COORDINATED SCIENCE LABORATORY

ENGINEERING AT ILLINOIS

ADVISE Meta – Alpha Tool Workshop

August 16, 2016

Andy Crapo, Brett Feddersen, Alfredo Galbadon, Ken Keefe, Carol Muehrcke, Michael Rausch, Bill Sanders, and Ron Wright

ITI.ILLINOIS.EDU

INFORMATION TRUST INSTITUTE

Agenda

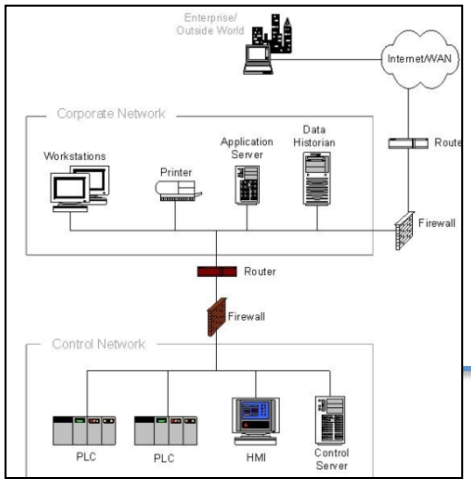
- Registration and Continental Breakfast
- Welcome
- Goals
  - Tool
  - Workshop
- Steps to Use ADVISE Meta
- Hands on Sessions
- Case Studies and Custom Ontologies
- Wrap Up

ADVISE Meta Introduction

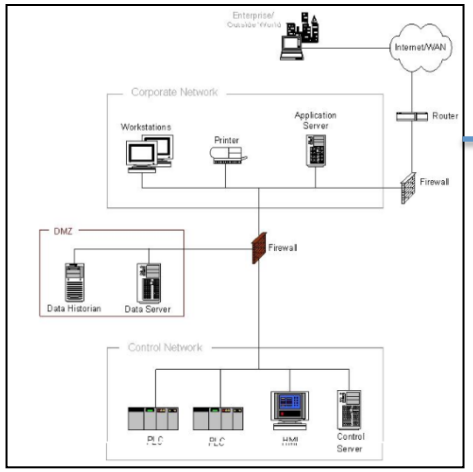
- Today: no scientific basis for designing security architectures
  - Follows from: no scientific basis for estimating effectiveness of security measures before deployment
- Today: security metrics
  - Before deployment, count countermeasures
    - Judge effectiveness based on experience, intuition
  - After deployment, count intrusions
- Purpose of ADVISE Meta
  - Provide scientific basis for design decisions by calculating security metrics at design time
  - Auditable results
  - No requirement for deep modeling or cybersecurity expertise

ADVISE Meta Tool

Architecture 1



Architecture 2



Compare architecture metrics: common attack paths, time to compromise, probability of compromise, cost of attack,…

Möbius SE Tool

Attack simulation

Architecture 1 Security metrics

Architecture 2 Security metrics

Example architectures: NIST 800-82 Figures 5-2 and 5-3

Workshop Goals

- Introduce the tool to the community
- Gather feedback about all aspects of the tool
  - High level concepts
  - Workflow
  - UI
  - Usability
- Feedback discussion at the end of each hands-on session

Agenda

- Registration and Continental Breakfast
- Welcome
- Goals
  - Tool
  - Workshop
- Steps to Use ADVISE Meta
- Hands on Sessions
- Case Studies and Custom Ontologies
- Wrap Up

Using ADVISE Meta

Step 1: Define purpose of analysis

–Analysis questions, concerns, scope

Step 2: Model System(s)

–Define system components, relationships and attributes
–Hosts, devices, applications, data, networks, firewalls, authentication, other countermeasures

Step 3: Model Adversaries, Attack Goals, Generate Possible Attack Paths

–Goals: View/modify data, install malware, gain network access, disable device, damage device…
–Select from standard adversary types, customize
–Set goal priorities of various adversaries
–Generate attack execution graph (AEG)

Step 4: Select Metrics

– Select from standard metrics or define custom
– Standard metric examples:
Probability goal met, cost to adversary

