DEFCON

NSM 101 for ICS

About me

Chris Sistrunk, PE

Electrical Engineer

Sr. ICS Security Consultant

- Control system security assessments
- ICS Village (DEF CON & RSA Conference)

Entergy (11+ years)

- SCADA Engineer (10 years)
- Project Robus (ICS Protocol Fuzzing)
  - 30+ implementation vulnerabilities in DNP3 stacks
- Substation Security Team

BSidesJackson

What happens when you use nmap or a fuzzer on an ICS?

If ICS are so vulnerable, why haven’t we seen more attacks?

We aren’t looking!

Two Key Reasons

Intent

Visibility

Intent

Very little ICS targeted attack data

- Maroochy Shire to Stuxnet to German Steel Plant

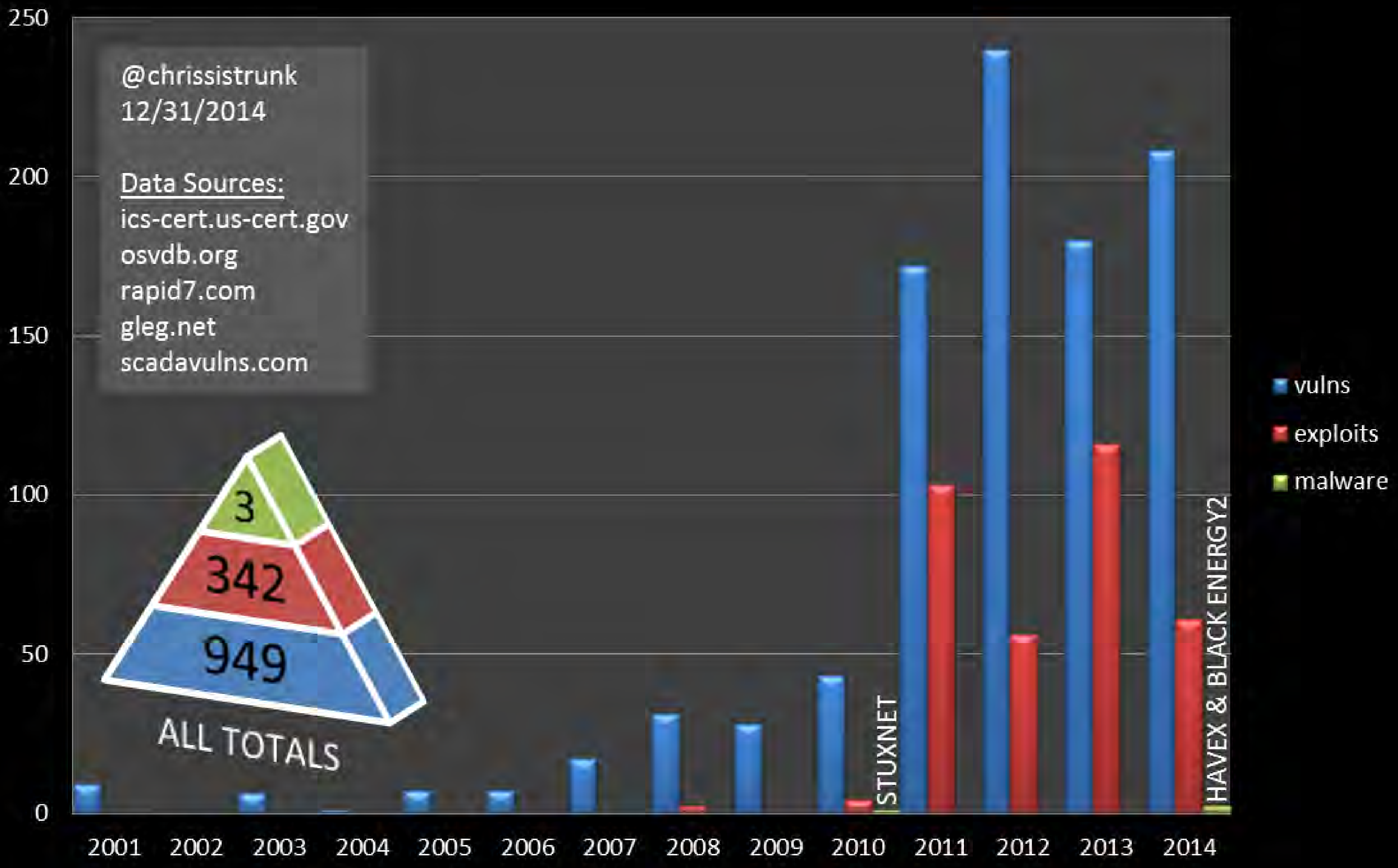
Why are targeted attacks different?

- It’s a “Who” not a “What”
- Professional, organized, well-funded
- If you kick them out, they will return

Visibility

Visibility

Public ICS Vulnerabilities Per Year



@chrissistrunk
12/31/2014

Data Sources:
ics-cert.us-cert.gov
osvdb.org
rapid7.com
gleg.net
scadavulns.com

If your ICS gets hacked…

gadgets

you can’t make water anymore

electricity

Now what?

- More Gov't security regulations
- ICS security still lagging
- Breaches are inevitable
  - Attacks aren't stopping
  - Every sector
  - Including ICS

What can we do to get ahead of this???

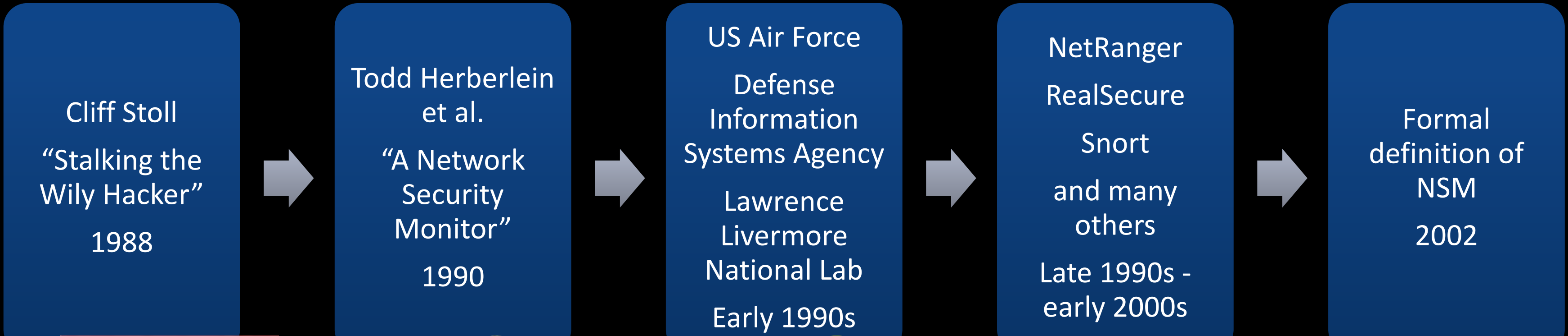
Network Security Monitoring

"The collection, analysis, and escalation of indications and warnings to detect and respond to intrusions. NSM is a way to find intruders on your network and do something about them before they damage your enterprise."

- *The Practice of Network Security Monitoring*

Network Security Monitoring

Invented in 1990, still in use today



Cliff Stoll

“Stalking the Wily Hacker”

1988

Todd Herberlein et al.

“A Network Security Monitor”

1990

US Air Force

Defense Information Systems Agency

Lawrence Livermore National Lab

Early 1990s

NetRanger

RealSecure

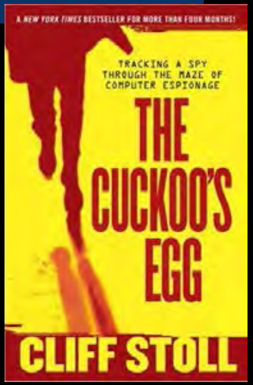
Snort

and many others

Late 1990s - early 2000s

Formal definition of NSM

2002


A NEW YORK TIMES BESTSELLER FOR MORE THAN FOUR MONTHS!
TRACKING A SPY THROUGH THE MAZE OF COMPUTER ESPIONAGE
THE CUCKOO'S EGG
CLIFF STOLL

THE UNIVERSITY OF CALIFORNIA · DAVIS

LET THERE BE LIGHT

DEFENSE INFORMATION SYSTEMS AGENCY

Network Security Monitoring

SearchSecurity.com webcast: 4 Dec 02

Richard Bejtlich, Foundstone
richard.bejtlich@foundstone.com

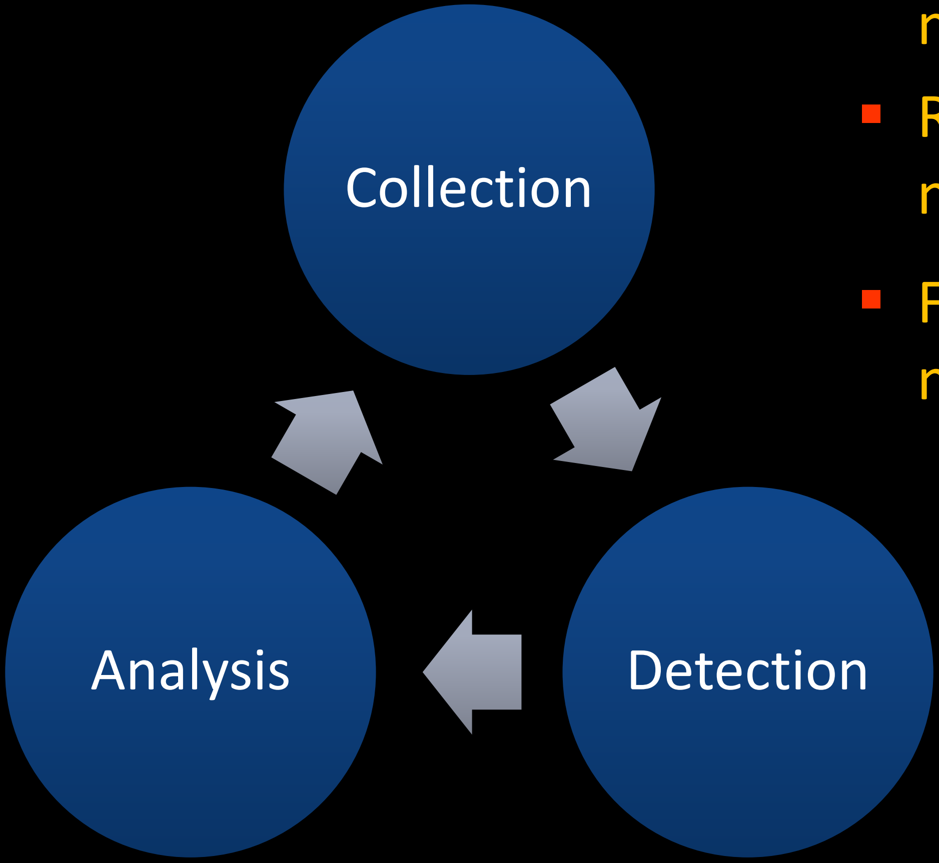
Robert Visscher, Ball Corporation
rvissche@ball.com

Before we start looking…

We need

- At least one person (to watch and hunt)
- The right tools to collect and analyze the data

The NSM Cycle



- Model for action, based on network-derived data
- Requires people and process, not just technology
- Focuses on the adversary, not the vulnerability

Methods of Monitoring

- **Network tap** – physical device which relays a copy of packets to an NSM sensor
- **SPAN or mirrored ports** – switch configuration which sends copies of packets to a separate port where NSM sensor can connect
- **Host NIC** – configured to watch all network traffic flowing on its segment (usually on NSM sensor)
- **Serial port tap** – physical device which relays serial traffic to another port, usually requires additional software to interpret data

Stratus Engineering

Fluke Networks

Types of Data Collected

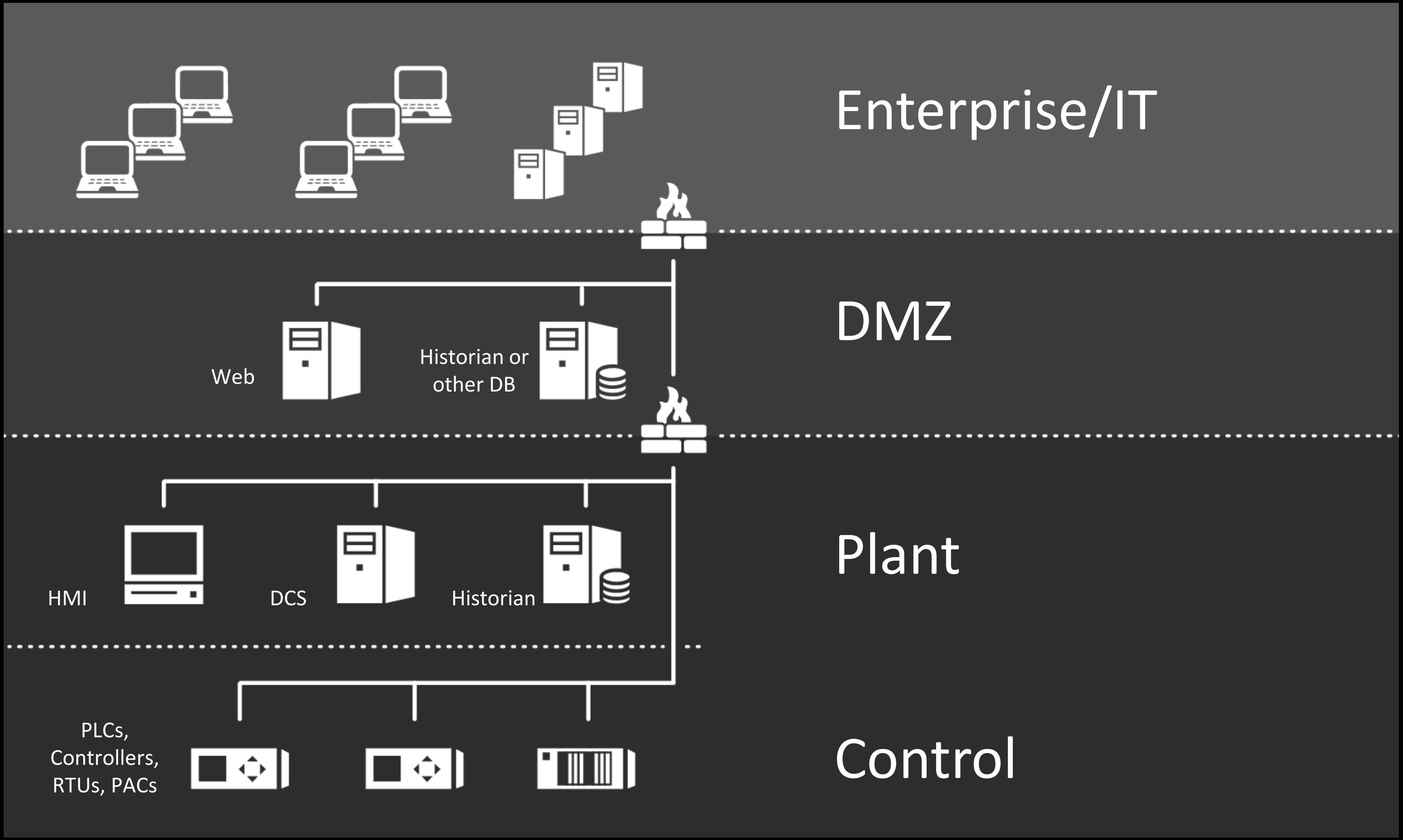
- Full content data – unfiltered collection of packets
- Extracted content – data streams, files, Web pages, etc.
- Session data – conversation between nodes
- Transaction data – requests and replies between nodes
- Statistical data – description of traffic, such as protocol and volume
- Metadata – aspects of data, e.g. who owns this IP address
- Alert/log data – triggers from IDS tools, tracking user logins, etc.

