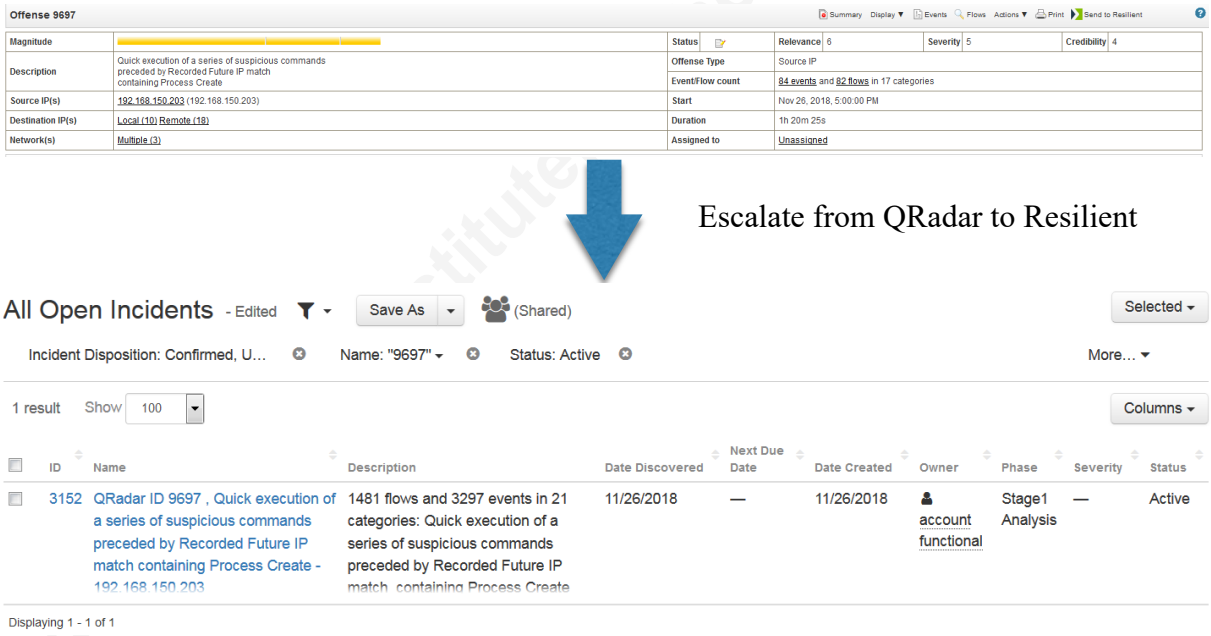

Figure 12: Step 1 – Qradar offense escalation

The QRadar offense escalation into Resilient is further illustrated in Figure 12. As you can see, the offense has a unique number which in our example is 9697. The source IP – or potential victim IP – address is 192.168.150.203. There is a total of 18 remote destination IP addresses, 84 events and 82 flows recorded as part of this offense. Once this offense is escalated into Resilient, either automatically or manually by clicking on the Send to Resilient button on the right top corner of the offense, this offense becomes an incident in the Resilient SOAR platform. When the incident is created, the name and description of the incident are derived from a field mapping configuration in the QRadar Resilient app. This app is installed on QRadar and is required to escalate QRadar offenses to Resilient.

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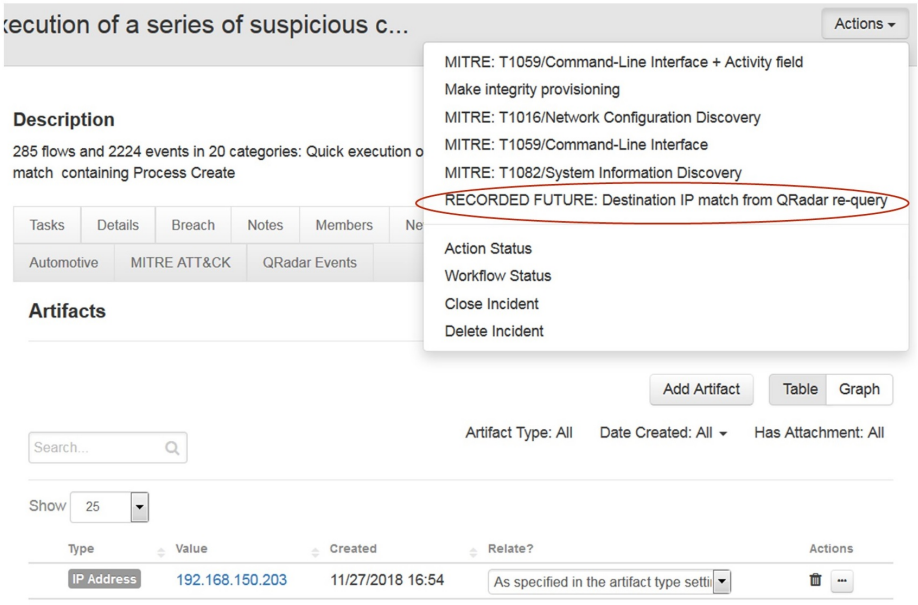

Figure 13: Step 2 – RECORDED FUTURE: Destination IP match...

In order to trigger the re-query from Resilient to QRadar we have provisioned the RECORDED FUTURE: Destination IP match from QRadar re-query action which constitutes step 2 and can be seen in Figure 13.

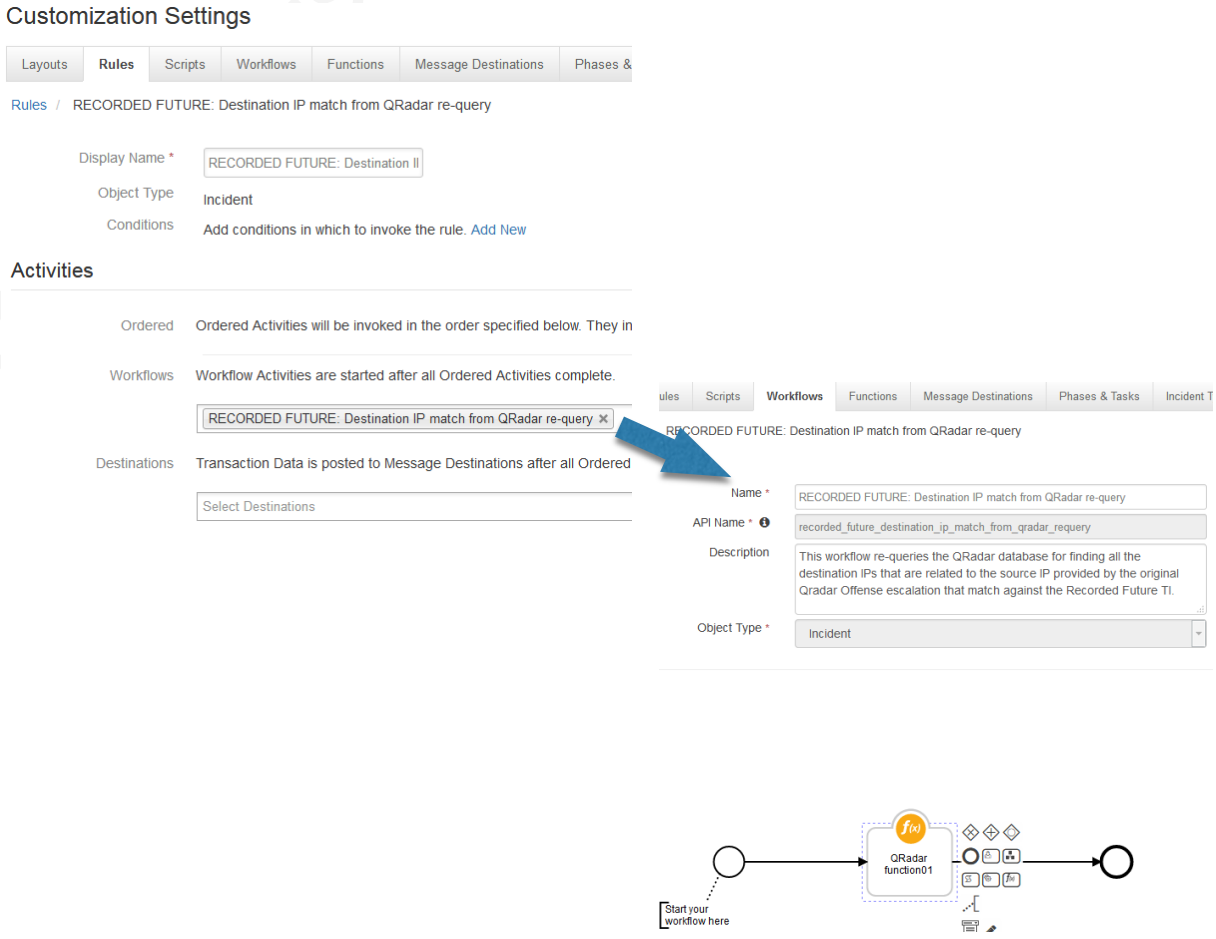

Figure 14: Steps 2-3 – Rule / Workflow

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This action is provisioned by a menu-item rule, also known as a semi-automation. A semi-automation requires user intervention to trigger the automation. In contrast to this a full automation is provisioned by an automatic rule that specifies one or more match conditions. If the match condition is true, the automation is triggered without user intervention.

