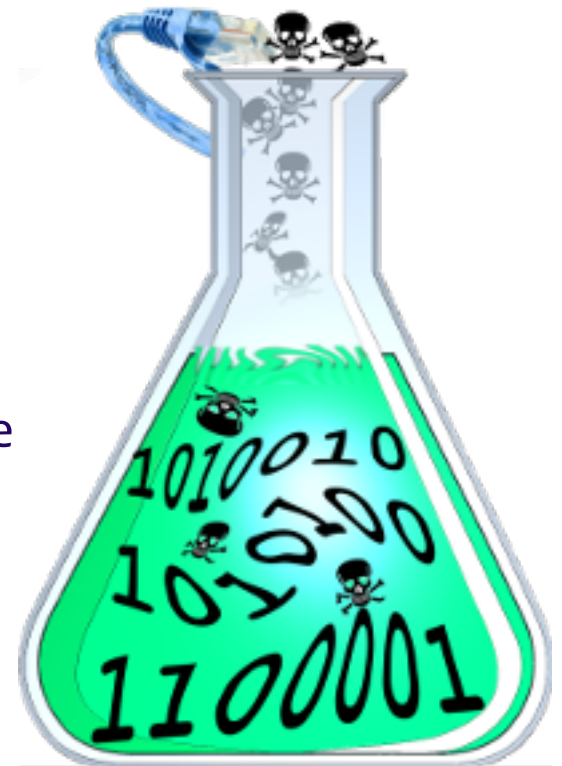




# Labtainers Cybersecurity Lab Exercises

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## Overview – What is Labtainers?

- A collection of fully provisioned free cyber exercises
- All within a local VM or a VM on the cloud
- Docker containers for efficiency & provisioning
- With automated assessment of student progress
- Individualized labs to discourage sharing
- A framework and tools for creating and deploying new labs



## Experiential learning is desirable, but ...

- Institutional infrastructure may be absent
- Labs difficult to build and maintain
  - Overworked instructors need well-vetted labs
- Student platform diversity introduces problems
  - Different operating systems, libraries, software tools, etc.
  - Platform setup for lab distracts from learning objectives
  - Lab results vary widely due to configuration differences
- Experiential labs require exploration
  - How is this facilitated and observed?
- Students may share or reuse other work
  - Need individualized labs, but grading effort becomes large



# Labtainers Objectives

## Consistent and Fair

- Students execute labs in identical environments
- Instructors see consistent results and assess students on their work rather than environmental effects

## Parameterizable

- Labs configured so each student's work can be unique
- Labs are same level of difficulty for all students
- Uniqueness should not complicate assessment

## Support for Automatic Assessment

- Generate & collect artifacts from student work, e.g., program outputs
- Provide instructors with insight into student progress per lab goals