Difficulties for NSM

- Encrypted networks
- Widespread NAT
- Devices moving between network segments
- Extreme traffic volume
- Privacy concerns

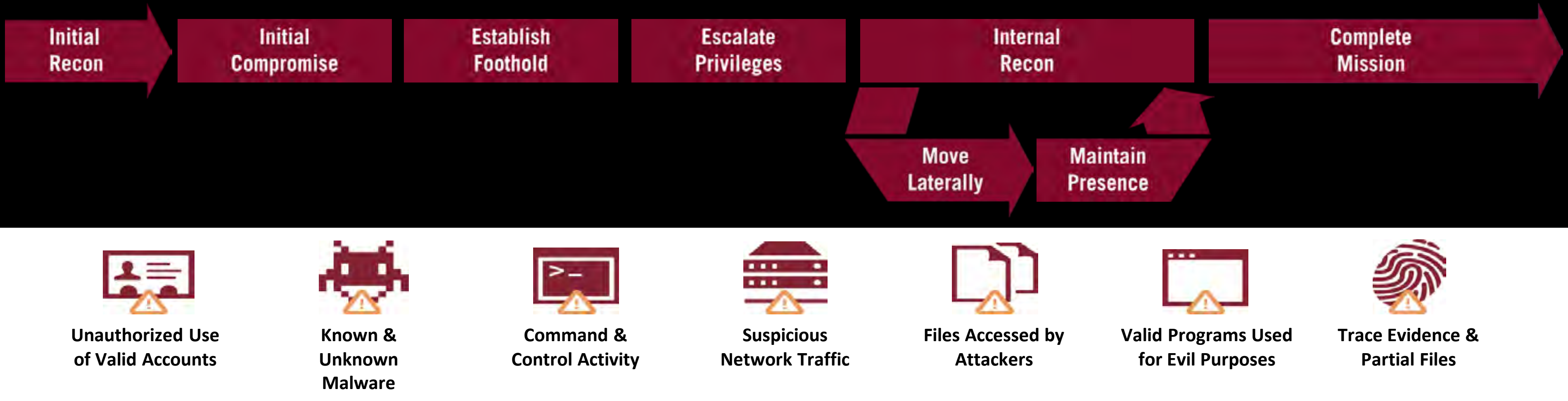
Issues that most ICS do not face!

Example ICS


Enterprise/IT
DMZ
Web
Historian or other DB
Plant
HMI
DCS
Historian
Control
PLCs, Controllers, RTUs, PACs

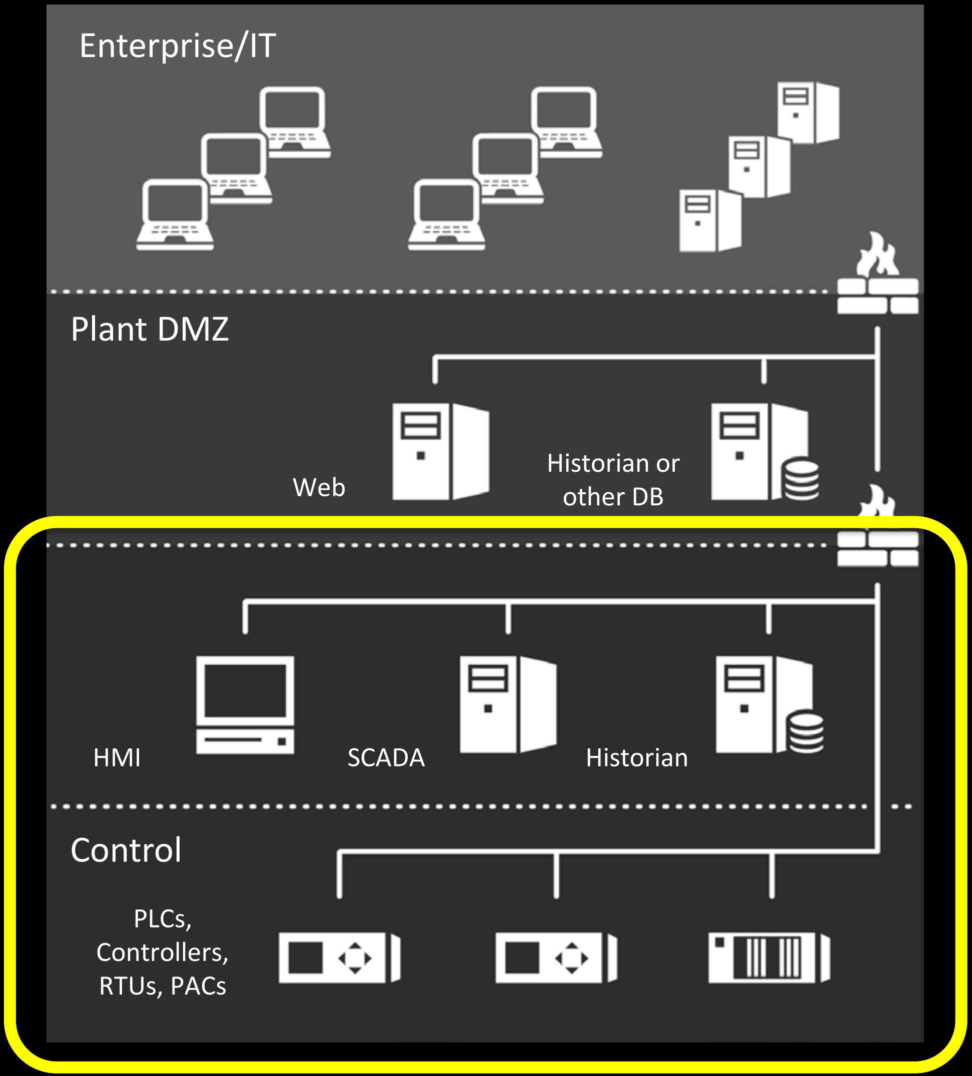
Anatomy of an Attack

While attackers often use malware to gain an initial foothold, they quickly move to other tactics to execute their attacks.


Initial Recon
Initial Compromise
Establish Foothold
Escalate Privileges
Internal Recon
Complete Mission
Move Laterally
Maintain Presence
Unauthorized Use of Valid Accounts
Known & Unknown Malware
Command & Control Activity
Suspicious Network Traffic
Files Accessed by Attackers
Valid Programs Used for Evil Purposes
Trace Evidence & Partial Files

Over all Mandiant attack investigations, only a little more than half of victim computers have malware on them.

Attacker Objectives



Attacker’s goals:

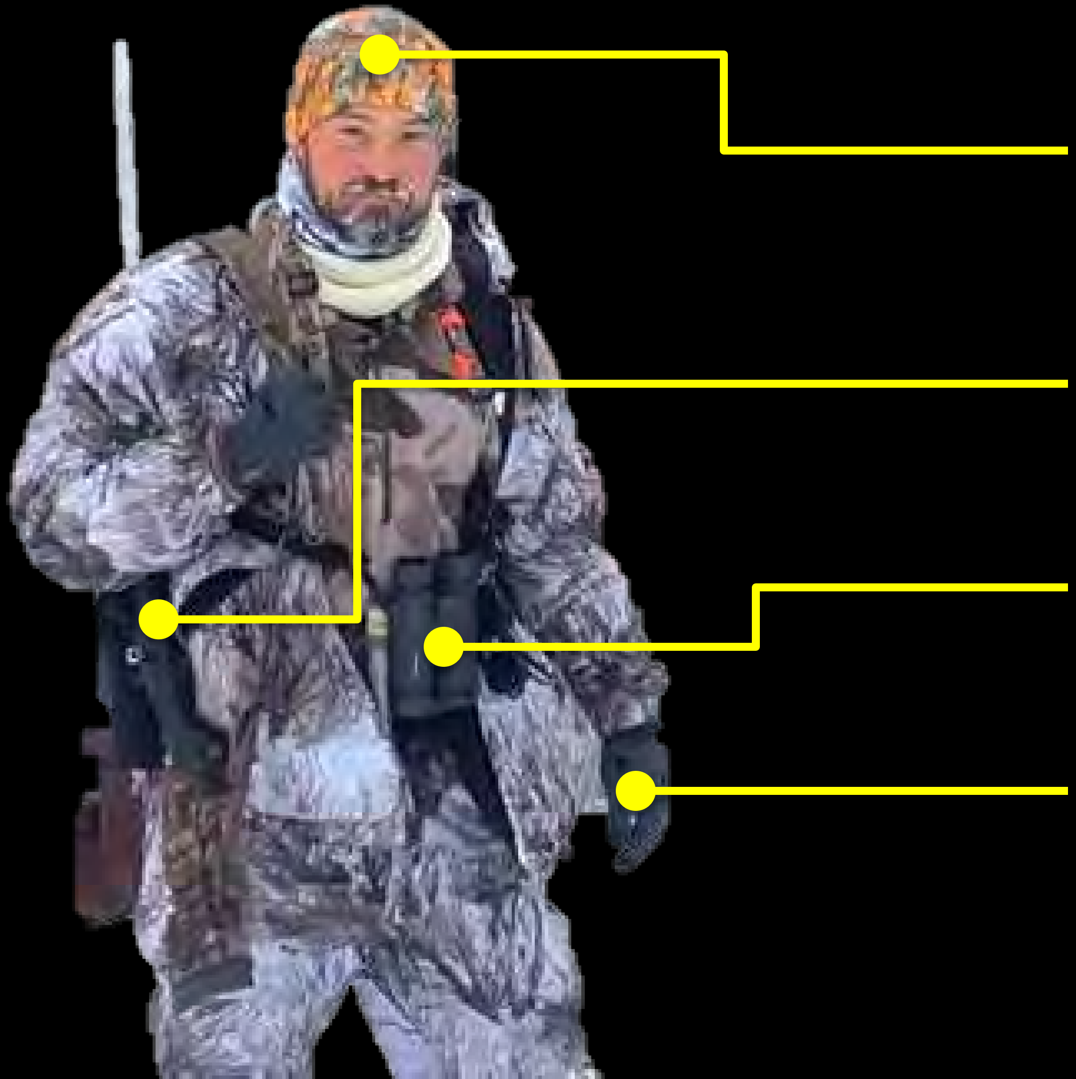
- Damage equipment
- Affect or steal process info
- Cause safety or compliance issue
- Pivot from vulnerable ICS to enterprise

Attacker’s options:

- Gain physical access to an ICS host
- Gain remote access to an ICS host
- Compromise a highly-privileged client machine with access to the ICS network

Let’s do some NSM!

Let’s do some NSM!



Inquisitive mind

NSM hunting tools

NSM collection tools

Protection

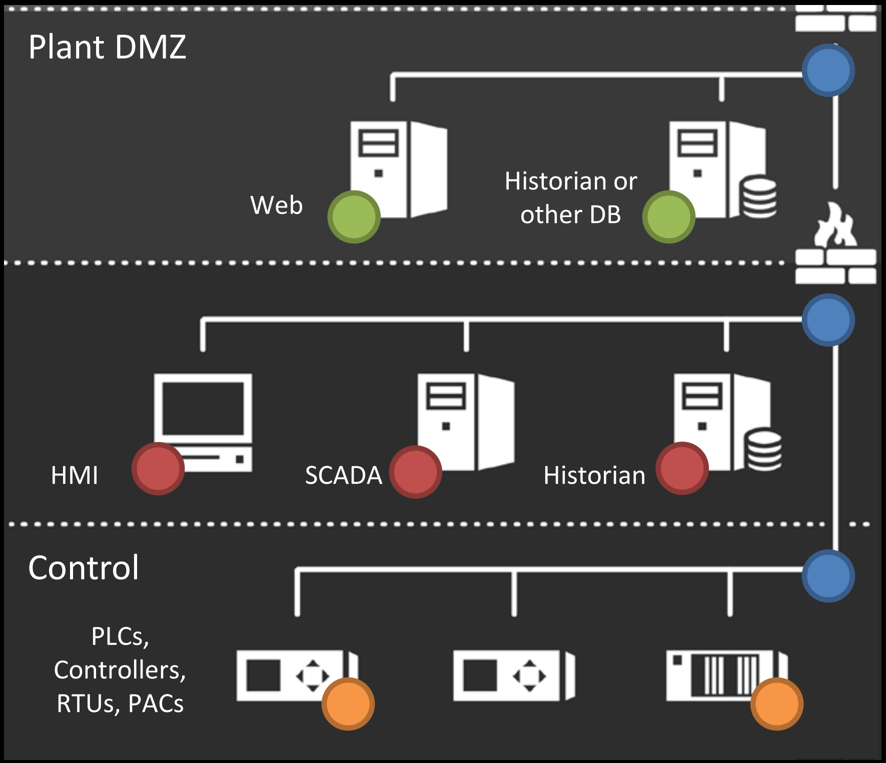
NSM Collection

🟢 Enterprise technology collectors

🔴 Logs and/or Agent

🔵 Network sensors

🟠 Logs only



- Firewall Logs
- Session Data
- NIDS/HIDS Logs
- Full packet capture
- Windows Logs and syslog
- SNMP (CPU % etc.)
- Alerts from security agents (AV, whitelisting, etc.)