Figure 14 is further elaborating on steps 2-3. On the left side of this illustration we can see that the rule RECORDED FUTURE: Destination IP match from QRadar re-query is calling a workflow. The workflow has only a single function. Functions have a pre-process script, a function processor and a post-process script.

```
inputs.ariel_sql_query = "select destinationip from events where inoffense(" +
    incident.properties.qradar_id + ") and qidname(qid) = 'Recorded Future IP
    match' GROUP BY destinationip START PARSEDATETIME('" + str(incident.
    discovered_date) + "') STOP PARSEDATETIME('now')"
inputs.incident_id = incident.id
inputs.source_ip = incident.properties.source_ip_address
inputs.typ_flag = ''
```

Figure 15: Steps 2-3 – Pre-process script

The pre-process script above defines an input variable name (inputs.ariel_sql_query) and a corresponding value which in our case is a select statement for querying the QRadar Ariel database. Our select statement is simply searching for all destination IP addresses that are part of the incident's offense ID (incident.properties.qradar_id) AND have a qidname equal to "Recorded Future IP match". Qidname is the name of the QRadar event, so we are matching only on events that have matched against the RF CTI. The query time range is further limited to the discovered date of the incident until now. Now is an Ariel Query Language function that specifies the current time. This input parameter is now taken into a function processor. A function processor is a Python script that can provide 3rd party system APIs and is able to integrate with these. In our example we have a function processor with the QRadar Python APIs. We are using this function processor to process our input parameter (select statement) and provide us with a corresponding result set.

```
for entry in results.events:
 if entry is None:
     break
 else:
     row = incident.addArtifact("IP Address", entry.destinationip, "Provided by
    RECORDED FUTURE TI match")
```

Figure 16: Steps 2-3 – Post-process script

The result set is formatted as a JSON string and is eventually taken as input into our post-process script (see Figure 16). The post-process script in our example is simply iterating over the result set and is creating an IP address artifact with the description "Provided by RECORDED FUTURE TI match" for every included destination IP address (see Figure 17). Resilient workflows, pre- and post-process scripts, function processors, the REST API and much more are described in detail under the IBM Resilient Developer portal (IBM Resilient Developer portal).

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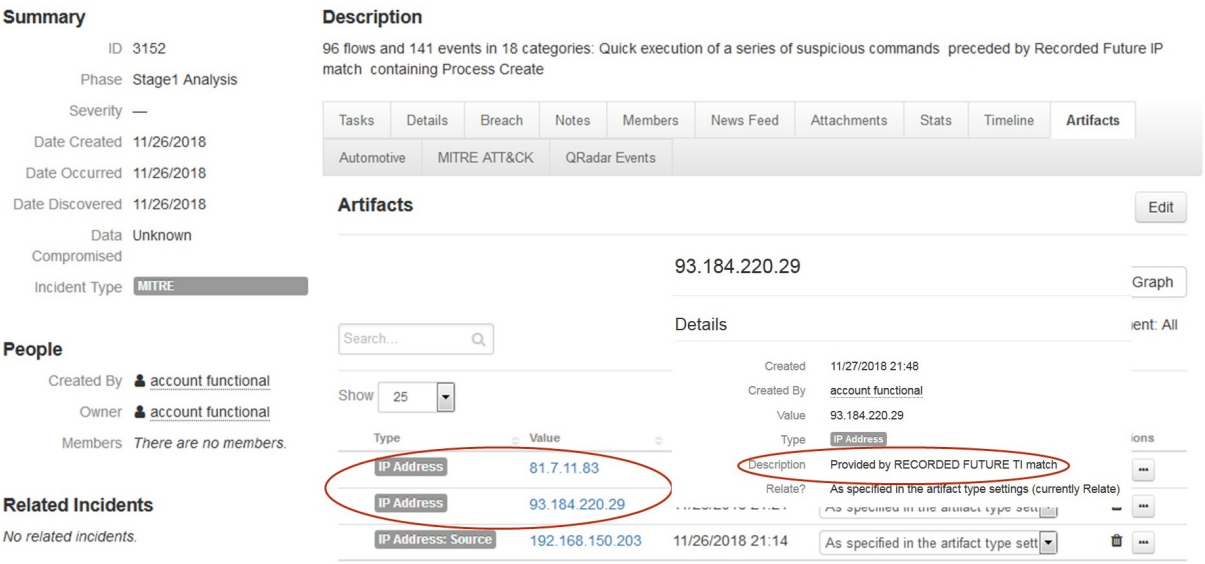

Figure 17: Step 4 – Result

Next, an automatic rule is triggered as part of step 5 if the following match condition is true: If an Artifact is created AND the Type is equal to IP Address AND its Description is equal to "Provided by RECORDED FUTURE TI match". As this condition is true in our example, a JSON message is sent to a queue named RF lookup on the Resilient message bus that triggers an action processor. See Figure 18.

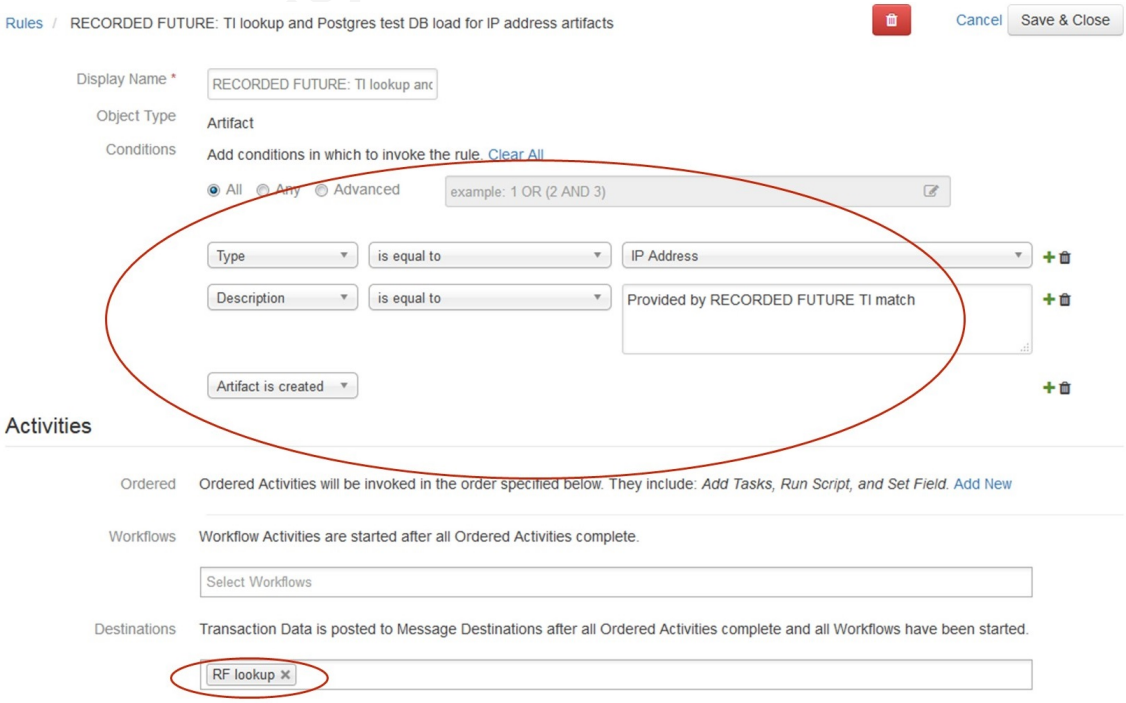

Figure 18: Step 5 – Automatic rule – RECORDED FUTURE: TI lookup...

In contrast to a function processor that is used when you want to write changes back into the Resilient platform efficiently, an action processor can be used when you need to trigger a script but do not necessarily need to write changes back into Resilient. As step 5 doesn't require this, we have chosen to call an action processor script by this rule. This script performs an IP lookup operation against the Recorded Future Connect API (Recorded Future)

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in order to search for the detailed CTI for the two RF matched destination IP addresses 81.7.11.83 and 93.184.220.29 and loads the result set into the Postgres test database (step 6).

Figure 19 is displaying some details on the stored CTI for entity 93.184.220.29 (IOC). As you can see, the evidenceDetails key has a list of multiple rules that are providing intelligence around the IOC. Later in our solution we will be concentrating on the key relatedIpAddress because we want to verify the local relevance of all the provided related IP addresses for this IOC.