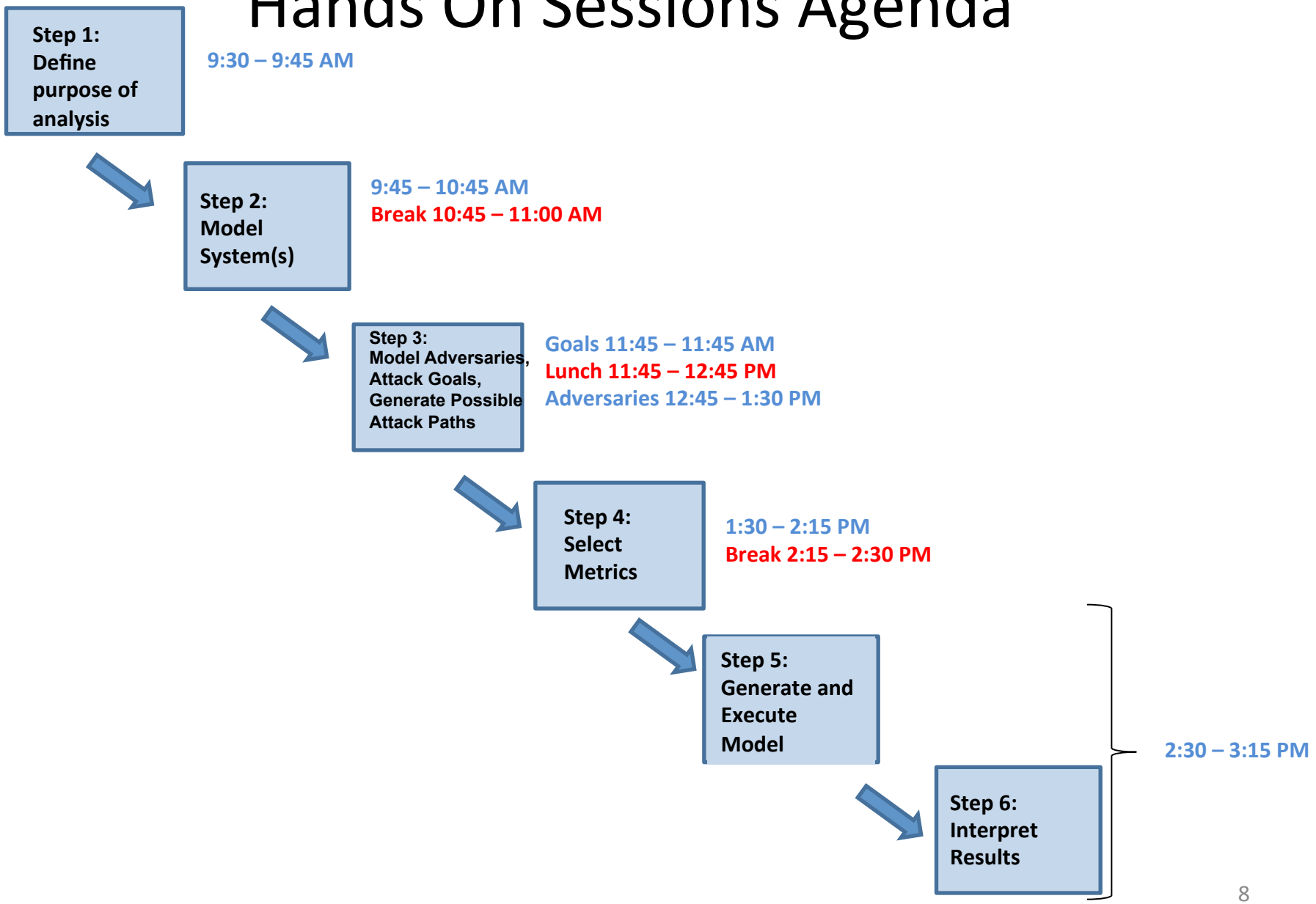
Step 5: Create and Execute Simulation

– Create and run simulation of adversary behavior

Step 6: Interpret Results

–Metric Values
–Visual display of common attack paths

Hands On Sessions Agenda



Agenda

- Registration and Continental Breakfast
- Welcome
- Goals
  - Tool
  - Workshop
- Steps to Use ADVISE Meta
- Hands on Sessions
- Case Studies and Custom Ontologies
- Wrap Up

Step 1 – Define Purpose of Analysis

What can be analyzed?