NSM Collection

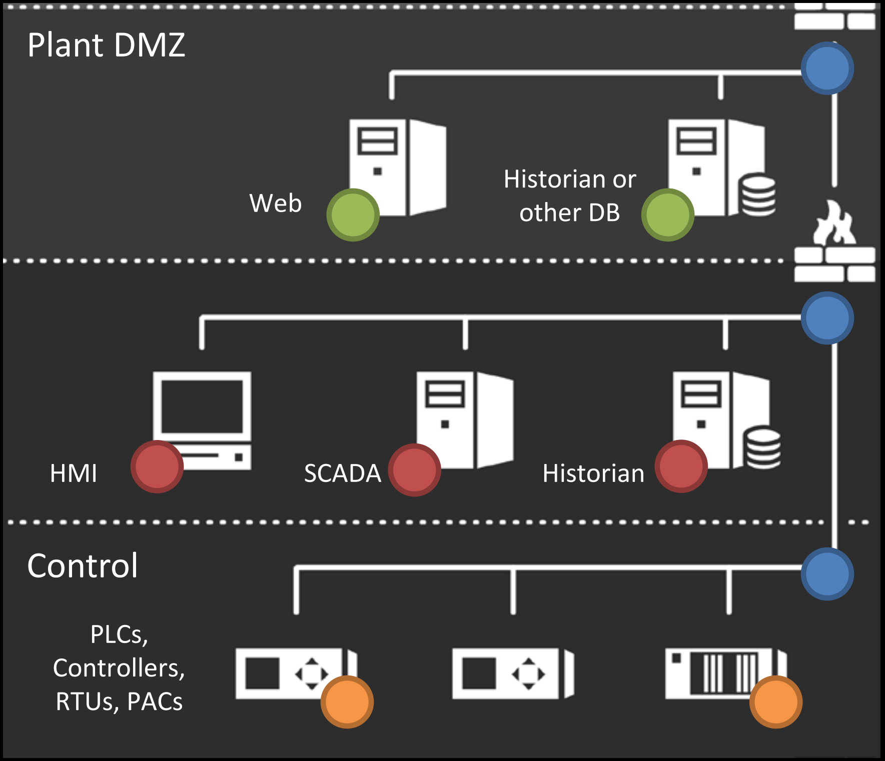
http://3.bp.blogspot.com/-B6PtheVJ9Jg/Uj4EErYhHdI/AAAAAAAAAFE/i_2dk9emrp4/s1600/Deer+tracks.jpg

What are we looking for?

- Exceptions from baseline (e.g. A talks to B but never C)
- “Top Talkers”
- Unexpected connectivity (to Internet, Business network)
- Known malicious IPs and domains
- Logins using default accounts
- Error messages that could correlate to vulnerabilities
- Unusual system and firewall log entries
- Host-based IDS or other security system alerts
- Unexpected file and firmware updates
- Antivirus alerts
- And others….

NSM Detection & "Hunting"

Analyst looks at detected anomalies or alerts then escalates to IR



- IDS alerts
- Anomaly detection
- Firmware updates, other commands
- Login with default credentials
- High CPU or network bandwidth
- Door alarms when nobody is supposed to be working
- Devices going off-line or behaving strangely

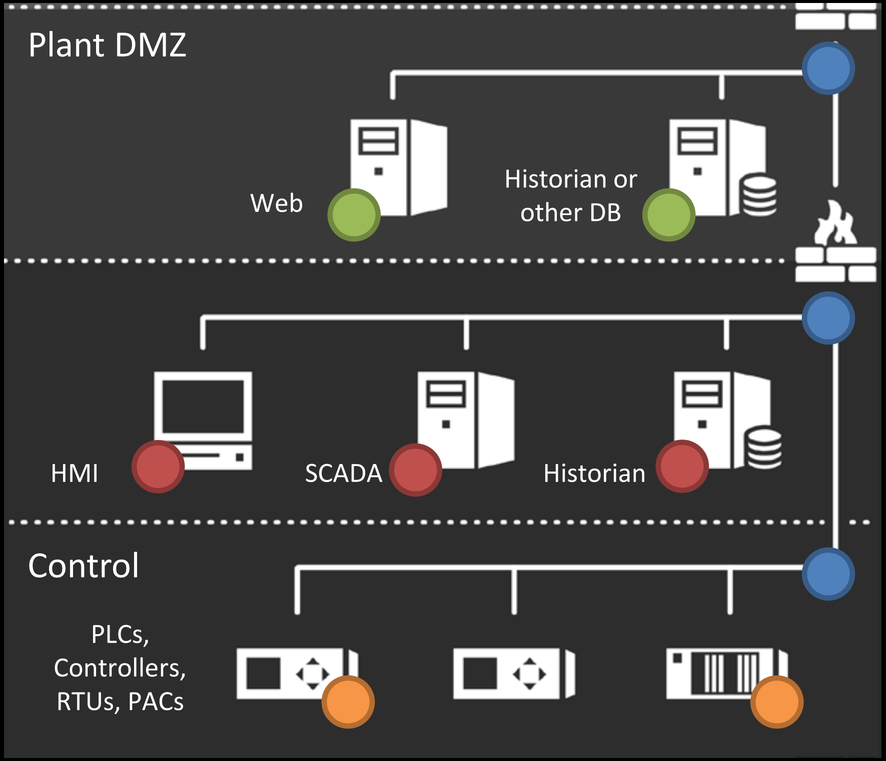
NSM Detection

http://www.buckmasters.com

http://www.jimyuskavitchphotography.com/data/photos/56_1wolf_track4.jpg

NSM Analysis

Incident responders analyze the detected anomalies to find evil



- Application exploitation
- Third-party connections (ex. ICCP or vendor access)
- ICS-specific communication protocol attacks (ex. Modbus, DNP3, Profinet, EtherNet/IP)
- Remote access exploitation
- Direct network access due to poor physical security
- USB-delivered malware

NSM Analysis

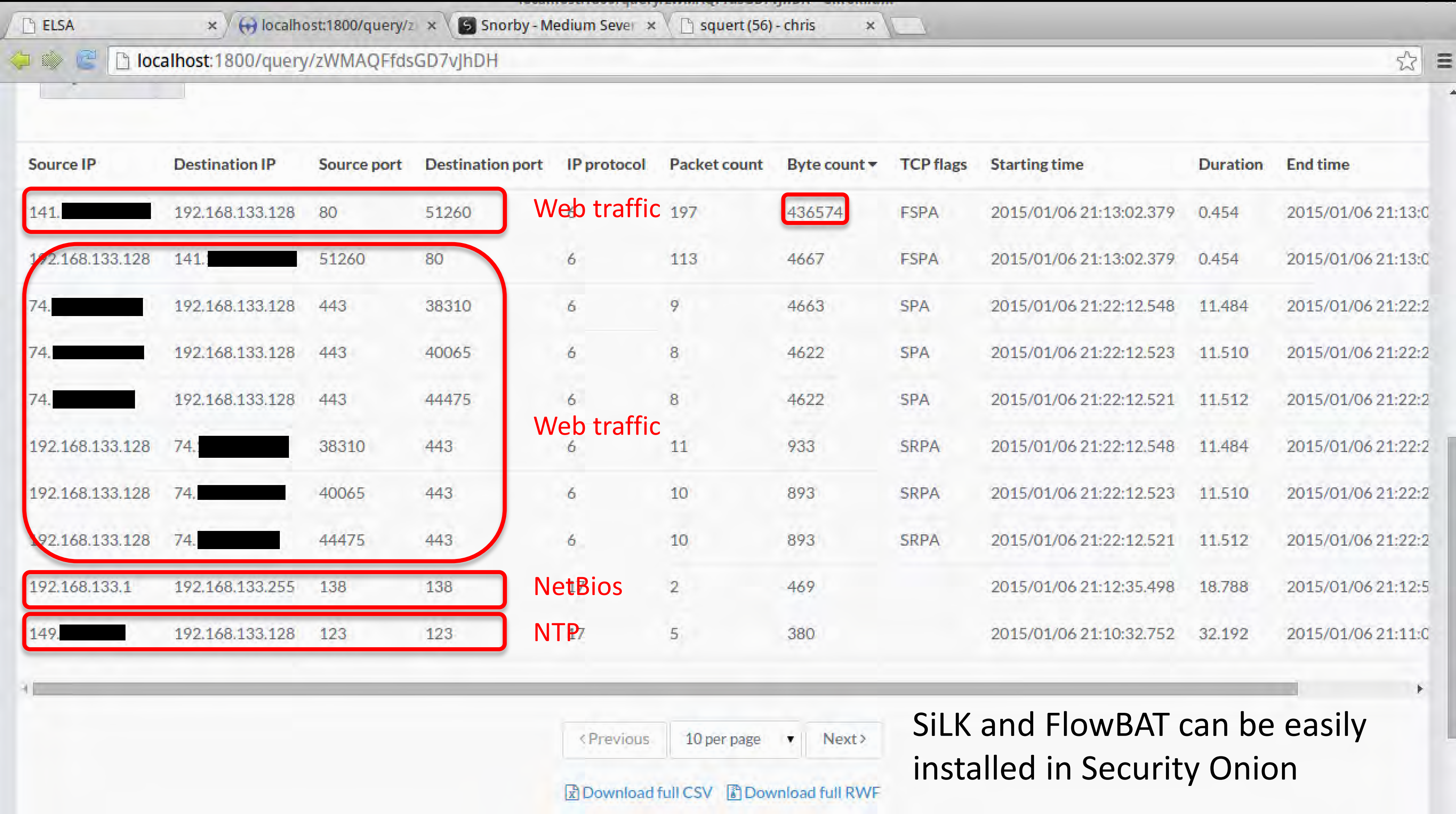
FLYING SQUIRREL ATTACK!!!!!

ICS NSM Examples

SecurityOnion

Session Data "Top Talkers"

FlowBAT characterizes Session Data, showing which nodes have the most traffic



Source IP	Destination IP	Source port	Destination port	IP protocol	Packet count	Byte count ▾	TCP flags	Starting time	Duration	End time
141.[redacted]	192.168.133.128	80	51260	6	197	436574	FSPA	2015/01/06 21:13:02.379	0.454	2015/01/06 21:13:0
192.168.133.128	141.[redacted]	51260	80	6	113	4667	FSPA	2015/01/06 21:13:02.379	0.454	2015/01/06 21:13:0
74.[redacted]	192.168.133.128	443	38310	6	9	4663	SPA	2015/01/06 21:22:12.548	11.484	2015/01/06 21:22:2
74.[redacted]	192.168.133.128	443	40065	6	8	4622	SPA	2015/01/06 21:22:12.523	11.510	2015/01/06 21:22:2
74.[redacted]	192.168.133.128	443	44475	6	8	4622	SPA	2015/01/06 21:22:12.521	11.512	2015/01/06 21:22:2
192.168.133.128	74.[redacted]	38310	443	6	11	933	SRPA	2015/01/06 21:22:12.548	11.484	2015/01/06 21:22:2
192.168.133.128	74.[redacted]	40065	443	6	10	893	SRPA	2015/01/06 21:22:12.523	11.510	2015/01/06 21:22:2
192.168.133.128	74.[redacted]	44475	443	6	10	893	SRPA	2015/01/06 21:22:12.521	11.512	2015/01/06 21:22:2
192.168.133.1	192.168.133.255	138	138	17	2	469		2015/01/06 21:12:35.498	18.788	2015/01/06 21:12:5
149.[redacted]	192.168.133.128	123	123	17	5	380		2015/01/06 21:10:32.752	32.192	2015/01/06 21:11:0