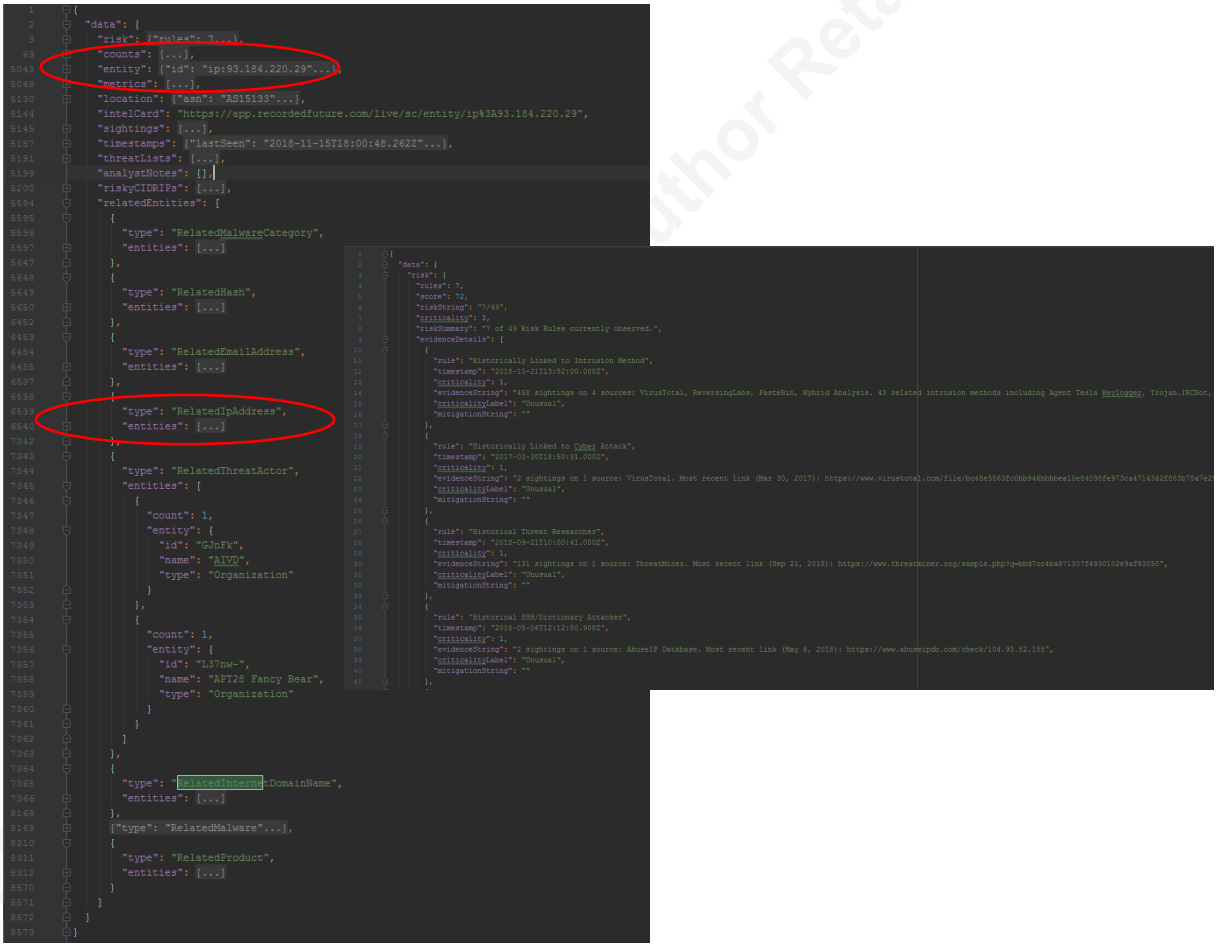

Figure 19: CTI – RECORDED FUTURE example JSON

3.1.2. Produce STIX bundle and fill data table – steps 7-10

As part of this solution "we are expressing the CTI provided IOCs in STIX Indicator SDOs and their local relevance in STIX Observed Data SDOs. We are further generating Sighting SROs in order to visualize that we sighted IOCs in the local context. We are also leveraging the Identity SDO in order to specify Recorded Future as an organization that we are receiving indicators from" (Operationalizing the MITRE ATT&CK framework for Security Operations, Threat Hunting and DFIR). In order to put the Identity SDO into a relationship with other SDOs we are making use of the Relationship SRO. For generating a visualized graph, we are finally creating a STIX bundle. A STIX bundle packages multiple STIX SDOs and SROs into a single entity which can be loaded into a STIX Visualizer (Oasis Open).

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Figure 20 is illustrating with steps 7-10 how we are achieving the above goal. Step 7 is first of all re-querying QRadar in order to receive flow details on the previously RF matched IP addresses. These flow details are required to provide context around the local relevance. We are expressing the local relevance in a STIX Observed Data SDO and the RF matched IP addresses in an Indicator SDO. As QRadar currently doesn't provide result sets in STIX format, we need to convert the received QRadar JSON of step 8 into STIX. For this we are using a free IBM Python library called STIX Shifter (Github) that we have customized to our needs. We are then loading the flow details into a data table available in the Resilient incident (step 9). In step 10 we are further loading the STIX bundle into our Postgres test database.

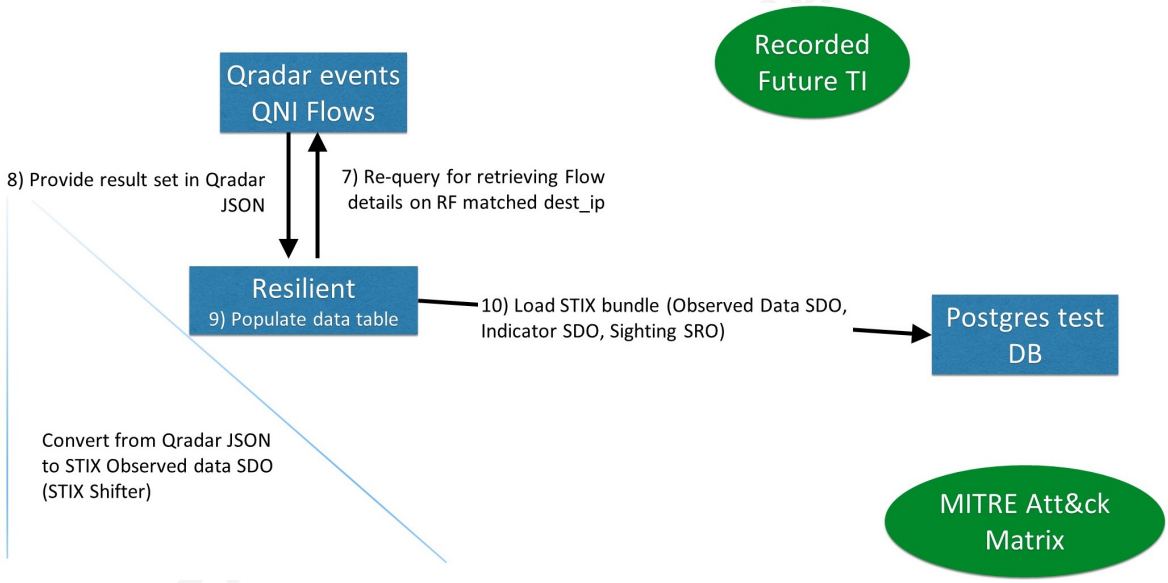

Figure 20: Figure 1.26: Steps 7-10 – Functions diagram

3.1.3. Verify Related entities – only relevant Related IPs, hashes and domain names – steps 11-15

Figure 21 is illustrating steps 11-15 of our solution. Taking benefit of our actionable CTI, the goal is to verify the related IP addresses, hashes and domain names of the RF matched destination IP address 93.184.220.29 that have been part of its corresponding CTI. We are verifying all these related entities "against the QRadar Ariel database and are only considering the ones that have a local relevance, i.e. local-to-remote network traffic that matched against a related entity" (Operationalizing the MITRE ATT&CK framework for Security Operations, Threat Hunting and DFIR). Finally, we are taking those matching related entities into the Resilient incident's Artifacts tab.