- With the base ontology: Enterprise system architectures that may have:
  - Networks hosting cyber and cyber-physical devices
  - Applications, data
  - Internet connections
  - Boundary protections and other common countermeasures
  - Design phase or existing
- With arbitrary ontology:
  - In theory, any system built of components, where attacks are constructed by linking attack steps against components

What kinds of questions can be answered?

- How susceptible is a system to cyber attacks?
- What can be done to decrease susceptibility?

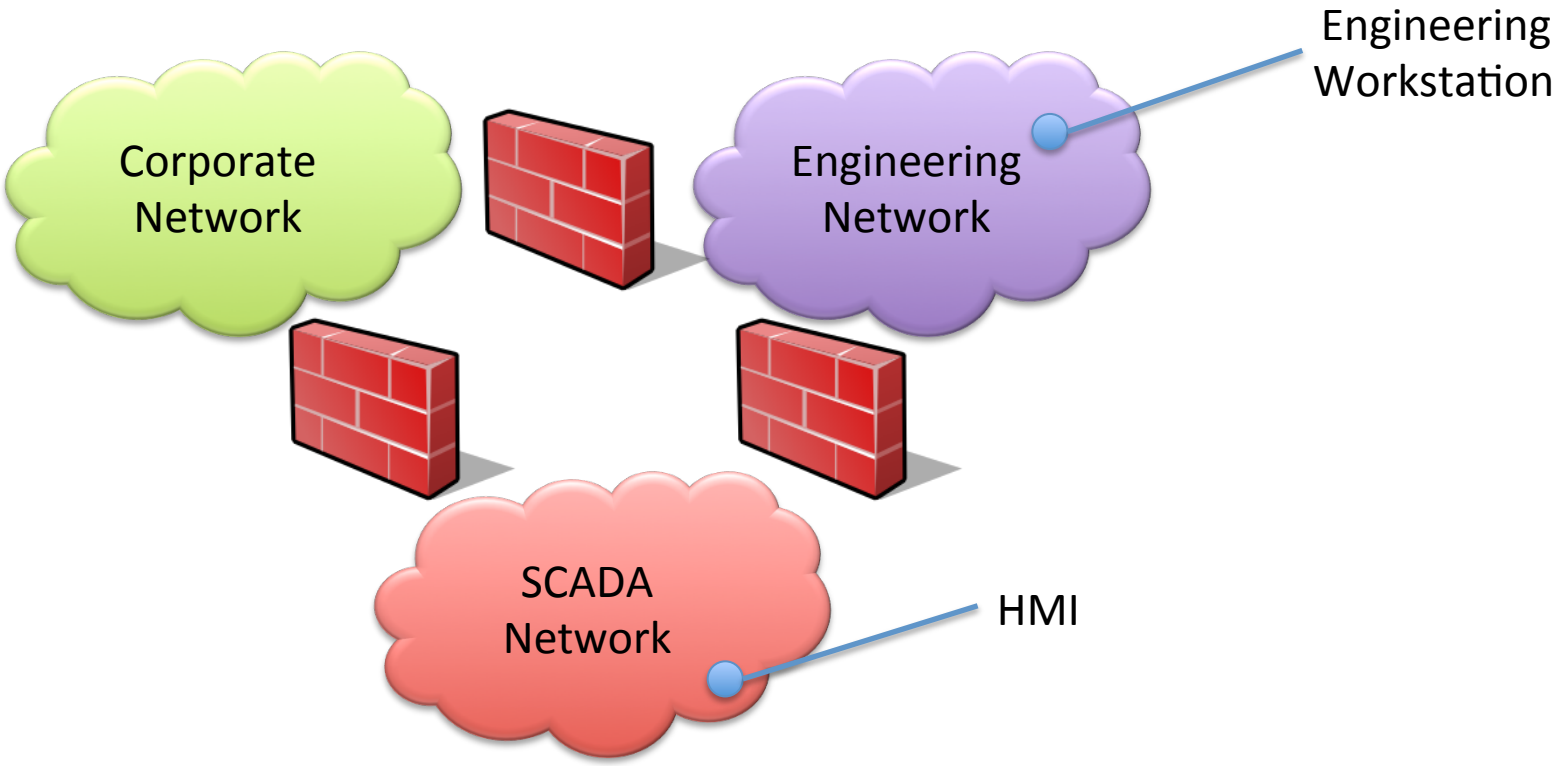
Typical examples of analyses

- Which among alternative architectures should be recommended?
- What are security weak points of an architecture?
- Is a proposed countermeasure worthwhile?
- How will proposed functional architecture changes impact security?