Web traffic

Web traffic

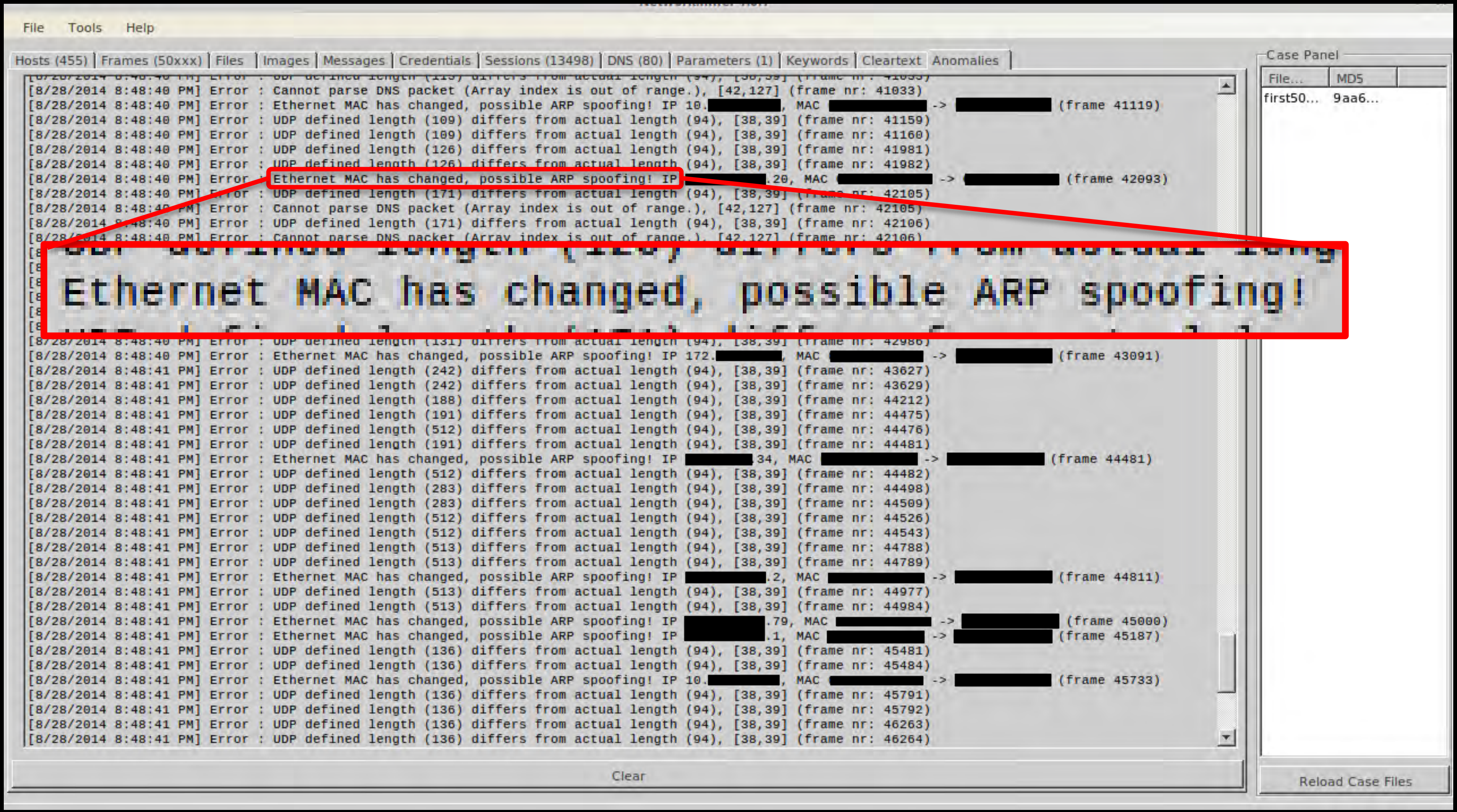
NetBios

NTP

SiLK and FlowBAT can be easily installed in Security Onion

Pcap Analysis for anomalies

NetworkMiner can find potential ARP spoofing (as well as many other indicators)

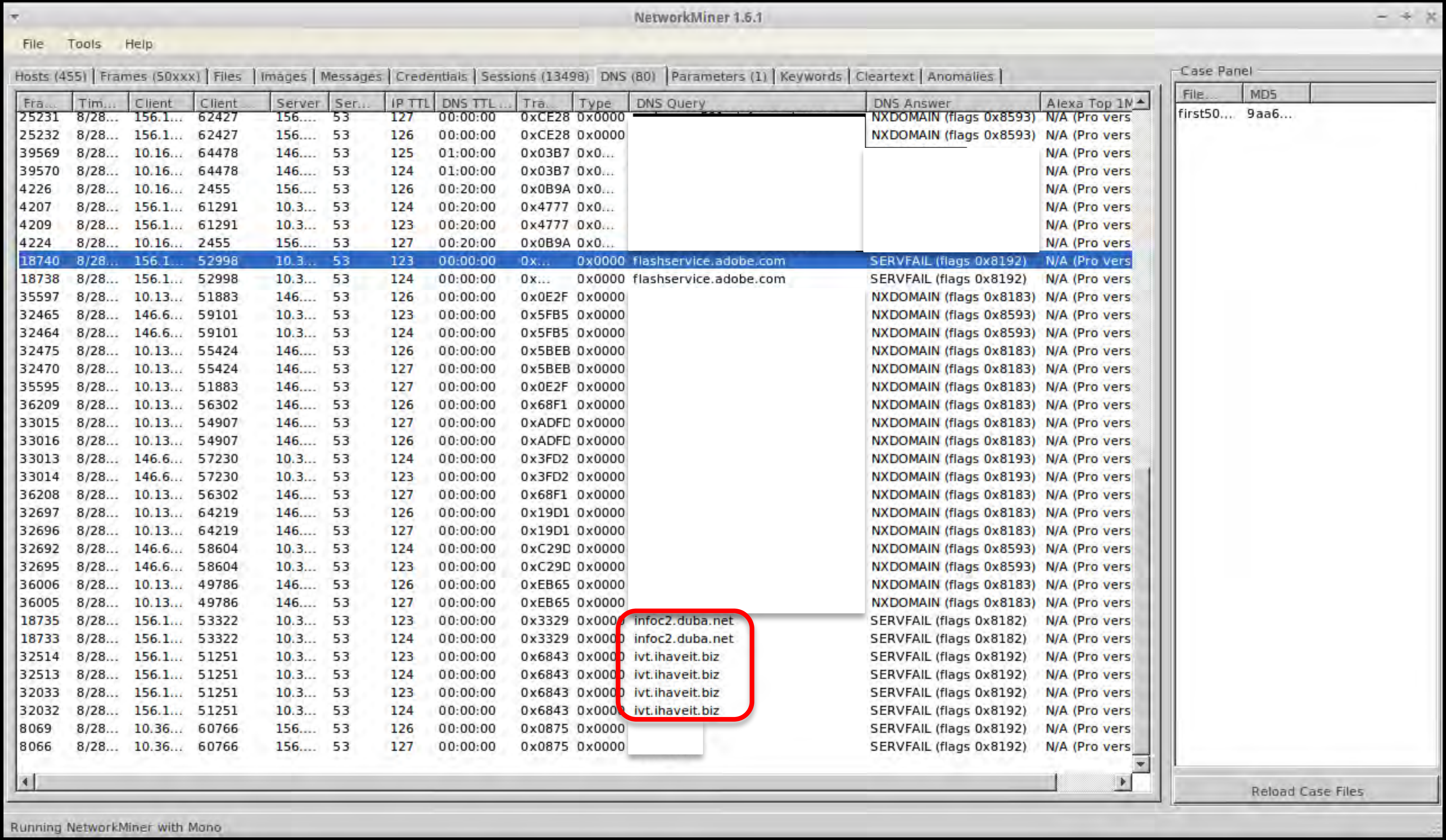


```
[8/28/2014 8:48:40 PM] Error : Cannot parse DNS packet (Array index is out of range.), [42,127] (frame nr: 41033)
[8/28/2014 8:48:40 PM] Error : Ethernet MAC has changed, possible ARP spoofing! IP 10.[redacted], MAC [redacted] -> [redacted] (frame 41119)
[8/28/2014 8:48:40 PM] Error : UDP defined length (109) differs from actual length (94), [38,39] (frame nr: 41159)
[8/28/2014 8:48:40 PM] Error : UDP defined length (109) differs from actual length (94), [38,39] (frame nr: 41160)
[8/28/2014 8:48:40 PM] Error : UDP defined length (126) differs from actual length (94), [38,39] (frame nr: 41981)
[8/28/2014 8:48:40 PM] Error : UDP defined length (126) differs from actual length (94), [38,39] (frame nr: 41982)
[8/28/2014 8:48:40 PM] Error : Ethernet MAC has changed, possible ARP spoofing! IP [redacted].20, MAC [redacted] -> [redacted] (frame 42093)
[8/28/2014 8:48:40 PM] Error : UDP defined length (171) differs from actual length (94), [38,39] (frame nr: 42105)
[8/28/2014 8:48:40 PM] Error : Cannot parse DNS packet (Array index is out of range.), [42,127] (frame nr: 42105)
[8/28/2014 8:48:40 PM] Error : UDP defined length (171) differs from actual length (94), [38,39] (frame nr: 42106)
[8/28/2014 8:48:40 PM] Error : Cannot parse DNS packet (Array index is out of range.), [42,127] (frame nr: 42106)
[8/28/2014 8:48:40 PM] Error : UDP defined length (131) differs from actual length (94), [38,39] (frame nr: 42986)
[8/28/2014 8:48:40 PM] Error : Ethernet MAC has changed, possible ARP spoofing! IP 172.[redacted], MAC [redacted] -> [redacted] (frame 43091)
[8/28/2014 8:48:41 PM] Error : UDP defined length (242) differs from actual length (94), [38,39] (frame nr: 43627)
[8/28/2014 8:48:41 PM] Error : UDP defined length (242) differs from actual length (94), [38,39] (frame nr: 43629)
[8/28/2014 8:48:41 PM] Error : UDP defined length (188) differs from actual length (94), [38,39] (frame nr: 44212)
[8/28/2014 8:48:41 PM] Error : UDP defined length (191) differs from actual length (94), [38,39] (frame nr: 44475)
[8/28/2014 8:48:41 PM] Error : UDP defined length (512) differs from actual length (94), [38,39] (frame nr: 44476)
[8/28/2014 8:48:41 PM] Error : UDP defined length (191) differs from actual length (94), [38,39] (frame nr: 44481)
[8/28/2014 8:48:41 PM] Error : Ethernet MAC has changed, possible ARP spoofing! IP [redacted].34, MAC [redacted] -> [redacted] (frame 44481)
[8/28/2014 8:48:41 PM] Error : UDP defined length (512) differs from actual length (94), [38,39] (frame nr: 44482)
[8/28/2014 8:48:41 PM] Error : UDP defined length (283) differs from actual length (94), [38,39] (frame nr: 44498)
[8/28/2014 8:48:41 PM] Error : UDP defined length (283) differs from actual length (94), [38,39] (frame nr: 44509)
[8/28/2014 8:48:41 PM] Error : UDP defined length (512) differs from actual length (94), [38,39] (frame nr: 44526)
[8/28/2014 8:48:41 PM] Error : UDP defined length (512) differs from actual length (94), [38,39] (frame nr: 44543)
[8/28/2014 8:48:41 PM] Error : UDP defined length (513) differs from actual length (94), [38,39] (frame nr: 44788)
[8/28/2014 8:48:41 PM] Error : UDP defined length (513) differs from actual length (94), [38,39] (frame nr: 44789)
[8/28/2014 8:48:41 PM] Error : Ethernet MAC has changed, possible ARP spoofing! IP [redacted].2, MAC [redacted] -> [redacted] (frame 44811)
[8/28/2014 8:48:41 PM] Error : UDP defined length (513) differs from actual length (94), [38,39] (frame nr: 44977)
[8/28/2014 8:48:41 PM] Error : UDP defined length (513) differs from actual length (94), [38,39] (frame nr: 44984)
[8/28/2014 8:48:41 PM] Error : Ethernet MAC has changed, possible ARP spoofing! IP [redacted].79, MAC [redacted] -> [redacted] (frame 45000)
[8/28/2014 8:48:41 PM] Error : Ethernet MAC has changed, possible ARP spoofing! IP [redacted].1, MAC [redacted] -> [redacted] (frame 45187)
[8/28/2014 8:48:41 PM] Error : UDP defined length (136) differs from actual length (94), [38,39] (frame nr: 45481)
[8/28/2014 8:48:41 PM] Error : UDP defined length (136) differs from actual length (94), [38,39] (frame nr: 45484)
[8/28/2014 8:48:41 PM] Error : Ethernet MAC has changed, possible ARP spoofing! IP 10.[redacted], MAC [redacted] -> [redacted] (frame 45733)
[8/28/2014 8:48:41 PM] Error : UDP defined length (136) differs from actual length (94), [38,39] (frame nr: 45791)
[8/28/2014 8:48:41 PM] Error : UDP defined length (136) differs from actual length (94), [38,39] (frame nr: 45792)
[8/28/2014 8:48:41 PM] Error : UDP defined length (136) differs from actual length (94), [38,39] (frame nr: 46263)
[8/28/2014 8:48:41 PM] Error : UDP defined length (136) differs from actual length (94), [38,39] (frame nr: 46264)
```

Ethernet MAC has changed, possible ARP spoofing!