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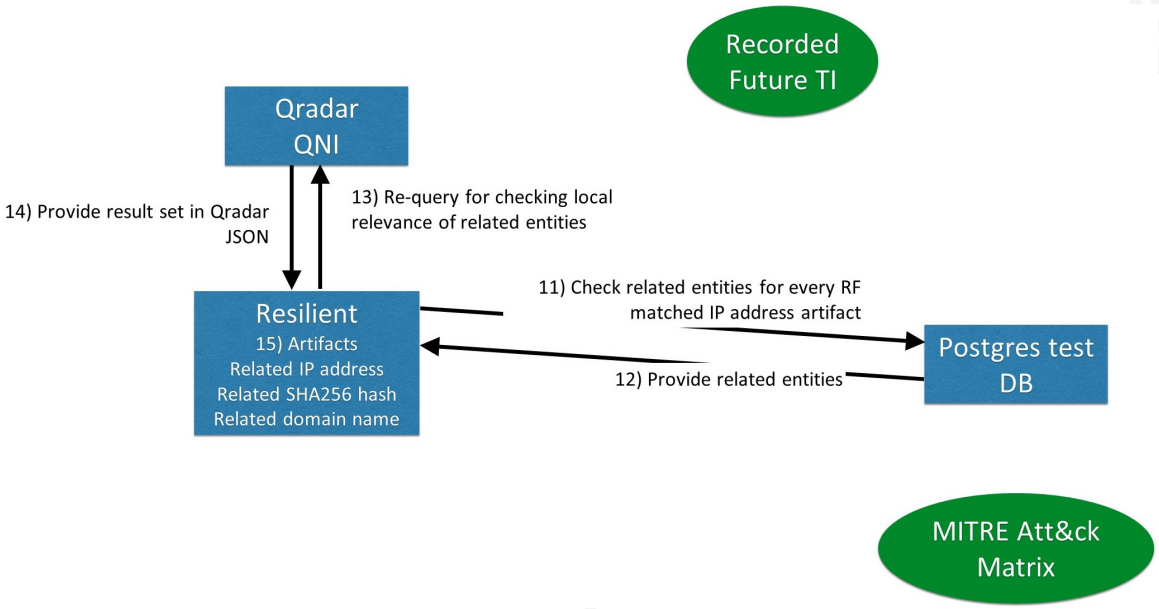

Figure 21: Steps 11-15 – Functions diagram

On the top left corner of Figure 22 we can see that a menu-item rule under the name RECORDED FUTURE: Verify Related Indicators "that relates to an incident artifact has been provisioned. Once we trigger this action against an IP address artifact another window pops up (bottom left) where we have to define a start and end time for the QRadar query. We are no longer specifying the query start time as the incident discovered date as we want to extend our search window to a selective value" (Implementation – Related IP Addresses – steps 11-15) that allows us to go beyond the incident discovered date.

As you can see on the right side of this figure all the Related IP addresses and Related domain names are shown up. If related hash values were also part of the local findings, they would also show up in the Resilient Artifacts tab.

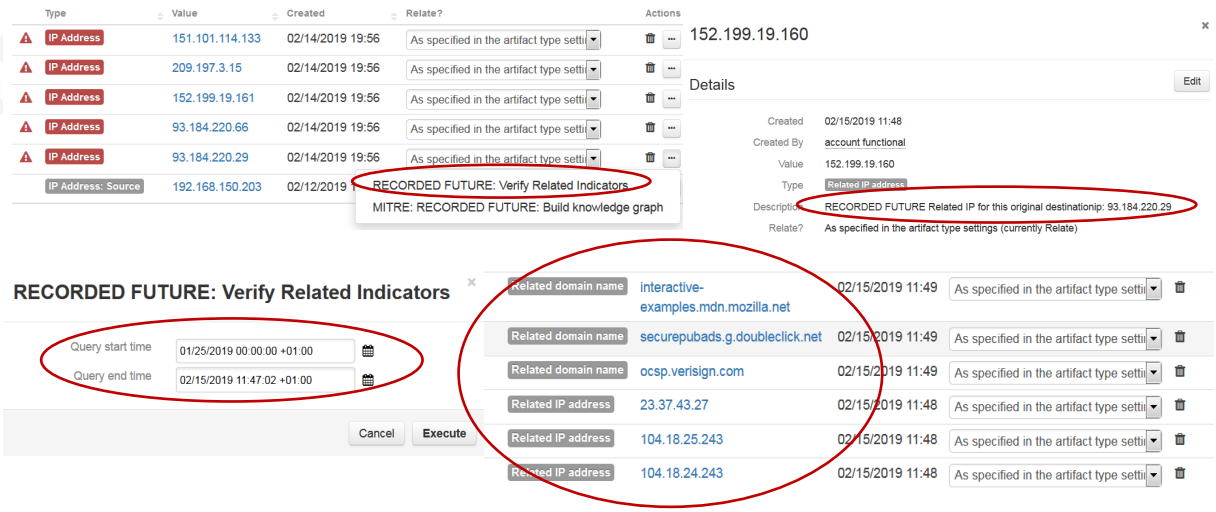

Figure 22: Steps 11-15 – RECORDED FUTURE: Verify Related Indicator. . .

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3.1.4. "Create STIX knowledge and Its relevance graph – steps 16-21

Once we have all the relevant information handy, we eventually want to generate two graphs, a STIX knowledge and a relevance graph.

In order to generate the knowledge graph, we are first checking whether a related Threat Actor (step 16) has been provided as part of the CTI, and if yes, we are mapping it out to the MITRE Intrusion Set (step 17). Next we are searching recursively what tools and malware are utilized by that specific Intrusion Set. Then we are creating a STIX file that includes all the identified Tool SDOs and Malware SDOs along with the Intrusion Set SDO, all provided by MITRE. Next, we are further leveraging the CTI in extracting reports and generating a Recorded Future Identity SDO along with Report SDOs and loading these into the same STIX file. Finally, we are loading the STIX file that is representing the knowledge graph into the Attachments tab of our Resilient incident (step 18). See Figure 23 below" (Implementation – STIX knowledge and relevance graph – steps 16-21).

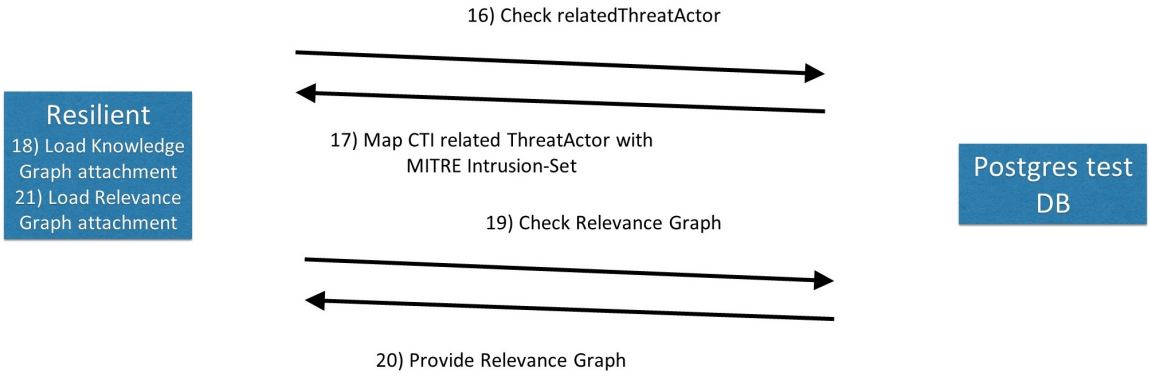

Figure 23: Steps 16-21 – Functions diagram

The goal with the knowledge graph is to consolidate as much as possible knowledge around a specific Intrusion Set or Threat Actor in a single graph. This allows us to learn very quickly how the Threat Actor is operating.

The goal with the relevance graph is to see at a single glance which CTI provided IOCs and their related entities do have a local relevance, how these are related to each other and what is the local context around these. The relevance graph is generated by pulling in and merging the previously created individual STIX bundles that are stored in our Postgres test database to a single larger bundle (steps 19-20). We also include a mapping of the relevant domain names and hash values to the corresponding Observed Data SDOs.

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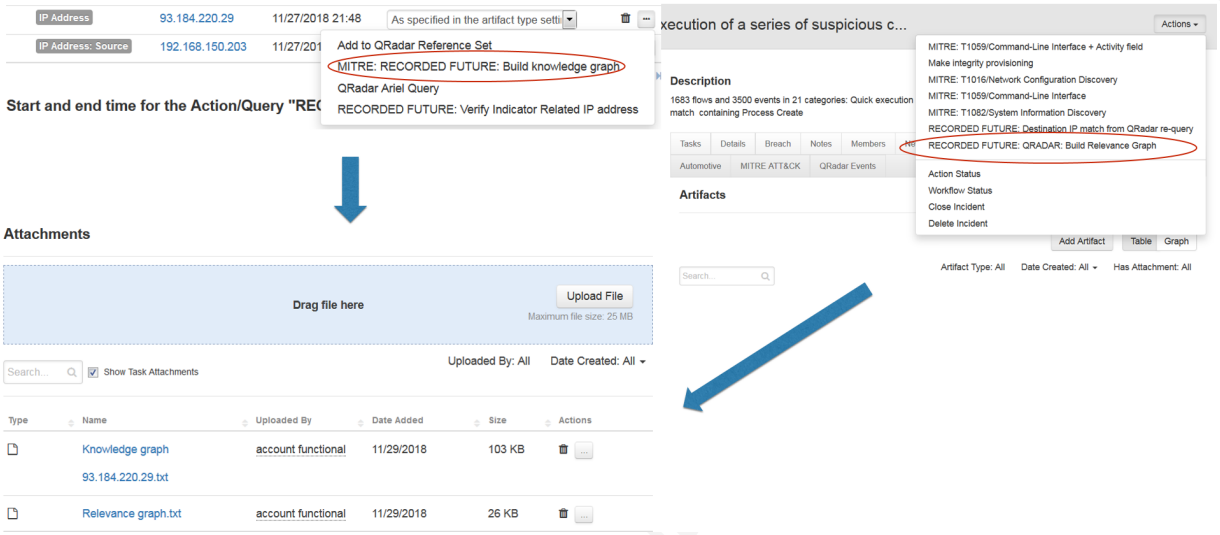

Figure 24: Steps 16-21 – Build knowledge and relevance graph

The knowledge and relevance graphs are both generated by triggering a corresponding menu-item rule in the Resilient platform and for each of these two actions a separate file is loaded in the incident's Attachment tab. See Figure 24 above.