Example Enterprise Systems

- Architecture to support stock trading
- SCADA architecture supporting an electric utility
- Control systems in a water treatment plant
- Operations and administration systems for a telecommunications provider
- 911 computer systems architecture
- Reactor safety architecture for a nuclear power plant
- Systems in a hospital that process patient information
- Air traffic or train control systems
- Computer infrastructure for a research and development facility
- Computer infrastructure for an ISP

Step 1 – Define Purpose of Analysis – Small SCADA Networks



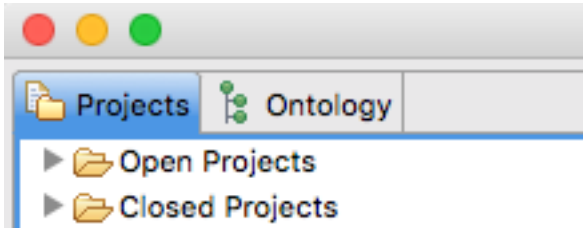
•Predicted electricity demand data stored on the SCADA LAN is found on the desk of an engineer not authorized to view this data. This data can be sold to competing electricity vendors to aid in their pricing.
•How could the engineer even gain access to the SCADA LAN?
•The engineer has physical access to all networks shown and to the HMI, and is an authorized user of the engineering workstation.
•What changes to the architecture would make this less likely to happen again?

Step 1 – Define Purpose of Analysis - Feedback

- Open questions/discussion on Step 1
  - Take notes here during meeting
- Questions for group:
  - What are some typical security architecture decisions for which rationale is hard to come by?
  - Are there specific systems that don't fall under enterprise systems, but that might benefit from this type of analysis?

Step 2 – Model Systems

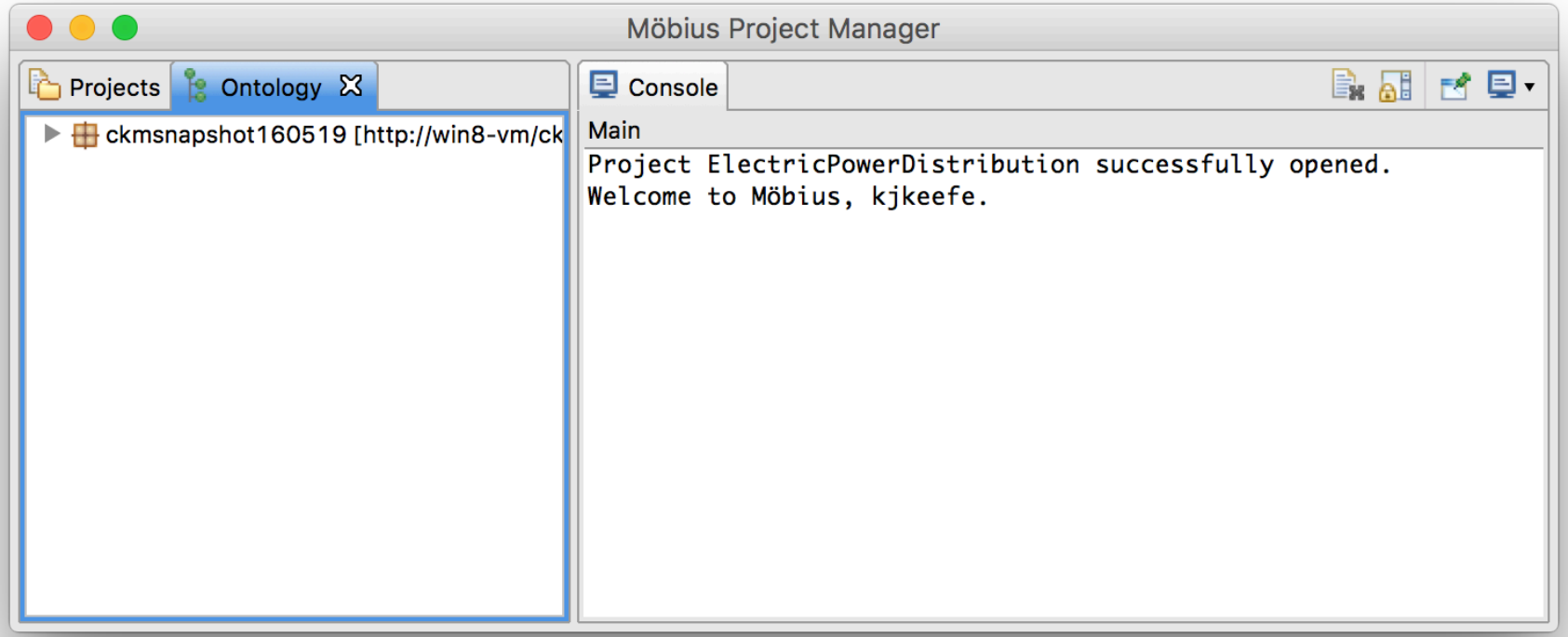
When you start Mobius, you will see two tabs in the upper left hand corner