Pcaps - Abnormal DNS Traffic

NetworkMiner sees“strange” DNS requests originating from within the ICS

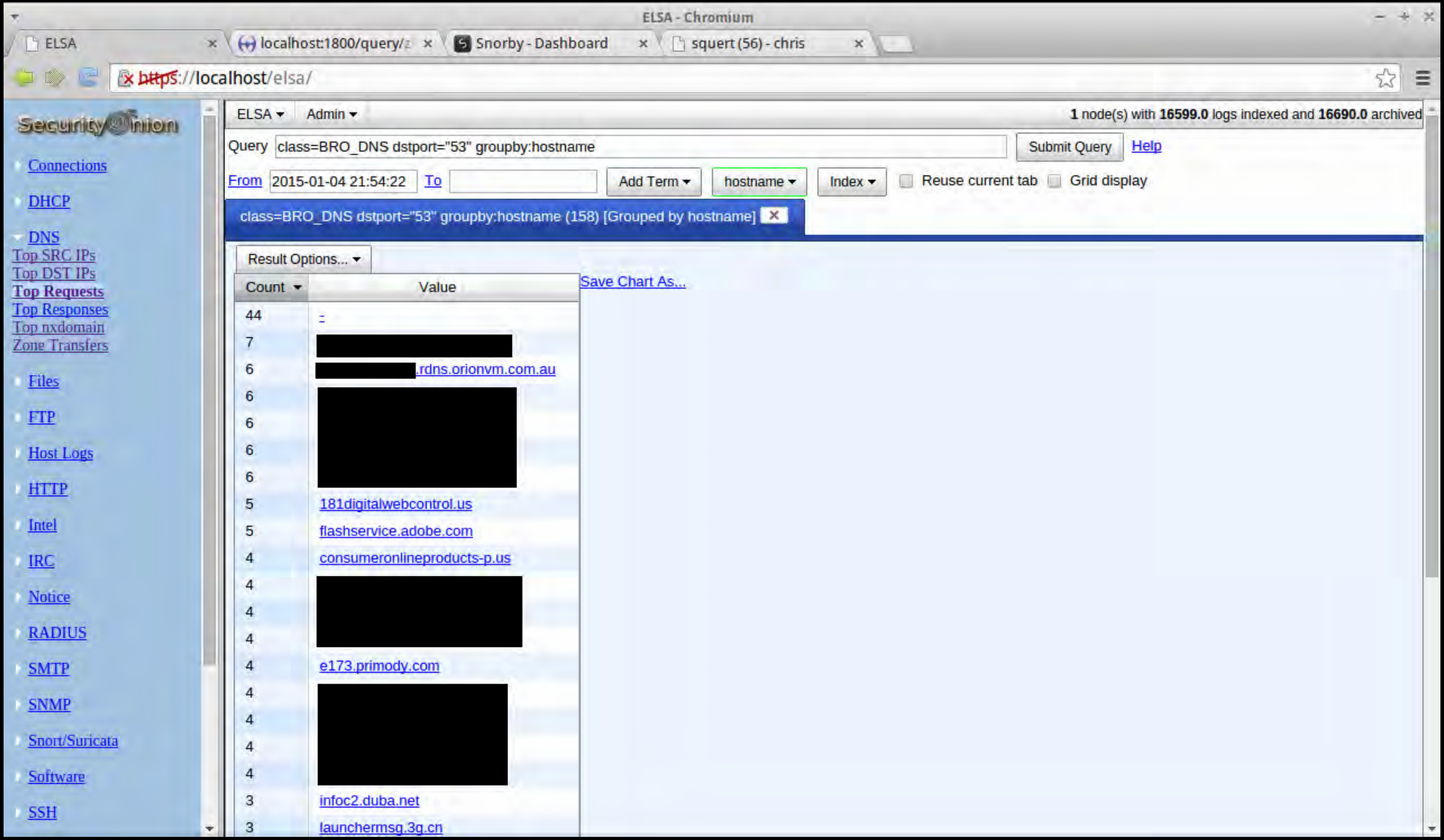


Fra...	Tim...	Client	Client	Server	Ser...	IP TTL	DNS TTL ...	Tra...	Type	DNS Query	DNS Answer	Alexa Top 1M
25231	8/28...	156.1...	62427	156....	53	127	00:00:00	0xCE28	0x0000	[redacted]	NXDOMAIN (flags 0x8593)	N/A (Pro vers
25232	8/28...	156.1...	62427	156....	53	126	00:00:00	0xCE28	0x0000	[redacted]	NXDOMAIN (flags 0x8593)	N/A (Pro vers
39569	8/28...	10.16...	64478	146....	53	125	01:00:00	0x03B7	0x0...	[redacted]	[redacted]	N/A (Pro vers
39570	8/28...	10.16...	64478	146....	53	124	01:00:00	0x03B7	0x0...	[redacted]	[redacted]	N/A (Pro vers
4226	8/28...	10.16...	2455	156....	53	126	00:20:00	0x0B9A	0x0...	[redacted]	[redacted]	N/A (Pro vers
4207	8/28...	156.1...	61291	10.3...	53	124	00:20:00	0x4777	0x0...	[redacted]	[redacted]	N/A (Pro vers
4209	8/28...	156.1...	61291	10.3...	53	123	00:20:00	0x4777	0x0...	[redacted]	[redacted]	N/A (Pro vers
4224	8/28...	10.16...	2455	156....	53	127	00:20:00	0x0B9A	0x0...	[redacted]	[redacted]	N/A (Pro vers
18740	8/28...	156.1...	52998	10.3...	53	123	00:00:00	0x...	0x0000	flashservice.adobe.com	SERVFAIL (flags 0x8192)	N/A (Pro vers
18738	8/28...	156.1...	52998	10.3...	53	124	00:00:00	0x...	0x0000	flashservice.adobe.com	SERVFAIL (flags 0x8192)	N/A (Pro vers
35597	8/28...	10.13...	51883	146....	53	126	00:00:00	0x0E2F	0x0000	[redacted]	NXDOMAIN (flags 0x8183)	N/A (Pro vers
32465	8/28...	146.6...	59101	10.3...	53	123	00:00:00	0x5FB5	0x0000	[redacted]	NXDOMAIN (flags 0x8593)	N/A (Pro vers
32464	8/28...	146.6...	59101	10.3...	53	124	00:00:00	0x5FB5	0x0000	[redacted]	NXDOMAIN (flags 0x8593)	N/A (Pro vers
32475	8/28...	10.13...	55424	146....	53	126	00:00:00	0x5BEB	0x0000	[redacted]	NXDOMAIN (flags 0x8183)	N/A (Pro vers
32470	8/28...	10.13...	55424	146....	53	127	00:00:00	0x5BEB	0x0000	[redacted]	NXDOMAIN (flags 0x8183)	N/A (Pro vers
35595	8/28...	10.13...	51883	146....	53	127	00:00:00	0x0E2F	0x0000	[redacted]	NXDOMAIN (flags 0x8183)	N/A (Pro vers
36209	8/28...	10.13...	56302	146....	53	126	00:00:00	0x68F1	0x0000	[redacted]	NXDOMAIN (flags 0x8183)	N/A (Pro vers
33015	8/28...	10.13...	54907	146....	53	127	00:00:00	0xADFD	0x0000	[redacted]	NXDOMAIN (flags 0x8183)	N/A (Pro vers
33016	8/28...	10.13...	54907	146....	53	126	00:00:00	0xADFD	0x0000	[redacted]	NXDOMAIN (flags 0x8183)	N/A (Pro vers
33013	8/28...	146.6...	57230	10.3...	53	124	00:00:00	0x3FD2	0x0000	[redacted]	NXDOMAIN (flags 0x8193)	N/A (Pro vers
33014	8/28...	146.6...	57230	10.3...	53	123	00:00:00	0x3FD2	0x0000	[redacted]	NXDOMAIN (flags 0x8193)	N/A (Pro vers
36208	8/28...	10.13...	56302	146....	53	127	00:00:00	0x68F1	0x0000	[redacted]	NXDOMAIN (flags 0x8183)	N/A (Pro vers
32697	8/28...	10.13...	64219	146....	53	126	00:00:00	0x19D1	0x0000	[redacted]	NXDOMAIN (flags 0x8183)	N/A (Pro vers
32696	8/28...	10.13...	64219	146....	53	127	00:00:00	0x19D1	0x0000	[redacted]	NXDOMAIN (flags 0x8183)	N/A (Pro vers
32692	8/28...	146.6...	58604	10.3...	53	124	00:00:00	0xC29D	0x0000	[redacted]	NXDOMAIN (flags 0x8593)	N/A (Pro vers
32695	8/28...	146.6...	58604	10.3...	53	123	00:00:00	0xC29D	0x0000	[redacted]	NXDOMAIN (flags 0x8593)	N/A (Pro vers
36006	8/28...	10.13...	49786	146....	53	126	00:00:00	0xEB65	0x0000	[redacted]	NXDOMAIN (flags 0x8183)	N/A (Pro vers
36005	8/28...	10.13...	49786	146....	53	127	00:00:00	0xEB65	0x0000	[redacted]	NXDOMAIN (flags 0x8183)	N/A (Pro vers
18735	8/28...	156.1...	53322	10.3...	53	123	00:00:00	0x3329	0x0000	infoc2.duba.net	SERVFAIL (flags 0x8182)	N/A (Pro vers
18733	8/28...	156.1...	53322	10.3...	53	124	00:00:00	0x3329	0x0000	infoc2.duba.net	SERVFAIL (flags 0x8182)	N/A (Pro vers
32514	8/28...	156.1...	51251	10.3...	53	123	00:00:00	0x6843	0x0000	ivt.ihaveit.biz	SERVFAIL (flags 0x8192)	N/A (Pro vers
32513	8/28...	156.1...	51251	10.3...	53	124	00:00:00	0x6843	0x0000	ivt.ihaveit.biz	SERVFAIL (flags 0x8192)	N/A (Pro vers
32033	8/28...	156.1...	51251	10.3...	53	123	00:00:00	0x6843	0x0000	ivt.ihaveit.biz	SERVFAIL (flags 0x8192)	N/A (Pro vers
32032	8/28...	156.1...	51251	10.3...	53	124	00:00:00	0x6843	0x0000	ivt.ihaveit.biz	SERVFAIL (flags 0x8192)	N/A (Pro vers
8069	8/28...	10.36...	60766	156....	53	126	00:00:00	0x0875	0x0000	[redacted]	SERVFAIL (flags 0x8192)	N/A (Pro vers
8066	8/28...	10.36...	60766	156....	53	127	00:00:00	0x0875	0x0000	[redacted]	SERVFAIL (flags 0x8192)	N/A (Pro vers

File...	MD5
first50...	9aa6...

IDS alerts - Abnormal DNS Traffic

DNS requests shown in the Bro IDS log in ELSA



1 node(s) with **16599.0** logs indexed and **16690.0** archived

Query: class=BRO_DNS dstport="53" groupby:hostname

From: 2015-01-04 21:54:22 To:

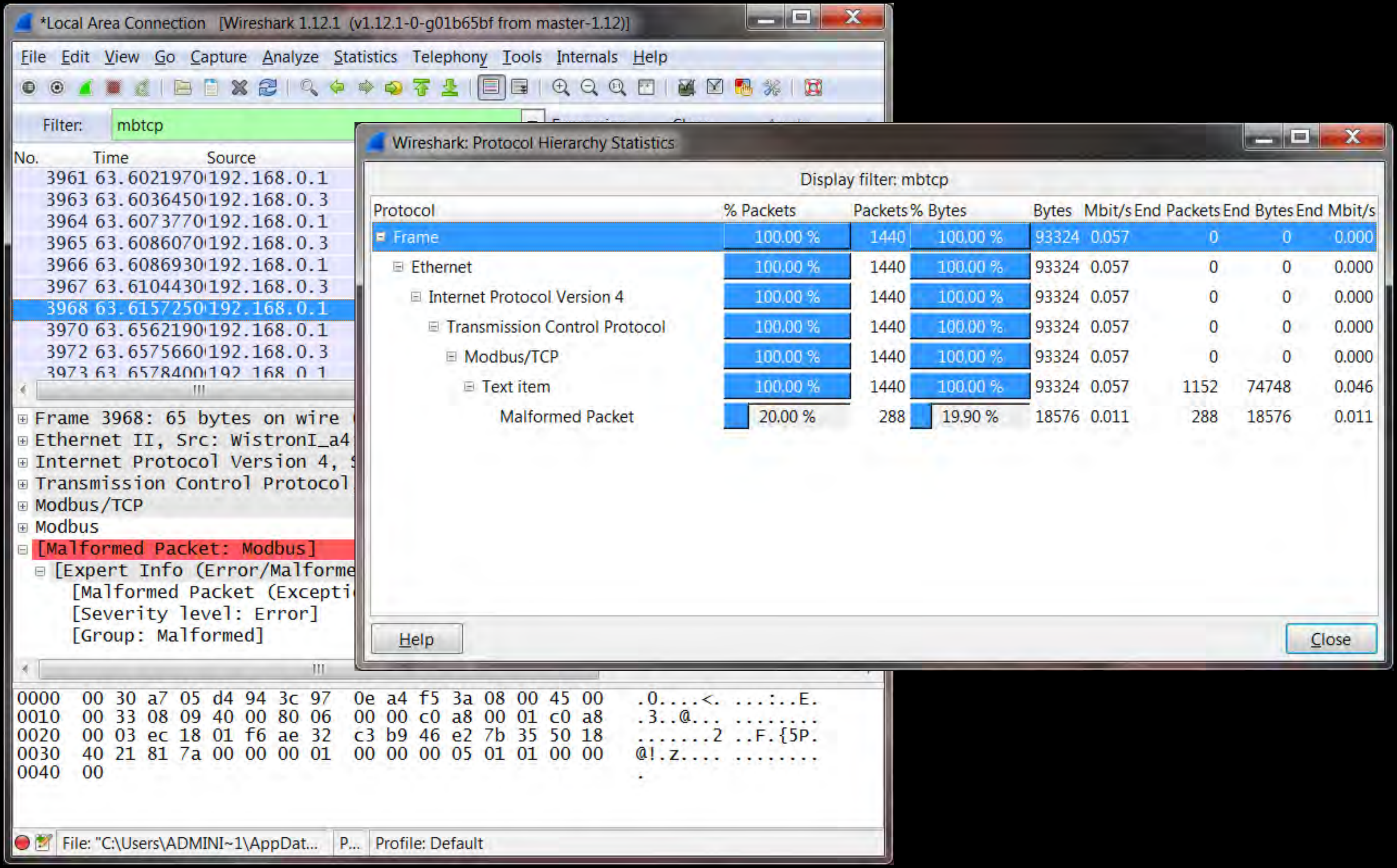
□ Reuse current tab □ Grid display

class=BRO_DNS dstport="53" groupby:hostname (158) [Grouped by hostname]

Count	Value
44	-
7	[redacted]
6	[redacted].rdns.orionvm.com.au
6	[redacted]
6	[redacted]
6	[redacted]
6	[redacted]
5	181digitalwebcontrol.us
5	flashservice.adobe.com
4	consumeronlineproducts-p.us
4	[redacted]
4	[redacted]
4	[redacted]
4	e173.primody.com
4	[redacted]
4	[redacted]
4	[redacted]
4	[redacted]
3	infoc2.duba.net
3	launchermsg.3g.cn

Pcaps - Malformed Modbus

Deep packet inspection of Modbus by Wireshark



*Local Area Connection [Wireshark 1.12.1 (v1.12.1-0-g01b65bf from master-1.12)]
File Edit View Go Capture Analyze Statistics Telephony Tools Internals Help
Filter: mbtcp

```
No.        Time          Source
  3961 63.6021970 192.168.0.1
  3963 63.6036450 192.168.0.3
  3964 63.6073770 192.168.0.1
  3965 63.6086070 192.168.0.3
  3966 63.6086930 192.168.0.1
  3967 63.6104430 192.168.0.3
  3968 63.6157250 192.168.0.1
  3970 63.6562190 192.168.0.1
  3972 63.6575660 192.168.0.3
  3973 63.6578400 192.168.0.1
```

```
⊞ Frame 3968: 65 bytes on wire (
⊞ Ethernet II, Src: WistronI_a4
⊞ Internet Protocol Version 4, S
⊞ Transmission Control Protocol
⊞ Modbus/TCP
⊞ Modbus
⊟ [Malformed Packet: Modbus]
  ⊟ [Expert Info (Error/Malforme
      [Malformed Packet (Excepti
      [Severity level: Error]
      [Group: Malformed]
```

```
0000  00 30 a7 05 d4 94 3c 97  0e a4 f5 3a 08 00 45 00   .0....<. ...:..E.
0010  00 33 08 09 40 00 80 06  00 00 c0 a8 00 01 c0 a8   .3..@... ........
0020  00 03 ec 18 01 f6 ae 32  c3 b9 46 e2 7b 35 50 18   .......2 ..F.{5P.
0030  40 21 81 7a 00 00 00 01  00 00 00 05 01 01 00 00   @!.z.... ........
0040  00                                                 .
```