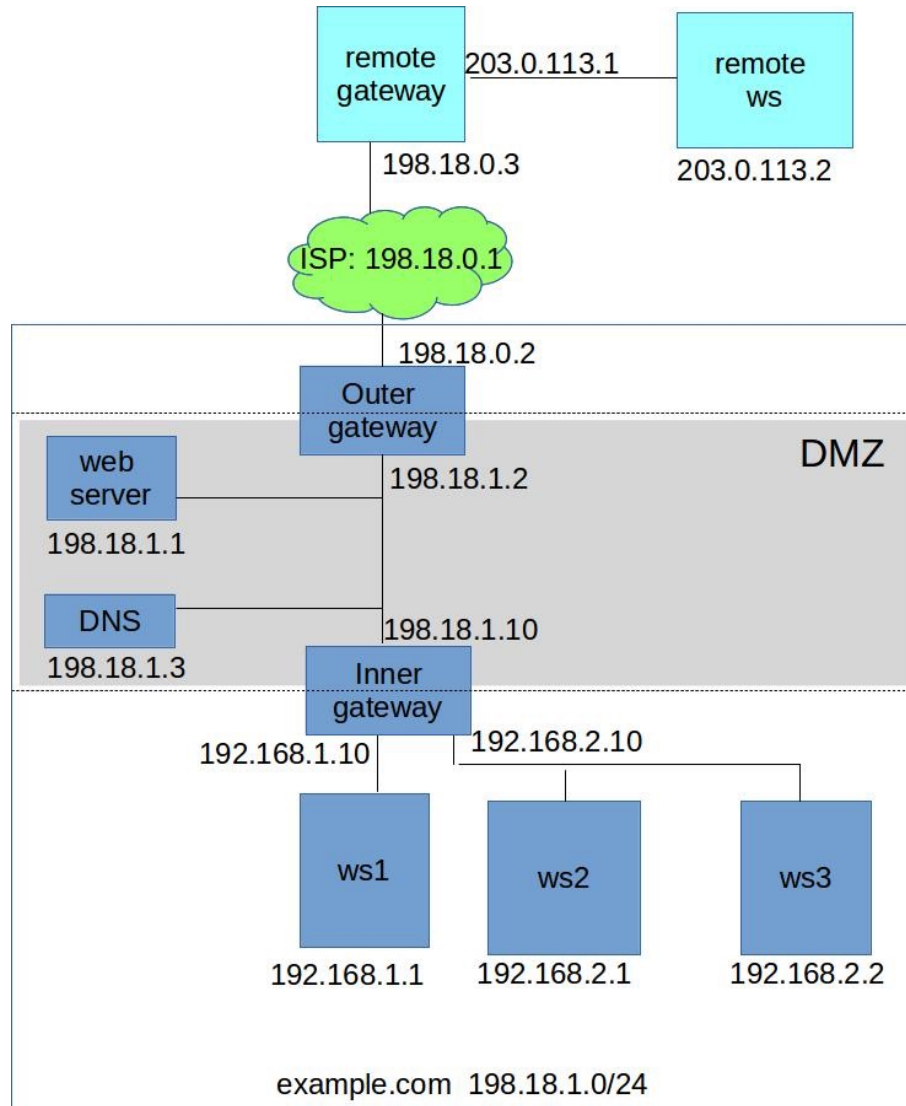


# Stand-alone Linux Cybersecurity Labs

- Multi-component network topologies
  - Packaged using Docker containers
  - Pre-configured execution environments
- Local to student's computer
  - One Linux host, (e.g., VM) runs many containers
  - No per-lab provisioning required by the student
- Cloud-based option, e.g., Azure and GCP
  - Free education accounts managed by student
  - Solves Mac M1 chip issue (won't run X86 VMs)
- Public repository of labs & open framework



# Run This Network on a Laptop





# Docker containers

- **Namespace isolation: like a VM but less overhead**
  - Commercial product with massive user base
  - Application vendors deploy for consistent environments
  - We break the model by running full Linux services
- **Student laptop can run many containers**
  - But may be bogged down by 2 or more VMs
  - Enables labs with many networked components
- **All containers share Linux kernel with host**
  - But can have distinct packages & library versions
  - Containers limited to Linux (mixed distributions)



# Automated Provisioning

- Student interacts with one Linux VM desktop
- Starting a lab pulls all necessary container images
- Containers created along with virtual networks
- Student sees multiple terminals and/or GUI apps
- Interacts with multiple computers
  - Each is fully provisioned
  - And instrumented to record results





# Parameterization

- Individualizes labs for each student (optional)
- Random number seed based on student ID
- Example: size of buffer to overflow
  - Symbolic replacement of value in source code
  - Vulnerable program compiled during first run
  - Affects offset of return address to overwrite
- *Individualizing Cybersecurity Lab Exercises with Labtainers*
  - <http://ieeexplore.ieee.org/document/8328979/>



# Automated Assessment

- Student activity and files collected as artifacts
  - Mostly transparent to students
  - *bash* hooks capture *stdin* & *stdout* into timestamped files
  - Artifacts forwarded to instructor
- Instructor tools assess student performance
  - Expected results as defined by lab designer
  - Insight into student progress and exploration
- Makes individualized labs practical



# Roles in the World of Labtainers

## Designer

SME who works with instructor to create labs based on learning objectives. Fine tunes and updates labs. May define assessment criteria.