- The Project tab contains projects with models of systems, attackers, and metrics.
- The Ontology tab is where individual system components, relationships, attributes, etc. are defined.

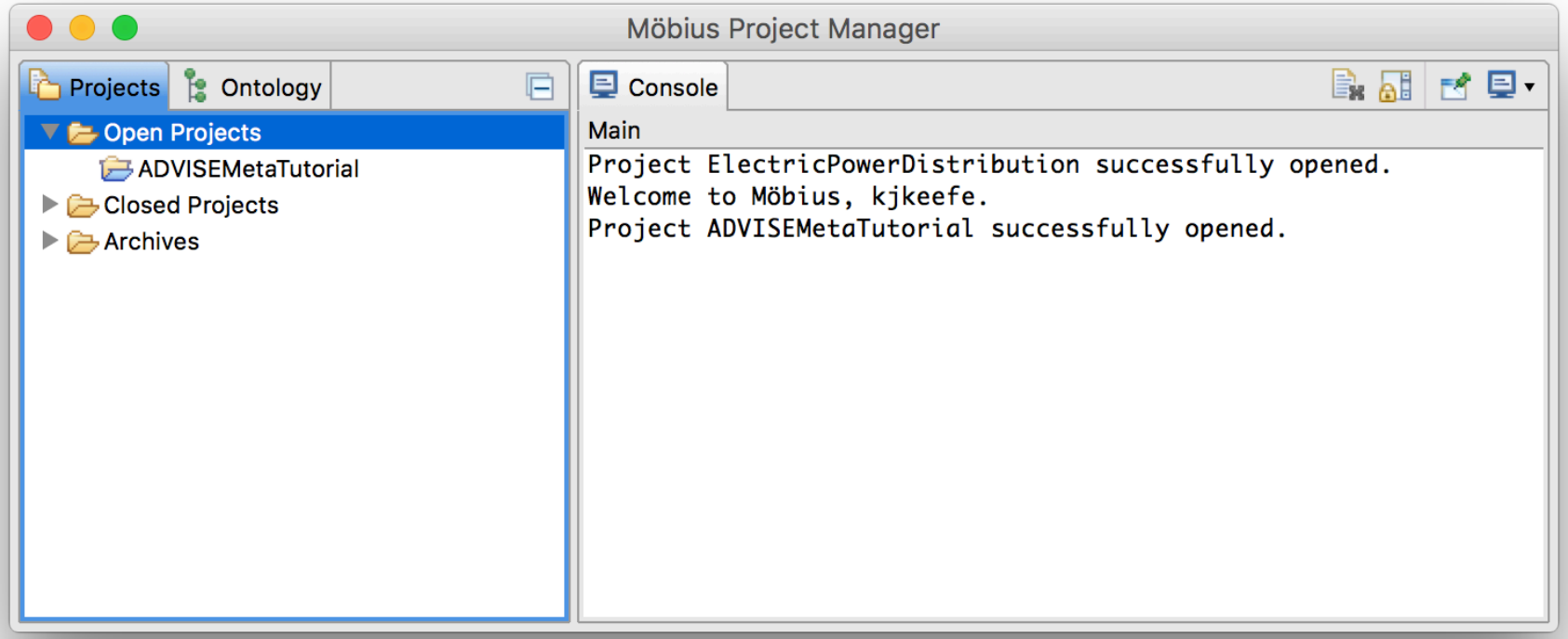
Step 2 – Model Systems

1. Download the ontology file: http://go.illinois.edu/am16ont
2. Right click the Ontology pane.
3. Select Import…
4. Choose the downloaded ontology file