File: "C:\Users\ADMINI~1\AppDat... P... Profile: Default

Display filter: mbtcp

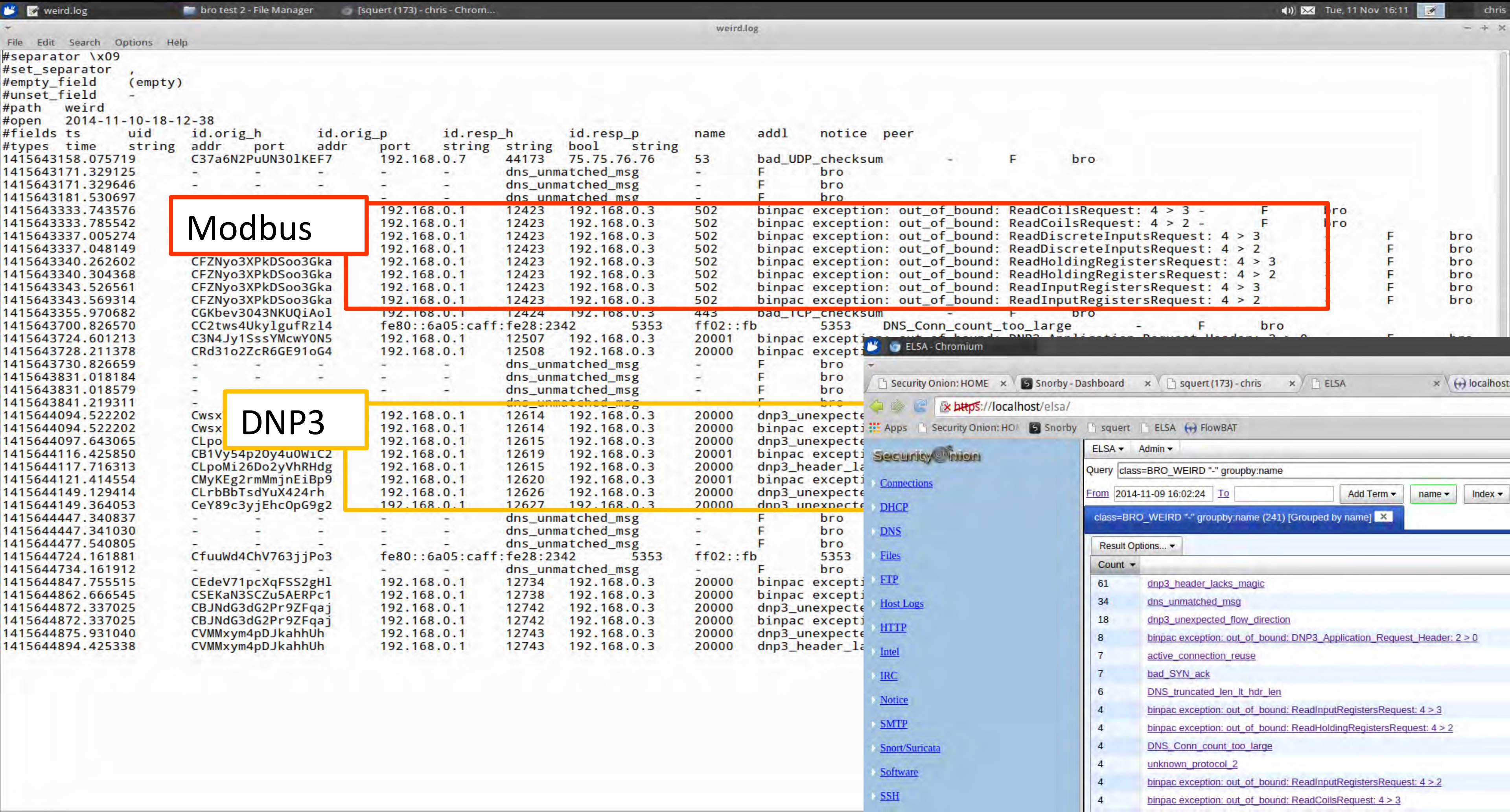
Protocol	% Packets	Packets	% Bytes	Bytes	Mbit/s	End Packets	End Bytes	End Mbit/s
⊟ Frame	100.00 %	1440	100.00 %	93324	0.057	0	0	0.000
⊟ Ethernet	100.00 %	1440	100.00 %	93324	0.057	0	0	0.000
⊟ Internet Protocol Version 4	100.00 %	1440	100.00 %	93324	0.057	0	0	0.000
⊟ Transmission Control Protocol	100.00 %	1440	100.00 %	93324	0.057	0	0	0.000
⊟ Modbus/TCP	100.00 %	1440	100.00 %	93324	0.057	0	0	0.000
⊟ Text item	100.00 %	1440	100.00 %	93324	0.057	1152	74748	0.046
Malformed Packet	20.00 %	288	19.90 %	18576	0.011	288	18576	0.011

IDS Logs

- Bro IDS
  - DNP3 & Modbus
  - More ICS protocols being developed by UIUC
- Snort IDS
  - DNP3 & Modbus preprocessors
  - ET SCADA & DigitalBond Quickdraw Snort rules
- Suricata IDS
  - New DNP3 parser & ET SCADA rules

IDS Logs

Bro IDS parses Modbus and DNP3 packets, ELSA consolidates Bro logs



```
#separator \x09
#set_separator  ,
#empty_field    (empty)
#unset_field    -
#path   weird
#open   2014-11-10-18-12-38
#fields ts      uid     id.orig_h       id.orig_p       id.resp_h       id.resp_p       name    addl    notice  peer
#types  time    string  addr    port    addr    port    string  string  bool    string
1415643158.075719       C37a6N2PuUN30lKEF7      192.168.0.7     44173   75.75.76.76     53      bad_UDP_checksum        -       F       bro
1415643171.329125       -       -       -       -       -       dns_unmatched_msg       -       F       bro
1415643171.329646       -       -       -       -       -       dns_unmatched_msg       -       F       bro
1415643181.530697                               -       -       dns_unmatched_msg       -       F       bro
1415643333.743576                       192.168.0.1     12423   192.168.0.3     502     binpac exception: out_of_bound: ReadCoilsRequest: 4 > 3 -       F       bro
1415643333.785542                       192.168.0.1     12423   192.168.0.3     502     binpac exception: out_of_bound: ReadCoilsRequest: 4 > 2 -       F       bro
1415643337.005274                       192.168.0.1     12423   192.168.0.3     502     binpac exception: out_of_bound: ReadDiscreteInputsRequest: 4 > 3        -       F       bro
1415643337.048149                       192.168.0.1     12423   192.168.0.3     502     binpac exception: out_of_bound: ReadDiscreteInputsRequest: 4 > 2        -       F       bro
1415643340.262602       CFZNyo3XPkDSoo3Gka      192.168.0.1     12423   192.168.0.3     502     binpac exception: out_of_bound: ReadHoldingRegistersRequest: 4 > 3      -       F       bro
1415643340.304368       CFZNyo3XPkDSoo3Gka      192.168.0.1     12423   192.168.0.3     502     binpac exception: out_of_bound: ReadHoldingRegistersRequest: 4 > 2      -       F       bro
1415643343.526561       CFZNyo3XPkDSoo3Gka      192.168.0.1     12423   192.168.0.3     502     binpac exception: out_of_bound: ReadInputRegistersRequest: 4 > 3        -       F       bro
1415643343.569314       CFZNyo3XPkDSoo3Gka      192.168.0.1     12423   192.168.0.3     502     binpac exception: out_of_bound: ReadInputRegistersRequest: 4 > 2        -       F       bro
1415643355.970682       CGKbev3043NKUQiAol      192.168.0.1     12424   192.168.0.3     443     bad_TCP_checksum        -       F       bro
1415643700.826570       CC2tws4UkylgufRzl4      fe80::6a05:caff:fe28:2342       5353    ff02::fb        5353    DNS_Conn_count_too_large        -       F       bro
1415643724.601213       C3N4Jy1SssYMcwY0N5      192.168.0.1     12507   192.168.0.3     20001   binpac exception: out_of_bound: DNP3_Application_Request_Header: 2 > 0  -       F       bro
1415643728.211378       CRd31o2ZcR6GE91oG4      192.168.0.1     12508   192.168.0.3     20000   binpac excepti
1415643730.826659       -       -       -       -       -       dns_unmatched_msg       -       F       bro
1415643831.018184       -       -       -       -       -       dns_unmatched_msg       -       F       bro
1415643831.018579       -                       -       -       dns_unmatched_msg       -       F       bro
1415643841.219311       -                                       dns_unmatched_msg       -       F       bro
1415644094.522202       Cwsx                    192.168.0.1     12614   192.168.0.3     20000   dnp3_unexpecte
1415644094.522202       Cwsx                    192.168.0.1     12614   192.168.0.3     20000   binpac excepti
1415644097.643065       CLpo                    192.168.0.1     12615   192.168.0.3     20000   dnp3_unexpecte
1415644116.425850       CB1Vy54p2Oy4u0WiC2      192.168.0.1     12619   192.168.0.3     20001   binpac excepti
1415644117.716313       CLpoMi26Do2yVhRHdg      192.168.0.1     12615   192.168.0.3     20000   dnp3_header_la
1415644121.414554       CMyKEg2rmMmjnEiBp9      192.168.0.1     12620   192.168.0.3     20001   binpac excepti
1415644149.129414       CLrbBbTsdYuX424rh       192.168.0.1     12626   192.168.0.3     20000   dnp3_unexpecte
1415644149.364053       CeY89c3yjEhcOpG9g2      192.168.0.1     12627   192.168.0.3     20000   dnp3_unexpecte
1415644447.340837       -       -       -       -       -       dns_unmatched_msg       -       F       bro
1415644447.341030       -       -       -       -       -       dns_unmatched_msg       -       F       bro
1415644477.540805       -       -       -       -       -       dns_unmatched_msg       -       F       bro
1415644724.161881       CfuuWd4ChV763jjPo3      fe80::6a05:caff:fe28:2342       5353    ff02::fb        5353
1415644734.161912       -       -       -       -       -       dns_unmatched_msg       -       F       bro
1415644847.755515       CEdeV71pcXqFSS2gHl      192.168.0.1     12734   192.168.0.3     20000   binpac excepti
1415644862.666545       CSEKaN3SCZu5AERPc1      192.168.0.1     12738   192.168.0.3     20000   binpac excepti
1415644872.337025       CBJNdG3dG2Pr9ZFqaj      192.168.0.1     12742   192.168.0.3     20000   dnp3_unexpecte
1415644872.337025       CBJNdG3dG2Pr9ZFqaj      192.168.0.1     12742   192.168.0.3     20000   binpac excepti
1415644875.931040       CVMMxym4pDJkahhUh       192.168.0.1     12743   192.168.0.3     20000   dnp3_unexpecte
1415644894.425338       CVMMxym4pDJkahhUh       192.168.0.1     12743   192.168.0.3     20000   dnp3_header_la
```

https://localhost/elsa/

Query: class=BRO_WEIRD "-" groupby:name

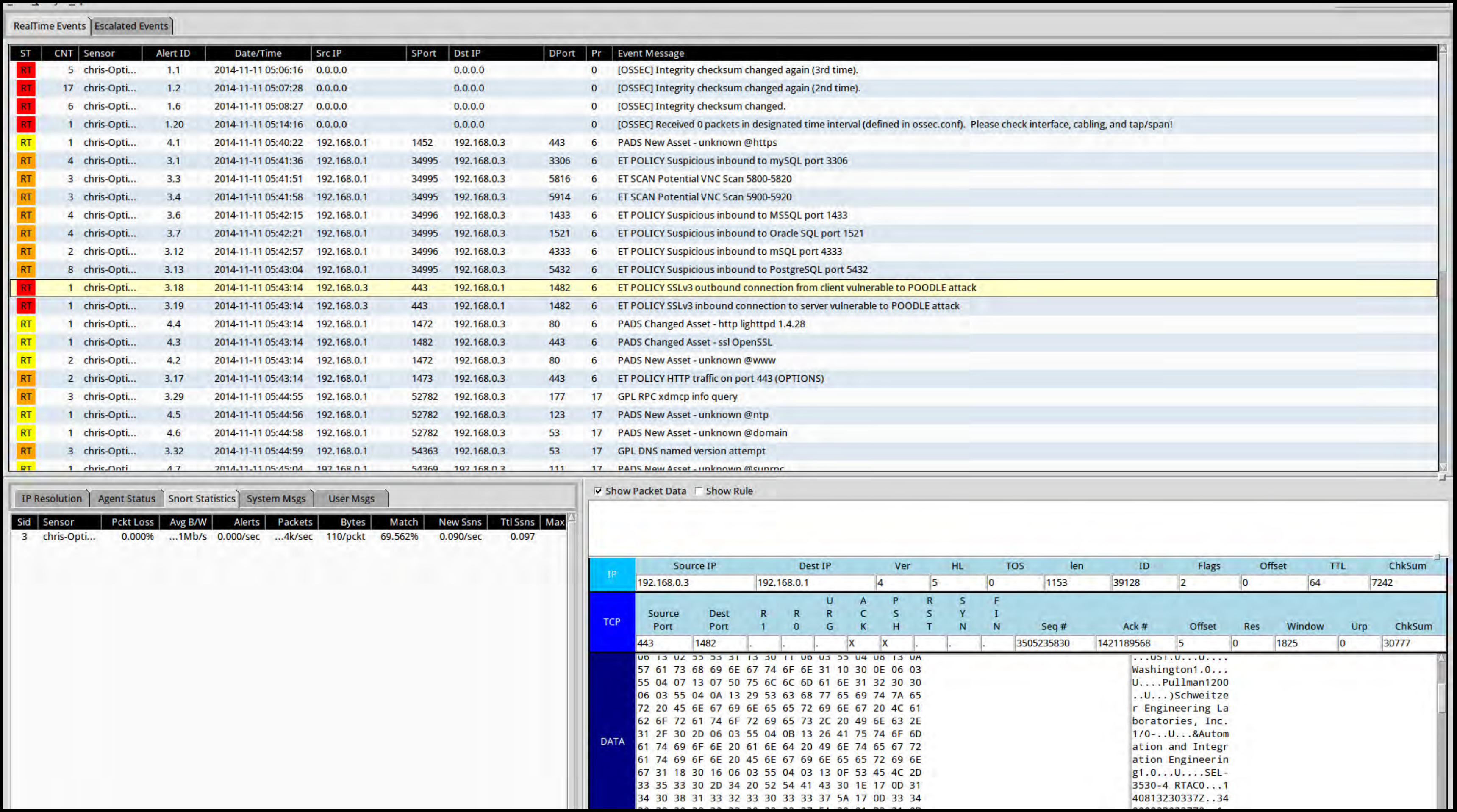
From: 2014-11-09 16:02:24 To:

class=BRO_WEIRD "-" groupby:name (241) [Grouped by name] ✕

Count	
61	dnp3_header_lacks_magic
34	dns_unmatched_msg
18	dnp3_unexpected_flow_direction
8	binpac exception: out_of_bound: DNP3_Application_Request_Header: 2 > 0
7	active_connection_reuse
7	bad_SYN_ack
6	DNS_truncated_len_lt_hdr_len
4	binpac exception: out_of_bound: ReadInputRegistersRequest: 4 > 3
4	binpac exception: out_of_bound: ReadHoldingRegistersRequest: 4 > 2
4	DNS_Conn_count_too_large
4	unknown_protocol_2
4	binpac exception: out_of_bound: ReadInputRegistersRequest: 4 > 2
4	binpac exception: out_of_bound: ReadCoilsRequest: 4 > 3