## Instructor

Defines learning objectives. Works with (or is) designer. Ensures student readiness to perform labs and conducts assessments.



## Student

Performs lab exercise. Learns! Delivers results to instructor for assessment.



# Student Workflow

- Student installs a VM appliance or creates VM on the cloud
- Performs lab exercises as directed by instructor
- Artifacts are automatically collected into a zip file
- Student sends zip file to instructor, e.g., via an LMS



## Performing a Lab

```
student@ubuntu: ~/labtainer/trunk/scripts/labtainer-student
File Edit View Search Terminal Help
student@ubuntu:~/labtainer/trunk/scripts/labtainer-student$ labtainer telnetlab
pulling telnetlab.client.student from labtainers
Done with pull
pulling telnetlab.server.student from labtainers
Done with pull
Please enter your e-mail address: [dog@cat.com]
Starting the lab, this may take a moment...

The lab manual is at
file:///home/student/labtainer/trunk/labs/telnetlab/docs/telnet.pdf

You may open this manual by right clicking
and select "Open Link".

Press <enter> to start the lab
```



## Performing a Lab

```
ubuntu@client: ~  
File Edit View Search Terminal Help  
ubuntu@client:~$  
  
ubuntu@server: ~  
File Edit View Search Terminal Help  
ubuntu@server:~$ ifconfig  
eth0    Link encap:Ethernet  HWaddr 02:42:ac:14:00:03  
        inet addr:172.20.0.3  Bcast:172.20.0.255  Mask:255.255.255.0  
        UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1  
        RX packets:54 errors:0 dropped:0 overruns:0 frame:0  
        TX packets:0 errors:0 dropped:0 overruns:0 carrier:0  
        collisions:0 txqueuelen:0  
        RX bytes:6865 (6.8 KB)  TX bytes:0 (0.0 B)  
  
lo      Link encap:Local Loopback  
        inet addr:127.0.0.1  Mask:255.0.0.0  
        UP LOOPBACK RUNNING  MTU:65536  Metric:1  
        RX packets:0 errors:0 dropped:0 overruns:0 frame:0  
        TX packets:0 errors:0 dropped:0 overruns:0 carrier:0  
        collisions:0 txqueuelen:1000  
        RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)  
  
ubuntu@server:~$
```



# Instructor Workflow

- Instructor collects zip files into a directory
- Runs grading tool and views table of student progress
- Optional browser-based deep dive into student activity
- Collected artifacts may include lab reports



# Automated Assessment

The screenshot shows a Linux desktop with a terminal window open. The terminal displays the output of the `gradelab telnetlab -wr` command. The output includes a table of assessment results for various student domains and a list of actions performed during the assessment.

```
student@LabtainersVM: ~/labtainer/trunk/scripts/labtainer-instructor
File Edit View Search Terminal Tabs Help
student@LabtainersVM: ~/labtainer/labtainer-stu... x student@LabtainersVM: ~/labtainer_xfer/telnetlab x student@LabtainersVM: ~/labtainer/trunk/scripts... x
student@LabtainersVM:~/labtainer/trunk/scripts/labtainer-instructor$ gradelab telnetlab -wr
Labname telnetlab

Student | telnetview | sshview | failed_login |
===== | ===== | ===== | ===== |
alice_at_my.edu | Y | Y | Y |
frank_at_beans.com | Y | Y | Y |
mary_at_what.eh | Y | Y | Y |
tony_at_here.there | Y | Y | Y |

What is automatically assessed for this lab:
failed_login: Failed login as expected.
telnetview: viewed file from telnet
sshview: viewed file from ssh


Point your browser to http://localhost:8008
student@LabtainersVM:~/labtainer/trunk/scripts/labtainer-instructor$
```