Figure 25 and Figure 26 are showing the two graphs, which need to get loaded into the STIX Visualizer by manually downloading the incident attachments to the file system of the local machine.

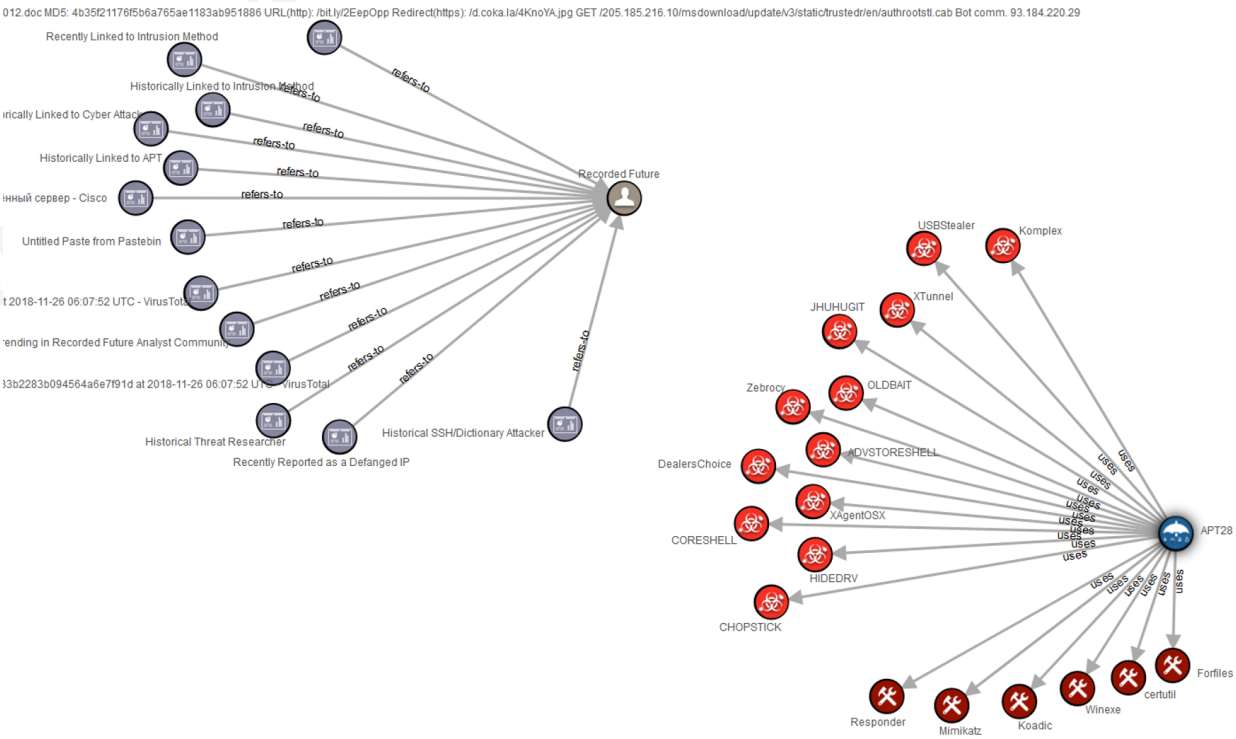

Figure 25: Steps 16-21 – knowledge graph

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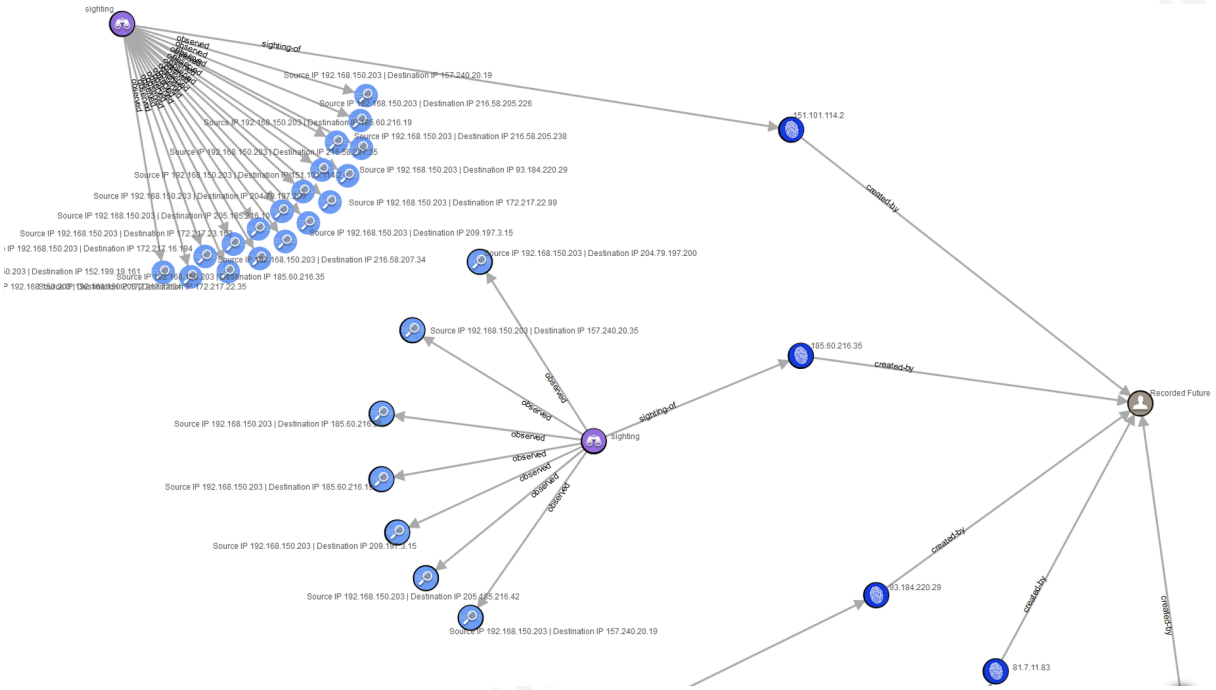

Figure 26: Steps 16-21 – relevance graph

All the nodes in the STIX Visualizer are a graphical representation of their corresponding STIX Domain or Relationship Object. If you klick on a node, the SDO or SRO details are shown on the right side of the browser tab. We have selected the Intrusion Set – APT28 – node in the knowledge graph. We can see an extract of the node details that are part of the Intrusion Set SDO provided by MITRE.

The way we have built the relevance graph is as follows:

- Create a Recorded Future Identity SDO as the root node of the tree.
- Create Indicator SDOs based on the RF matched destination IP addresses found in QRadar, which BTW have increased over time during our analysis.
- For every Indicator SDO, create a STIX pattern that searches for the Indicator IP address or any of its related IP addresses. E.g. ipv4-addr:value=’93.184.220.29’ OR ipv4-addr:value=’205.185.216.42’. See Figure 27.
- Create Observed Data SDOs for every source-destination IP address relationship that is related to the Indicator SDO or any of its related IP addresses.
- Create a Sighting SRO in order to put an Indicator SDO into a sighting relationship with all its corresponding Observed Data SDOs.