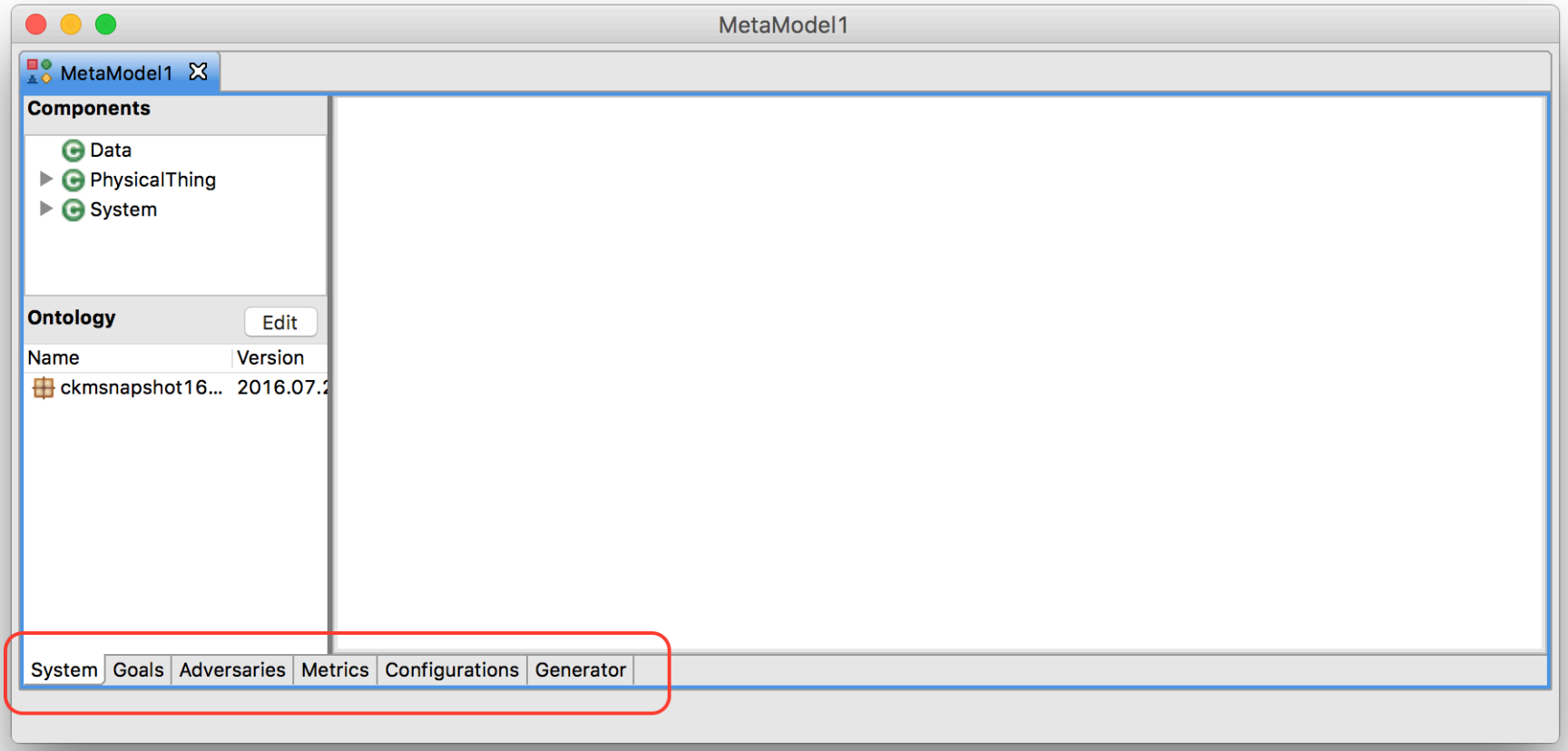
Step 2 – Model Systems

1. Select the Projects tab.
2. Right click Open Projects and select New Project…
3. Name the project **ADVISEMetaTutorial** and click Finish