# Automated Assessment

The screenshot shows a Firefox browser window with the address bar at localhost:8008. The page content is as follows:

## Labtainers Gradelab for Lab: telnetlab



- [Table of Student Goals](#)
- [Lab Manual for telnetlab](#)
- [Labtainer Instructor Guide](#)
- [Lab Designer Guide](#)
- [Labtainers web page](#)

This is an early release version of the web-based student assessment tool. Please send feedback to Mike Thompson (mfthomps@nps.edu), or open a [GitHub issue](#)

At the bottom of the browser window, a video player interface is visible with a play button, a progress bar at 1:35 / 2:06, and volume and full-screen icons.



# Automated Assessment

home

## Student Assessment for Lab: telnetlab

Name	telnetview	sshview	failed_login
tony	True	True	True
mary	True	True	True
frank	True	True	True
alice	True	True	True

What is automatically assessed for this lab:  
failed\_login: Failed login as expected.  
telnetview: viewed file from telnet  
sshview: viewed file from ssh

[Goals configuration files](#)

1:38 / 2:06



## More than 50 Existing Labs

- Software vulnerabilities, e.g., buffer overflow
- Networking, e.g., arp-spoof, DNS-spoof, Snort
- Operations, e.g., ACLs, system logs
- Web, e.g., cross site scripting (OWASP IModules)
- Cryptography, e.g., hashing, VPNs
- Industrial control systems (PLCs)



# Find labs using keywords

```
student@LabtainersVM: ~/labtainer/labtainer-student
File Edit View Search Terminal Help
sql injection
ssh
ssh agent
ssl
symmetric keys
syn flood
syslog
tcp/ip
tcpdump
teleportation
telnet
traffic analysis
trojan horse
tshark
users
vpn
vpn gateway
vulnerability
wireshark
xsite
xsrif
student@LabtainersVM:~/labtainer/labtainer-student$ labtainer -f ssh
denyhost -- Explores the use of denyhosts to limit SSH login attempts from IP addresses.
ssh-agent -- Use of an SSH agent SSHing to remote computers without entering a passphrase for each access.
sshlab -- Use of a public/private key pair to access a server via ssh.
telnetlab -- Illustrates the telnet protocol transmission of plain-text passwords.
student@LabtainersVM:~/labtainer/labtainer-student$
```



# Finding labs with Labpacks

```
student@LabtainersVM: ~/labtainer/labtainer-student
File Edit View Search Terminal Help
ssh-agent -- Use of an SSH agent SSHing to remote computers without entering a passphrase for each access.
sshlab -- Use of a public/private key pair to access a server via ssh.
telnetlab -- Illustrates the telnet protocol transmission of plain-text passwords.
student@LabtainersVM:~/labtainer/labtainer-student$ labpack
List of installed Labpacks:
network-intro -- Introduction to basic network concepts
networks -- Network security labs
operations -- Computer security operations and administration
crypto -- Applied cryptography
access -- Authentication and access control
net-traffic -- Network traffic analysis
web-security -- Web security labs
vuln -- Software vulnerability analysis and exploitation
ics -- Industrial Control Systems / Operational Technology

usage: labpack [-h] [-a ADD] [-u] [name]

Track performance of labs in a Labpack

positional arguments:
  name                The Labpack to track.

optional arguments:
  -h, --help          show this help message and exit
  -a ADD, --add ADD  Get a Labpack from a URL.
  -u, --updates       Update Labpacks for this installation.
student@LabtainersVM:~/labtainer/labtainer-student$
```



## Lab content

- Each exercise has a lab manual for student reference
- Labs optionally support automated assessment (most do)
- Students can use automated assessment to check work
- Some lab have interactive quiz questions
- Most labs have “solution” scripts, contact me for those





## Create new labs

- Lab editing tool for GUI-based lab creation
- Provision each container in the lab
- Network definitions; configuration settings; etc.
- Creates a set of container images and config files
- Publish as “IModules” and share with others
- Or customize existing labs and or lab manuals