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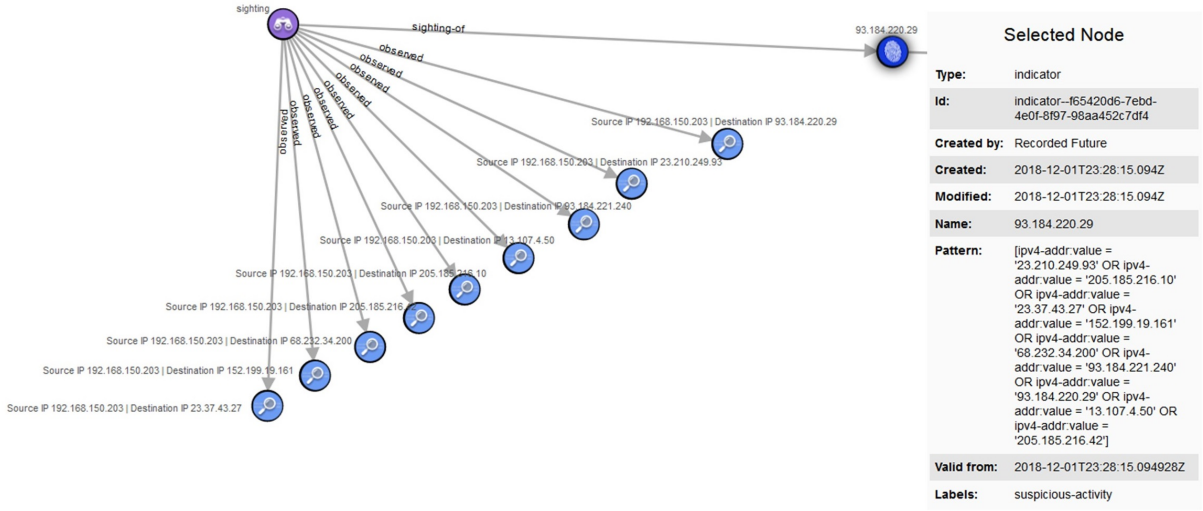

Figure 27: Relevance graph – Indicator SDO

By clicking through the Observed Data SDOs of IOC 93.184.220.29 and its related IP addresses, we quickly found some suspicion (see Figure 28). The source-destination relationship 192.168.150.203 –> 205.185.216.4 (right column) is showing that the source IP has sent more than 4 MB in 3910 flows in about 150 milliseconds. This definitely needs some closer look. More specifically we need to understand what exactly has been sent and whether that was legitimate network traffic or a malicious data exfiltration.

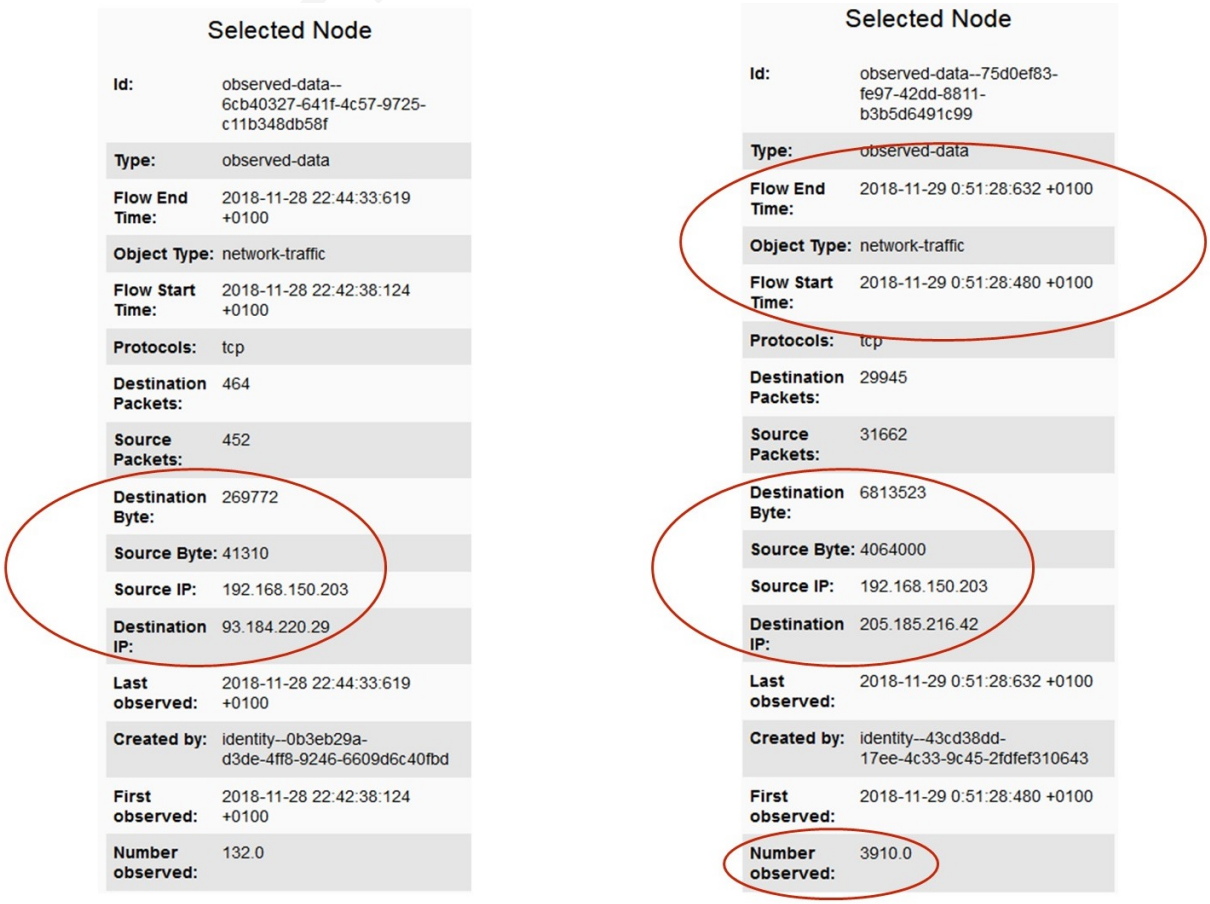

Figure 28: Relevance graph – Observed Data SDOs

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"As we have learned, all the TTPs potentially used by a known MITRE Intrusion Set are put into relationship by the Relationship SROs that are provided as part of the ATT&CK framework. Since we have loaded the complete framework in STIX2 format in our Postgres test database, we can identify these TTPs recursively by verifying the relationships of the Intrusion Set" (Resilient Workflows and Playbooks).

A SOAR tool like IBM Resilient can further help us by providing workflows and playbooks in order to trigger additional automation actions and giving instructions to an analyst. Depending on which Intrusion Set / Threat Actor has been identified, a generic workflow can call another workflow in order to satisfy the analysis requirements implemented for the corresponding TTPs. E.g. Figure 29 is illustrating how a generic workflow named MITRE is calling the workflow MITRE: APT28 after identifying APT28 as the Threat Actor. The MITRE: APT28 workflow extract can be seen on the right side of this illustration. This workflow combines the creation of task instructions (e.g. MITRE: T1003/Credential Dumping, MITRE: T1056/Input Capture) that are provided to the analyst in the form of a playbook and the calling of another workflow named MITRE: T1059/Command-Line Interface (top right) that is triggering an automation script for additional data collection and enrichment for satisfying TTP # T1059 requirements.

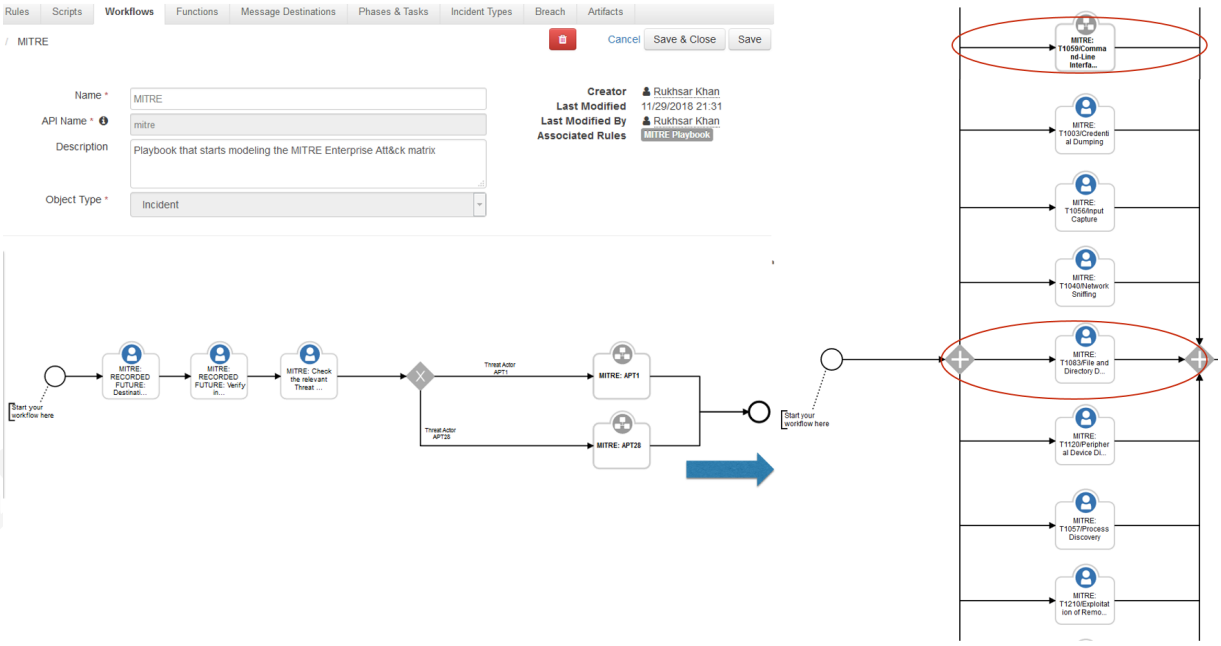

Figure 29: MITRE workflow calls APT28 workflow

Figure 30 "is further elaborating on how the playbook that is eventually providing task instructions to the analyst teams looks like. Some initial triage task instructions are listed under the *Stage 1 Analysis* phase of the incident which are processed by the Security Operations team. Once completed, the incident is handed off to the Threat Hunting team for scoping the attack and developing further intelligence. As you can see, all the TTP task instructions regarding APT28 have been loaded into the *Stage 2 Analysis* phase of this playbook" (Resilient Playbook and automated actions for Threat Hunting and DFIR).