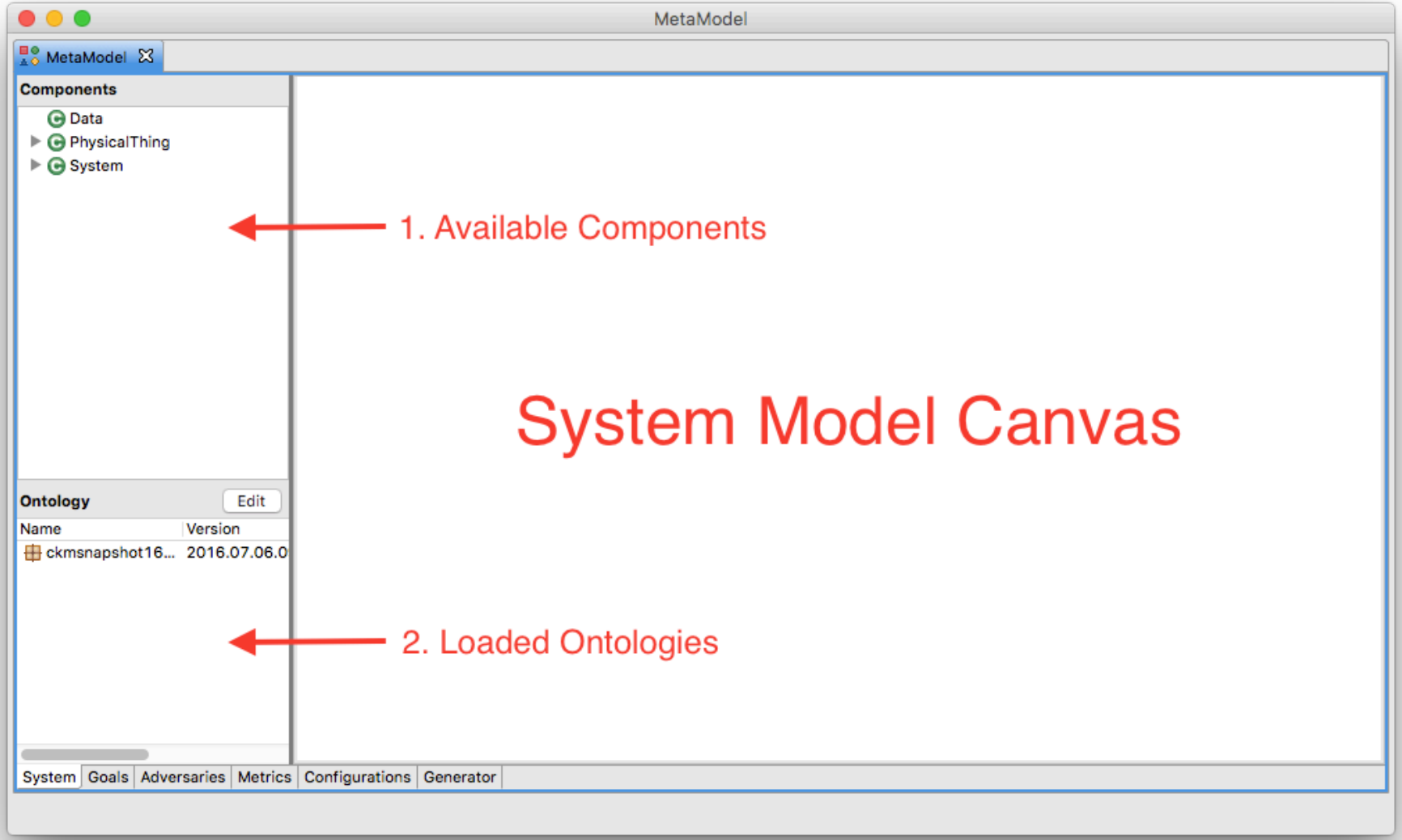


Step 2 – Model Systems

1. Right click on the ADVISEMetaTutorial project and select New...
2. Select the Atomic category in the bottom pane and click Next.
3. Select ADVISE Meta Model, enter the name **MetaModel1**, and click Finish.