# Lab Editor

Labtainers



File Run Edit Help View

Lab: telnetlab

Lab running: No

Grader running: No

## Containers

Add

Copy from

client

server

## Networks

Add

SOME\_NETWORK 172.20.0.0/24

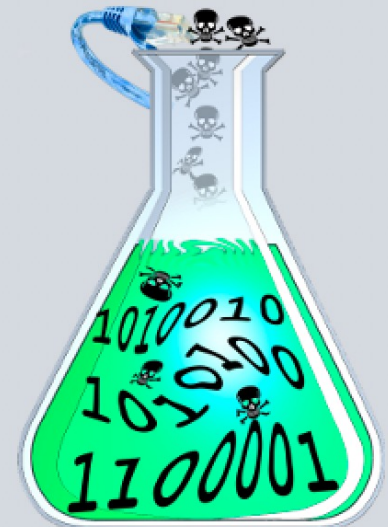
## Automated Assessment

Results

Goals

## Individualize

Parameters







# Configure a Container

Container Config: server

Edit

General Docker Hosts Other GNS3

Container: server Base: labtainer.network

User name:

Terminal quantity:

Password:

Terminal group:

Lab Gateway:

nameserver:

X11 enabled

No external gateway

No resolv.conf server

Add

Networks

SOME_NETWORK	172.20.0.3	Delete
--------------	------------	--------

OK Cancel

Labtainers

No

g: No

### Networks

Add

SOME_NETWORK	172.20.0.0/24
--------------	---------------

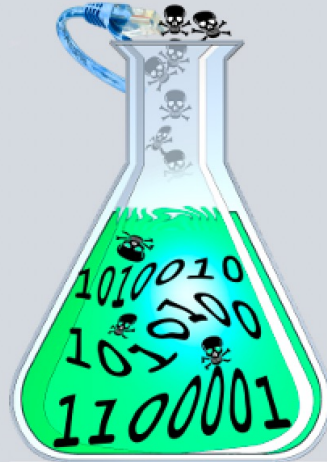
### Automated Assessment

Results

Goals

### Individualize

Parameters





# Add Packages in Dockerfile

File Edit View Search Terminal Help

```
ARG registry
FROM $registry/labtainer.network
ARG lab
ARG labdir
ARG imagedir
ARG apt_source
ARG user_name
#
#
ENV APT_SOURCE $apt_source
RUN /usr/bin/apt-source.sh
RUN apt-get update && apt-get install -y --no-install-recommends \
    telnetd

ADD $labdir/sys_$lab.tar.gz /

RUN useradd -ms /bin/bash $user_name
RUN echo "$user_name:$user_name" | chpasswd
RUN adduser $user_name sudo

USER $user_name
ENV HOME /home/$user_name
ADD $labdir/$lab.tar.gz $HOME

USER root
CMD ["/bin/bash", "-c", "exec /sbin/init --log-target=journal 3>&1"]
```

1,1

All



# Example Artifact Identification

Results for telnetlab

Create Remove All

	Result Tag	Container	File	Field Type	Field ID	Line Type	Line ID	
1	fileview	client	telnet.stdout	TOKEN	4	STARTSWITH	My string is:	^ Delete v Doc
2	sshfileview	client	ssh.stdout	TOKEN	4	STARTSWITH	My string is:	^ Delete v Doc
3	failed_login	server	/var/log/auth.log	CONTAINS	FAILED LOGIN	File		^ Delete v Doc

OK Cancel



# Resources

- Labtainers web page: <https://nps.edu/web/c30/labtainers>
  - Links to VM appliance
  - Student guide describes use of cloud based VMs
- Video tutorials on installation, use and assessment
- Student guide and Instructor guide
- Lab Designer Guide (how to build your own)
- IModules shared from other developers
- Published papers
- <https://github.com/mfthomps/Labtainers>
- Write me!



# Labtainers

[nps.edu/web/c30/labtainers](https://nps.edu/web/c30/labtainers)

## Contact

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