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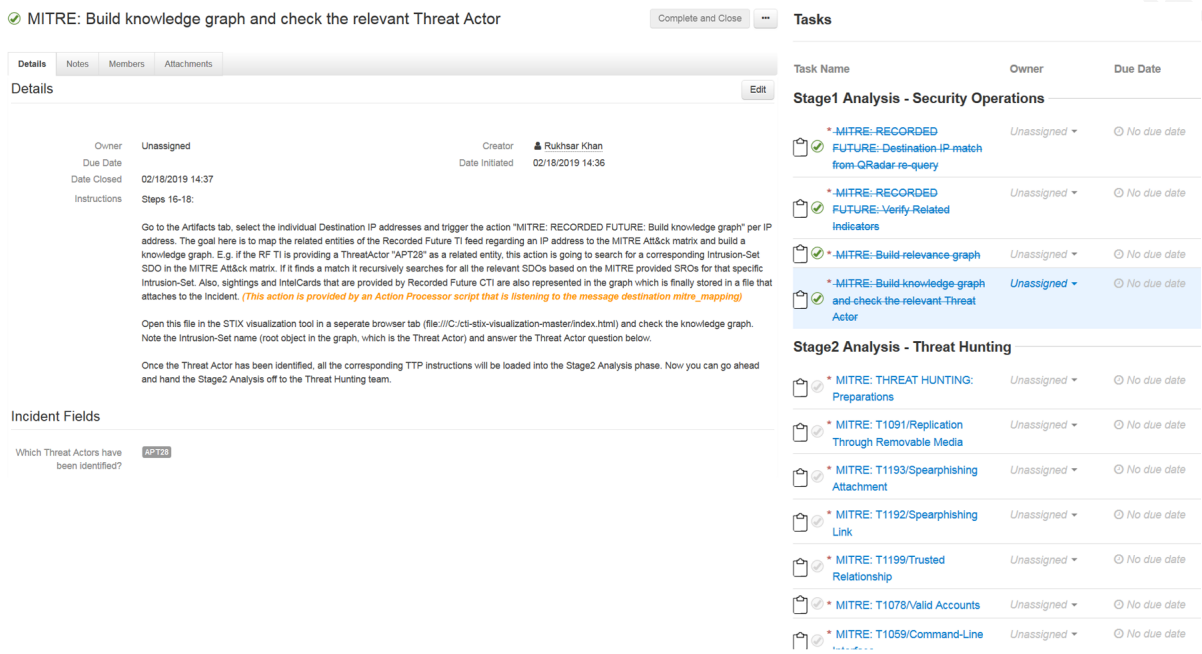

Figure 30: MITRE Playbook loads TTPs for APT28

3.2. Stage 2/3 Analysis

It is important to note that the Threat Actors are watching the endeavors of the Cyber defense community exactly in the same way as we are observing their movements. We expect that they will change their attack vectors once they know that we have identified these. This means that we need to be agile in Incident Response and quickly adapt to changing attack vectors.

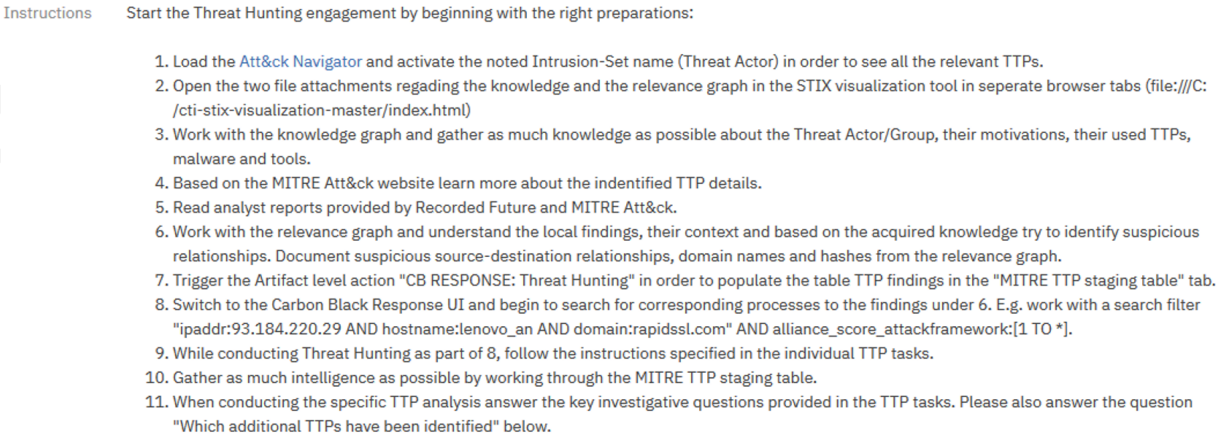

Figure 31: MITRE Threat Hunting preparations

Figure 31 is showing the details of the MITRE: Threat Hunting: Preparations task. The goal of this task is to identify additional TTPs that have been used by an attacker as part of the local compromise. Additional TTP tasks are loaded into the playbook once the question in the left bottom corner “Which additional TTPs have been identified” is answered. However, answering this question requires to first trigger the action CB Response: Threat Hunting demonstrated in Figure 32.

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This action pulls in the findings of Carbon Black (CB) Response into a Resilient data table named “MITRE TTP staging table" via an integration with the Carbon Black API for Python (CBAPI). More precisely, we have activated the Threat Intelligence (TI) named “MITRE ATT&CK” within CB Response and configured it to generate alerts whenever some endpoint activity matches this TI.

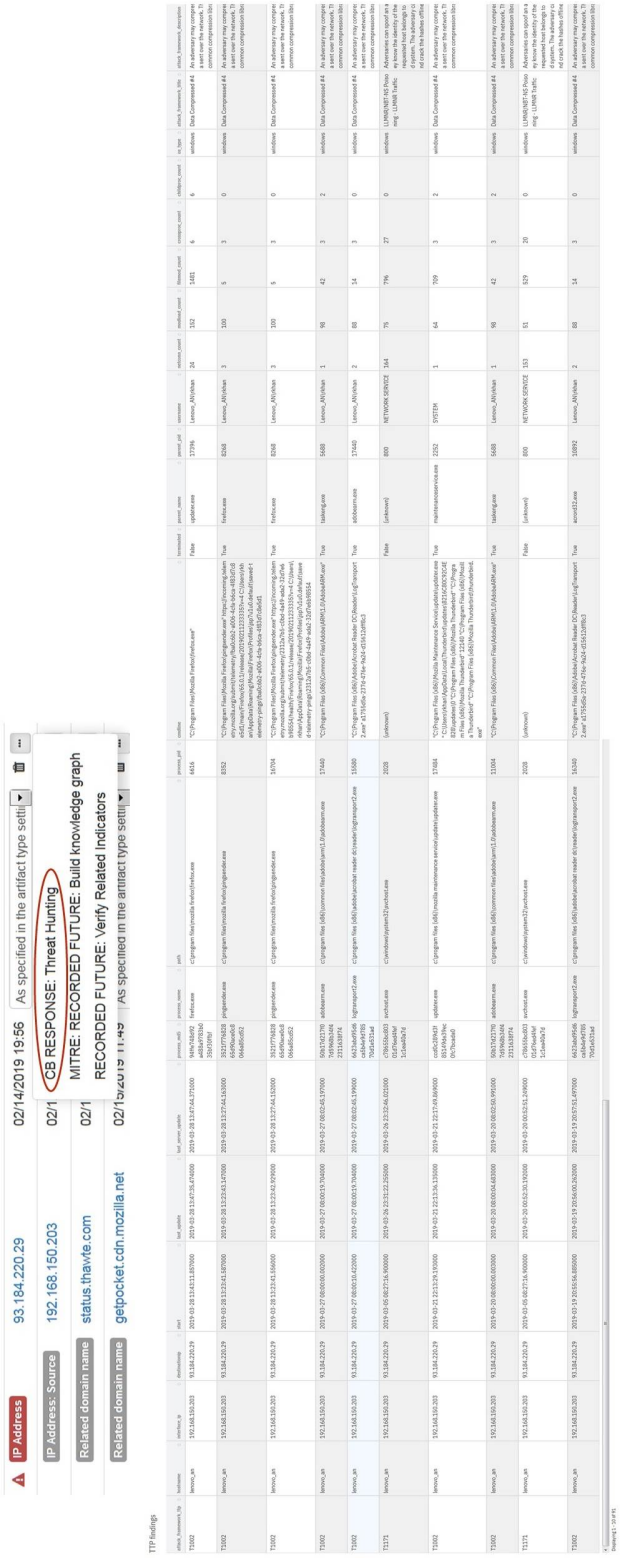

Figure 32: MITRE TTP staging table - Threat Hunting

This allows the Threat Hunting team to triage the table details and switch to the CB Response UI as required in order to understand the individual TTP details by triggering ad-hoc queries and conducting live response.