IDS GUIs

Alerts in Sguil of scanning activity



ST	CNT	Sensor	Alert ID	Date/Time	Src IP	SPort	Dst IP	DPort	Pr	Event Message
RT	5	chris-Opti...	1.1	2014-11-11 05:06:16	0.0.0.0		0.0.0.0		0	[OSSEC] Integrity checksum changed again (3rd time).
RT	17	chris-Opti...	1.2	2014-11-11 05:07:28	0.0.0.0		0.0.0.0		0	[OSSEC] Integrity checksum changed again (2nd time).
RT	6	chris-Opti...	1.6	2014-11-11 05:08:27	0.0.0.0		0.0.0.0		0	[OSSEC] Integrity checksum changed.
RT	1	chris-Opti...	1.20	2014-11-11 05:14:16	0.0.0.0		0.0.0.0		0	[OSSEC] Received 0 packets in designated time interval (defined in ossec.conf). Please check interface, cabling, and tap/span!
RT	1	chris-Opti...	4.1	2014-11-11 05:40:22	192.168.0.1	1452	192.168.0.3	443	6	PADS New Asset - unknown @https
RT	4	chris-Opti...	3.1	2014-11-11 05:41:36	192.168.0.1	34995	192.168.0.3	3306	6	ET POLICY Suspicious inbound to mySQL port 3306
RT	3	chris-Opti...	3.3	2014-11-11 05:41:51	192.168.0.1	34995	192.168.0.3	5816	6	ET SCAN Potential VNC Scan 5800-5820
RT	3	chris-Opti...	3.4	2014-11-11 05:41:58	192.168.0.1	34995	192.168.0.3	5914	6	ET SCAN Potential VNC Scan 5900-5920
RT	4	chris-Opti...	3.6	2014-11-11 05:42:15	192.168.0.1	34996	192.168.0.3	1433	6	ET POLICY Suspicious inbound to MSSQL port 1433
RT	4	chris-Opti...	3.7	2014-11-11 05:42:21	192.168.0.1	34995	192.168.0.3	1521	6	ET POLICY Suspicious inbound to Oracle SQL port 1521
RT	2	chris-Opti...	3.12	2014-11-11 05:42:57	192.168.0.1	34996	192.168.0.3	4333	6	ET POLICY Suspicious inbound to mSQL port 4333
RT	8	chris-Opti...	3.13	2014-11-11 05:43:04	192.168.0.1	34995	192.168.0.3	5432	6	ET POLICY Suspicious inbound to PostgreSQL port 5432
RT	1	chris-Opti...	3.18	2014-11-11 05:43:14	192.168.0.3	443	192.168.0.1	1482	6	ET POLICY SSLv3 outbound connection from client vulnerable to POODLE attack
RT	1	chris-Opti...	3.19	2014-11-11 05:43:14	192.168.0.3	443	192.168.0.1	1482	6	ET POLICY SSLv3 inbound connection to server vulnerable to POODLE attack
RT	1	chris-Opti...	4.4	2014-11-11 05:43:14	192.168.0.1	1472	192.168.0.3	80	6	PADS Changed Asset - http lighttpd 1.4.28
RT	1	chris-Opti...	4.3	2014-11-11 05:43:14	192.168.0.1	1482	192.168.0.3	443	6	PADS Changed Asset - ssl OpenSSL
RT	2	chris-Opti...	4.2	2014-11-11 05:43:14	192.168.0.1	1472	192.168.0.3	80	6	PADS New Asset - unknown @www
RT	2	chris-Opti...	3.17	2014-11-11 05:43:14	192.168.0.1	1473	192.168.0.3	443	6	ET POLICY HTTP traffic on port 443 (OPTIONS)
RT	3	chris-Opti...	3.29	2014-11-11 05:44:55	192.168.0.1	52782	192.168.0.3	177	17	GPL RPC xdmcp info query
RT	1	chris-Opti...	4.5	2014-11-11 05:44:56	192.168.0.1	52782	192.168.0.3	123	17	PADS New Asset - unknown @ntp
RT	1	chris-Opti...	4.6	2014-11-11 05:44:58	192.168.0.1	52782	192.168.0.3	53	17	PADS New Asset - unknown @domain
RT	3	chris-Opti...	3.32	2014-11-11 05:44:59	192.168.0.1	54363	192.168.0.3	53	17	GPL DNS named version attempt
RT	1	chris-Opti	4.7	2014-11-11 05:45:04	192.168.0.1	54369	192.168.0.3	111	17	PADS New Asset - unknown @sunrpc

Sid	Sensor	Pckt Loss	Avg B/W	Alerts	Packets	Bytes	Match	New Ssns	Ttl Ssns	Max
3	chris-Opti...	0.000%	...1Mb/s	0.000/sec	...4k/sec	110/pckt	69.562%	0.090/sec	0.097	

☑ Show Packet Data □ Show Rule

IP	Source IP	Dest IP	Ver	HL	TOS	len	ID	Flags	Offset	TTL	ChkSum
	192.168.0.3	192.168.0.1	4	5	0	1153	39128	2	0	64	7242

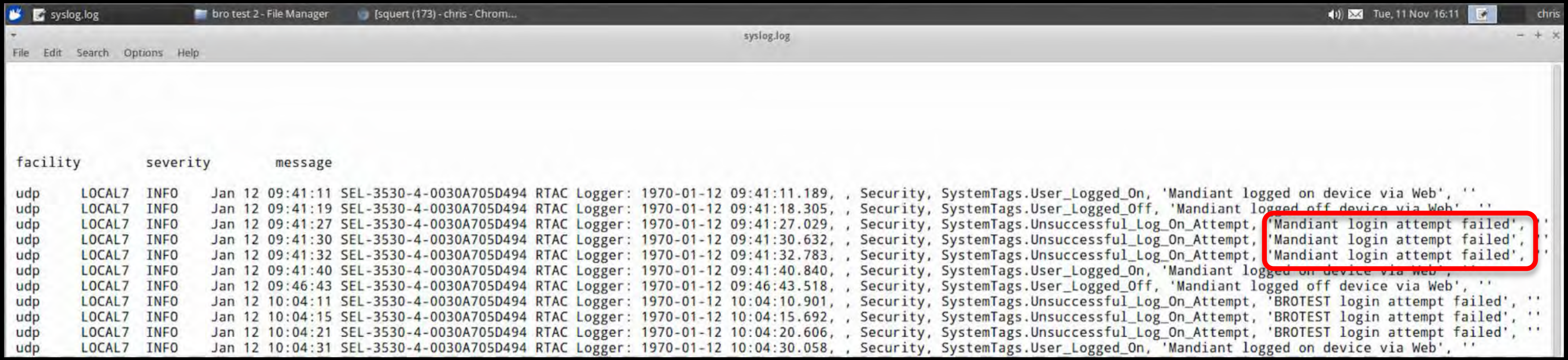
TCP	Source Port	Dest Port	R 1	R 0	U R G	A C K	P S H	R S T	S Y N	F I N	Seq #	Ack #	Offset	Res	Window	Urp	ChkSum
	443	1482	.	.	.	X	X	.	.	.	3505235830	1421189568	5	0	1825	0	30777

DATA

```
06 13 02 55 53 31 13 30 11 06 03 55 04 08 13 0A                 ...US1.0...U....
57 61 73 68 69 6E 67 74 6F 6E 31 10 30 0E 06 03                 Washington1.0...
55 04 07 13 07 50 75 6C 6C 6D 61 6E 31 32 30 30                 U....Pullman1200
06 03 55 04 0A 13 29 53 63 68 77 65 69 74 7A 65                 ..U...)Schweitze
72 20 45 6E 67 69 6E 65 65 72 69 6E 67 20 4C 61                 r Engineering La
62 6F 72 61 74 6F 72 69 65 73 2C 20 49 6E 63 2E                 boratories, Inc.
31 2F 30 2D 06 03 55 04 0B 13 26 41 75 74 6F 6D                 1/0-..U...&Autom
61 74 69 6F 6E 20 61 6E 64 20 49 6E 74 65 67 72                 ation and Integr
61 74 69 6F 6E 20 45 6E 67 69 6E 65 65 72 69 6E                 ation Engineerin
67 31 18 30 16 06 03 55 04 03 13 0F 53 45 4C 2D                 g1.0...U....SEL-
33 35 33 30 2D 34 20 52 54 41 43 30 1E 17 0D 31                 3530-4 RTAC0...1
34 30 38 31 33 32 33 30 33 33 37 5A 17 0D 33 34                 40813230337Z..34
```

Syslog

Syslog can be configured to send to a NSM sensor or detected in network traffic if sent elsewhere. This is the Bro IDS Log for Syslog from an RTU.



```
facility        severity        message

udp     LOCAL7  INFO    Jan 12 09:41:11 SEL-3530-4-0030A705D494 RTAC Logger: 1970-01-12 09:41:11.189, , Security, SystemTags.User_Logged_On, 'Mandiant logged on device via Web', ''
udp     LOCAL7  INFO    Jan 12 09:41:19 SEL-3530-4-0030A705D494 RTAC Logger: 1970-01-12 09:41:18.305, , Security, SystemTags.User_Logged_Off, 'Mandiant logged off device via Web', ''
udp     LOCAL7  INFO    Jan 12 09:41:27 SEL-3530-4-0030A705D494 RTAC Logger: 1970-01-12 09:41:27.029, , Security, SystemTags.Unsuccessful_Log_On_Attempt, 'Mandiant login attempt failed', ''
udp     LOCAL7  INFO    Jan 12 09:41:30 SEL-3530-4-0030A705D494 RTAC Logger: 1970-01-12 09:41:30.632, , Security, SystemTags.Unsuccessful_Log_On_Attempt, 'Mandiant login attempt failed', ''
udp     LOCAL7  INFO    Jan 12 09:41:32 SEL-3530-4-0030A705D494 RTAC Logger: 1970-01-12 09:41:32.783, , Security, SystemTags.Unsuccessful_Log_On_Attempt, 'Mandiant login attempt failed', ''
udp     LOCAL7  INFO    Jan 12 09:41:40 SEL-3530-4-0030A705D494 RTAC Logger: 1970-01-12 09:41:40.840, , Security, SystemTags.User_Logged_On, 'Mandiant logged on device via Web', ''
udp     LOCAL7  INFO    Jan 12 09:46:43 SEL-3530-4-0030A705D494 RTAC Logger: 1970-01-12 09:46:43.518, , Security, SystemTags.User_Logged_Off, 'Mandiant logged off device via Web', ''
udp     LOCAL7  INFO    Jan 12 10:04:11 SEL-3530-4-0030A705D494 RTAC Logger: 1970-01-12 10:04:10.901, , Security, SystemTags.Unsuccessful_Log_On_Attempt, 'BROTEST login attempt failed', ''
udp     LOCAL7  INFO    Jan 12 10:04:15 SEL-3530-4-0030A705D494 RTAC Logger: 1970-01-12 10:04:15.692, , Security, SystemTags.Unsuccessful_Log_On_Attempt, 'BROTEST login attempt failed', ''
udp     LOCAL7  INFO    Jan 12 10:04:21 SEL-3530-4-0030A705D494 RTAC Logger: 1970-01-12 10:04:20.606, , Security, SystemTags.Unsuccessful_Log_On_Attempt, 'BROTEST login attempt failed', ''
udp     LOCAL7  INFO    Jan 12 10:04:31 SEL-3530-4-0030A705D494 RTAC Logger: 1970-01-12 10:04:30.058, , Security, SystemTags.User_Logged_On, 'Mandiant logged on device via Web', ''
```

RTUs with Syslog

- SEL-3530 RTAC
- GE D20MX
- Novatech OrionLX
- Cooper SMP 16

If not…require syslog and other logs in the ICS procurement language

NSM Tools for the 7 Data Types

Security Onion Linux distribution

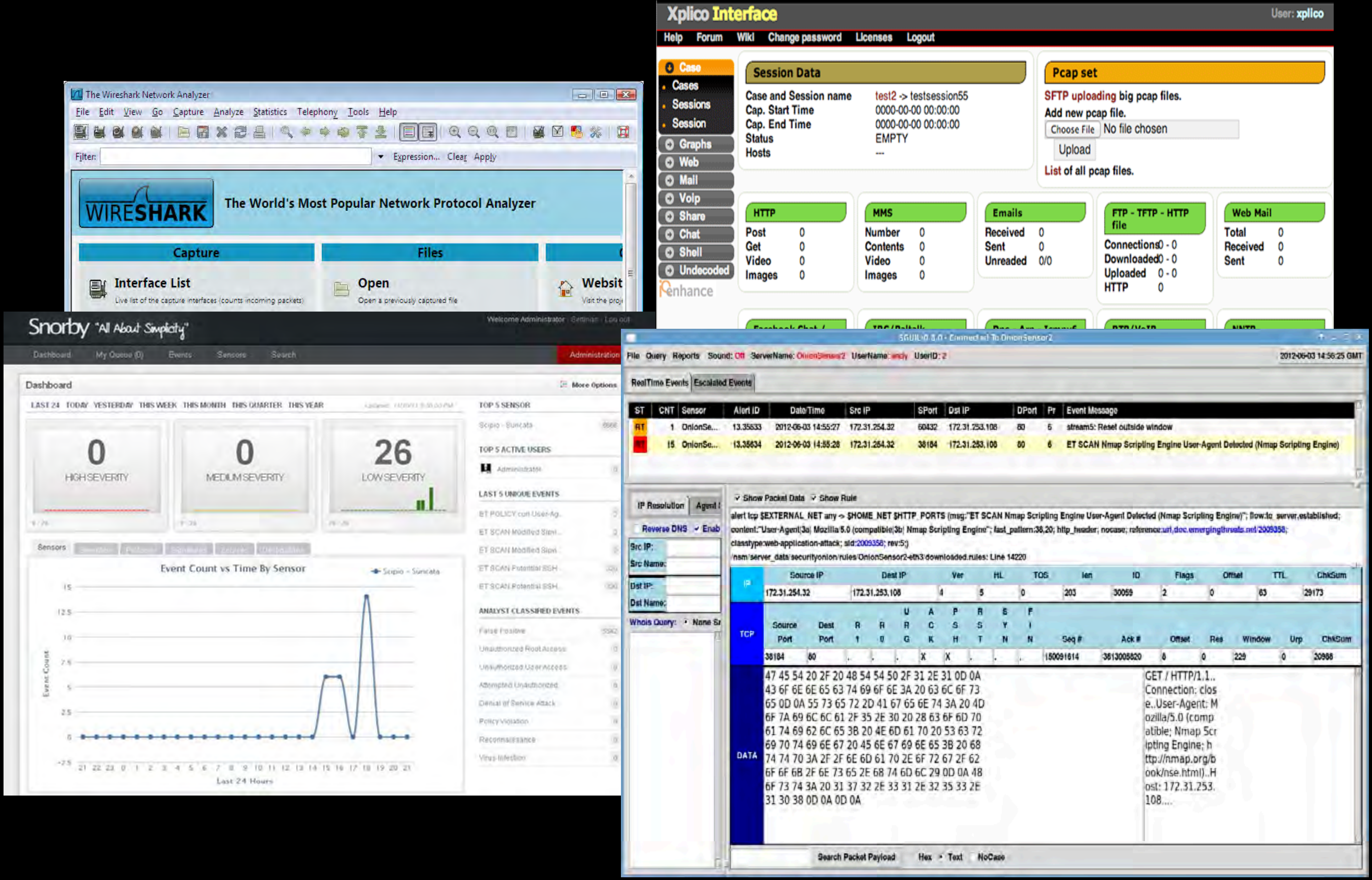
  – Easy to install and lots of documentation

- Full packet capture – Tcpdump/Wireshark/NetworkMiner
- Extracted content – Xplico/NetworkMiner
- Session data – Bro/FlowBAT
- Transaction data – Bro
- Statistical data – Capinfos/Wireshark
- Metadata – ELSA (Whois)
- Alert data – Snort, Suricata, Sguil, Snorby

Security Onion

Peel Back the Layers of Your Network

Security Onion Tools



The Wireshark Network Analyzer

File Edit View Go Capture Analyze Statistics Telephony Tools Help
Filter: Expression... Clear Apply
WIRESHARK
The World's Most Popular Network Protocol Analyzer
Capture
Files
Interface List
Live list of the capture interfaces (counts incoming packets)
Open
Open a previously captured file
Websit
Visit the proj

Xplico Interface

User: xplico
Help Forum Wiki Change password Licenses Logout
Case
Cases
Sessions
Session
Graphs
Web
Mail
Voip
Share
Chat
Shell
Undecoded
enhance

Session Data

Case and Session name	test2 -> testsession55
Cap. Start Time	0000-00-00 00:00:00
Cap. End Time	0000-00-00 00:00:00
Status	EMPTY
Hosts	---

Pcap set

SFTP uploading big pcap files.

Add new pcap file.

Choose File No file chosen

Upload

List of all pcap files.

HTTP

Post	0
Get	0
Video	0
Images	0

MMS

Number	0
Contents	0
Video	0
Images	0

Emails

Received	0
Sent	0
Unreaded	0/0

FTP - TFTP - HTTP file

Connections	0 - 0
Downloaded	0 - 0
Uploaded	0 - 0
HTTP	0

Web Mail

Total	0
Received	0
Sent	0

Snorby "All About Simplicity"

SGUIL-0.8.0 - Connected To OnionSensor2

File Query Reports Sound: Off ServerName: OnionSensor2 UserName: andy UserID: 2
2012-06-03 14:56:25 GMT
RealTime Events Escalated Events
IP Resolution Agent
Reverse DNS Enab
Src IP:
Src Name:
Dst IP:
Dst Name:
Whois Query: None
Show Packet Data Show Rule
Search Packet Payload Hex Text NoCase

ST	CNT	Sensor	Alert ID	Date/Time	Src IP	SPort	Dst IP	DPort	Pr	Event Message
RT	1	OnionSe...	13.35633	2012-06-03 14:55:27	172.31.254.32	60432	172.31.253.108	80	6	stream5: Reset outside window
RT	15	OnionSe...	13.35634	2012-06-03 14:55:28	172.31.254.32	38184	172.31.253.108	80	6	ET SCAN Nmap Scripting Engine User-Agent Detected (Nmap Scripting Engine)

```
alert tcp $EXTERNAL_NET any -> $HOME_NET $HTTP_PORTS (msg:"ET SCAN Nmap Scripting Engine User-Agent Detected (Nmap Scripting Engine)"; flow:to_server,established; content:"User-Agent|3a| Mozilla/5.0 (compatible|3b| Nmap Scripting Engine"; fast_pattern:38,20; http_header; nocase; reference:url,doc.emergingthreats.net/2009358; classtype:web-application-attack; sid:2009358; rev:5;)
/nsm/server_data/securityonion/rules/OnionSensor2-eth3/downloaded.rules: Line 14220
```

IP	Source IP	Dest IP	Ver	HL	TOS	len	ID	Flags	Offset	TTL	ChkSum
	172.31.254.32	172.31.253.108	4	5	0	203	30059	2	0	63	29173

TCP	Source Port	Dest Port	R 1	R 0	URG	ACK	PSH	RST	SYN	FIN	Seq #	Ack #	Offset	Res	Window	Urp	ChkSum
	38184	80	.	.	.	X	X	.	.	.	150091614	3613005820	8	0	229	0	20986

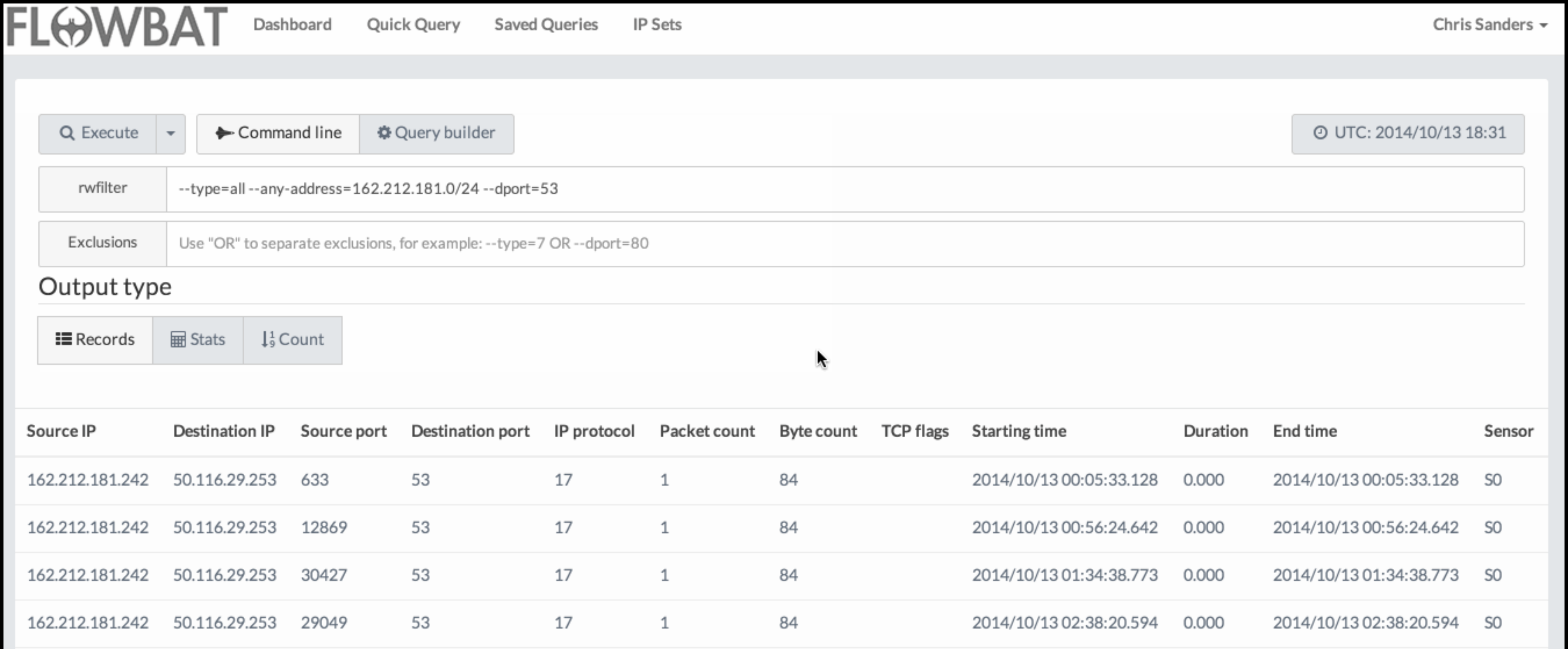
DATA

```
47 45 54 20 2F 20 48 54 54 50 2F 31 2E 31 0D 0A    GET / HTTP/1.1..
43 6F 6E 6E 65 63 74 69 6F 6E 3A 20 63 6C 6F 73    Connection: clos
65 0D 0A 55 73 65 72 2D 41 67 65 6E 74 3A 20 4D    e..User-Agent: M
6F 7A 69 6C 6C 61 2F 35 2E 30 20 28 63 6F 6D 70    ozilla/5.0 (comp
61 74 69 62 6C 65 3B 20 4E 6D 61 70 20 53 63 72    atible; Nmap Scr
69 70 74 69 6E 67 20 45 6E 67 69 6E 65 3B 20 68    ipting Engine; h
74 74 70 3A 2F 2F 6E 6D 61 70 2E 6F 72 67 2F 62    ttp://nmap.org/b
6F 6F 6B 2F 6E 73 65 2E 68 74 6D 6C 29 0D 0A 48    ook/nse.html)..H
6F 73 74 3A 20 31 37 32 2E 33 31 2E 32 35 33 2E    ost: 172.31.253.
31 30 38 0D 0A 0D 0A                               108....
```

NetFlow Tools

SiLK & FlowBAT

- Install on Security Onion with 2 scripts
- www.flowbat.com



rwfilter: --type=all --any-address=162.212.181.0/24 --dport=53

Exclusions: Use "OR" to separate exclusions, for example: --type=7 OR --dport=80

Output type

Source IP	Destination IP	Source port	Destination port	IP protocol	Packet count	Byte count	TCP flags	Starting time	Duration	End time	Sensor
162.212.181.242	50.116.29.253	633	53	17	1	84		2014/10/13 00:05:33.128	0.000	2014/10/13 00:05:33.128	S0
162.212.181.242	50.116.29.253	12869	53	17	1	84		2014/10/13 00:56:24.642	0.000	2014/10/13 00:56:24.642	S0
162.212.181.242	50.116.29.253	30427	53	17	1	84		2014/10/13 01:34:38.773	0.000	2014/10/13 01:34:38.773	S0
162.212.181.242	50.116.29.253	29049	53	17	1	84		2014/10/13 02:38:20.594	0.000	2014/10/13 02:38:20.594	S0

Security Onion Implementation

- Test in a lab first
- Select suitable hardware platform
  - More RAM is better
  - Bigger hard drive is better (longer retention)
- Mirrored/SPAN port on router/switch or a good network tap
- Select proper placement of SO sensor
  - *The Practice of Network Security Monitoring*
  - *Applied Network Security Monitoring*
- Work with the right stakeholders if placing in production

SO for ICS = Security Ogre

NSM References/Resources

- *The Cuckoo's Egg* by Cliff Stoll
  https://www.youtube.com/watch?v=EcKxaq1FTac
  1-hour NOVA Special (1990)
- *The Practice of Network Security Monitoring* by Richard Bejtlich
  http://www.nostarch.com/nsm
- *Applied Network Security Monitoring* by Chris Sanders & Jason Smith
  http://www.appliednsm.com/
- The NSM Wiki http://nsmwiki.org
- http://securityonion.net

Takeaways

- ✓You can implement NSM in ICS today – without impacting your operations
- ✓There are free tools available to help you start looking at your ICS and hunting for evil

People…

…the most important part of NSM!

- Gigabytes of data and 1000s of IDS alerts are useless without interpretation
- Analyze data collected to understand what’s normal – and what’s not
- Identify adversary TTPs and act to disrupt them

Remember

Adversaries are a “Who”, not a “What”

Find Evil

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