Once the Threat Hunting team works through the individual TTP tasks and scopes the attack, it provides additional intelligence to the SecOps and DFIR teams. E.g. if it has identified that the attacker is about to exfiltrate data, they can advise the SecOps team to restrict the capabilities of the intruder. Also, as part of the scoping process the Threat Hunting team narrows down an attack to a few highly suspicious or confirmed compromised systems while scanning thousands or tens of thousands of endpoints.
When a small amount of confirmed compromised systems has been identified, an automated action for creating a memory dump of each of these endpoints helps the Threat Hunting team in handing these images off to the DFIR team. The DFIR team can then go for the deep dive forensic analysis and work on a strategy for a fully-fledged remediation, eradication and recovery process.

Figure 33 shows additional automated actions in IBM Resilient SOAR that aid in further streamlining the security and forensic analysis as well as restrict the capabilities of the intruder. E.g. the action CB RESPONSE: Create memdump creates a memory dump for the selected endpoint, VOLATILITY: Scan memory image allows to analyze the memory dump with the open source tool Volatility, A10: Activate SSL interception and A10: Deactivate SSL interception enables and disables SSL interception on the A10 SSL

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interception proxy and the action A10: Block IP address allows to block an IP address as part of the containment process.

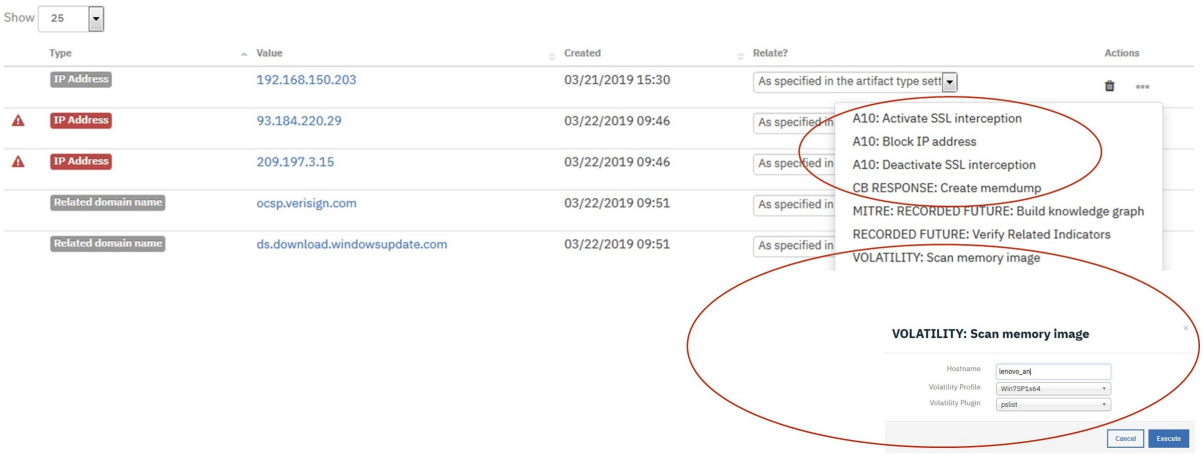

Figure 33:Additional actions for SecOps, Threat Hunting and DFIR

4. Conclusion

Figure 34 Figure 35 summarize what we learned in this publication. Starting the investigation with a robust and actionable CTI is key. As analysts are progressing through the Stage 1 and Stage 2 phases of our solution, they need to stick on the CTI in order to remain focused. We've also learned what MITRE ATT&CK is about. More specifically we got acquainted with the human readable MITRE website in contrast to the MITRE framework provided in STIX2 for integration with an organization's Cyber defense ecosystem.

- Robust and actionable Cyber Threat Intelligence
- Holistic detection and response framework – MITRE Att&ck
- Meaningful IOC expression language – STIX2, OpenIOC

Figure 34: Summary

We also learned that it's vital to do a proper incident or threat identification and scoping in order to understand the big picture, especially before starting with any remediation. Figure 35 is illustrating a six-step IR process communicated by the SANS institute (SANS institute). This process further refines the NIST IR process that we learned about earlier in this publication. As you can see, it especially emphasizes on the importance of the Identification and Scoping phase.

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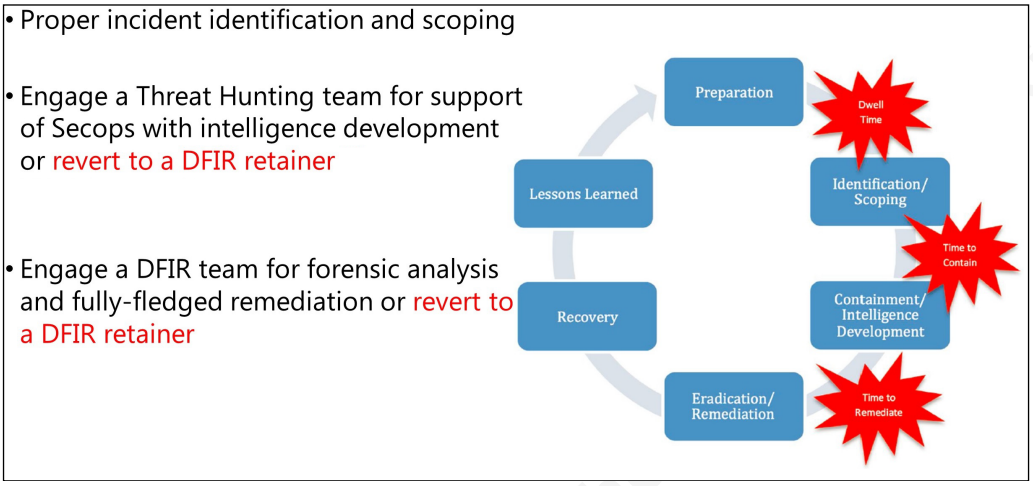

Figure 35: Summary continued

A Threat Hunting team can help an organization in this process. Also, a DFIR team can further help in conducting a deep dive forensic analysis on specific confirmed compromised endpoints and work on a fully-fledged remediation strategy in order to completely wipe out an attacker's foothold from the compromised environment. If an organization can't afford to engage a Threat Hunting or DFIR team, they can revert to a Threat Hunting or DFIR retainer.

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6. Acronyms and Glossary

Ariel Query Language: This is the name of the QRadar query language which has a SQL-like syntax. 16
CBAPI: Carbon Black API for Python 28
CERT: Computer Emergency Response Team 2
CSIRT: Computer Security Incident Response Team 2
CTI: Cyber Threat Intelligence 1
DFIR: Digital Forensics and Incident Response 1
EDR: Endpoint Detection and Response 5
IPFIX: Internet Protocol Flow Information Export 12
Reference Sets: A QRadar reference set is a reference table that can include objects like IP addresses, hash values, domain names, etc. Reference sets can be populated manually or automatically by an app. E.g. the Recorded Future app loads risklists into reference sets. A QRadar rule can then refer to a reference set in order to trigger an offense if for example an IP address or hash value has matched against an entry in the reference set. 13
REST API: In computing, representational state transfer (REST) or RESTful is an architectural style used for web development. Systems and sites designed using this style aim for fast performance, reliability and the ability to scale (to grow and easily support extra users). To achieve these goals, developers work with reusable components that can be managed and updated without affecting the system as a whole while it is running. Source: https://en.wikipedia.org/wiki/ Representational_state_transfer 5
RF: Recorded Future 13
Risklists: Recorded Future can provide IOCs as part of a risklist. E.g. an IP risklist can contain hundreds or thousands of malicious IP addresses. 13
SDOs: STIX Domain Objects 11
SIEM: Security Information and Event Management 6
SOAR: Security Orchestration, Automation and Response 1
SROs: STIX Relationship Objects 11
STIX: Structured Threat Information Expression 1

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TTPs: Tactics, Techniques and Procedures.....4

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