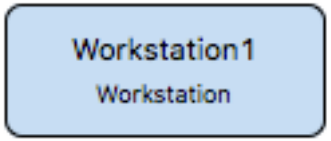


Step 2 – Model Systems

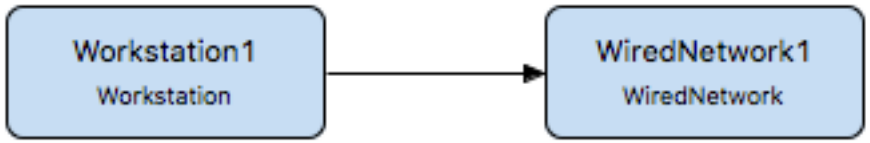


Step 2 – Model Systems

- Component
  - Part or element of the system
  - Physical objects, e.g., computer, firewall, building, etc.
  - Logical objects, e.g., data, software, network, etc.
  - Components are represented as blue rectangles on the system diagram

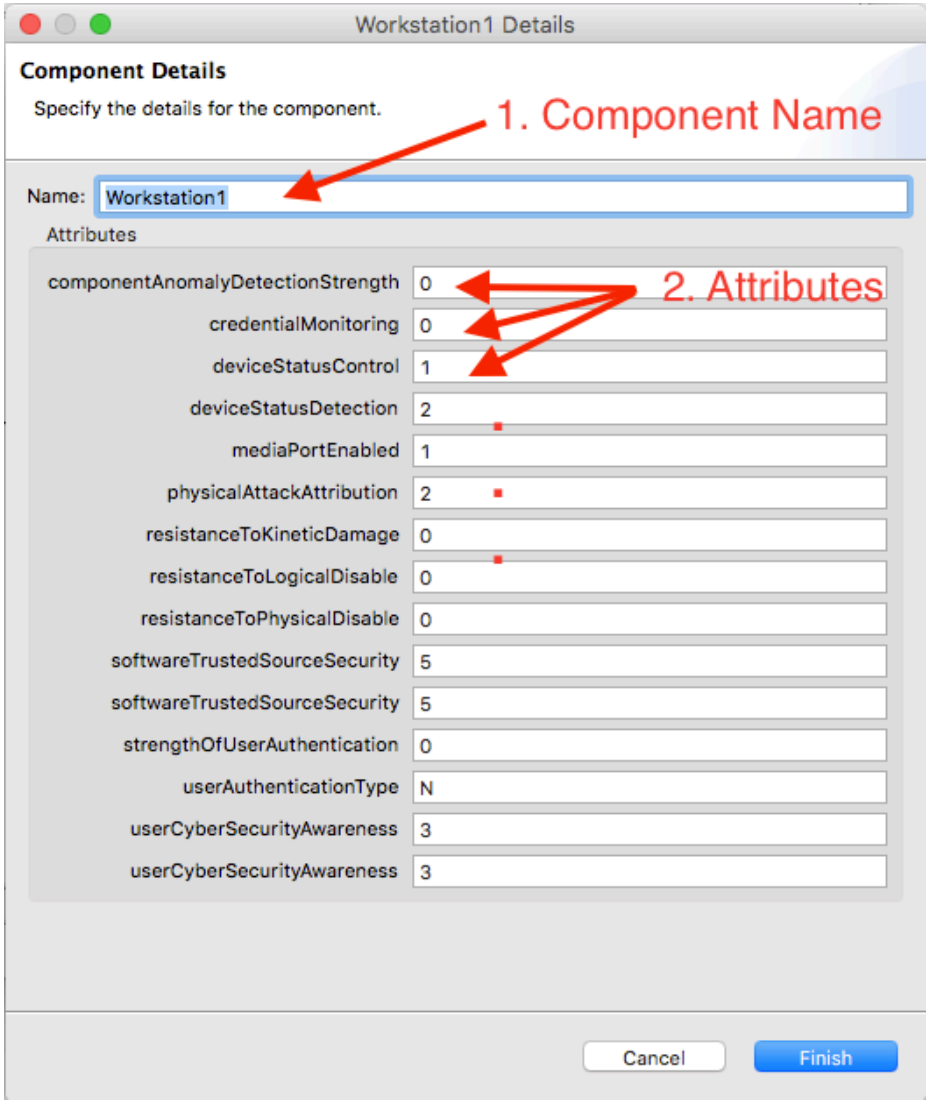


- Relationship
  - A semantic connection between two components.
  - For example, a computer is connected to a network through a **onNetwork** relationship, or a data is managed by a software application through a **managedBy** relationship.
  - A relationship is represented as arcs on the system diagram.



Step 2 – Model Systems

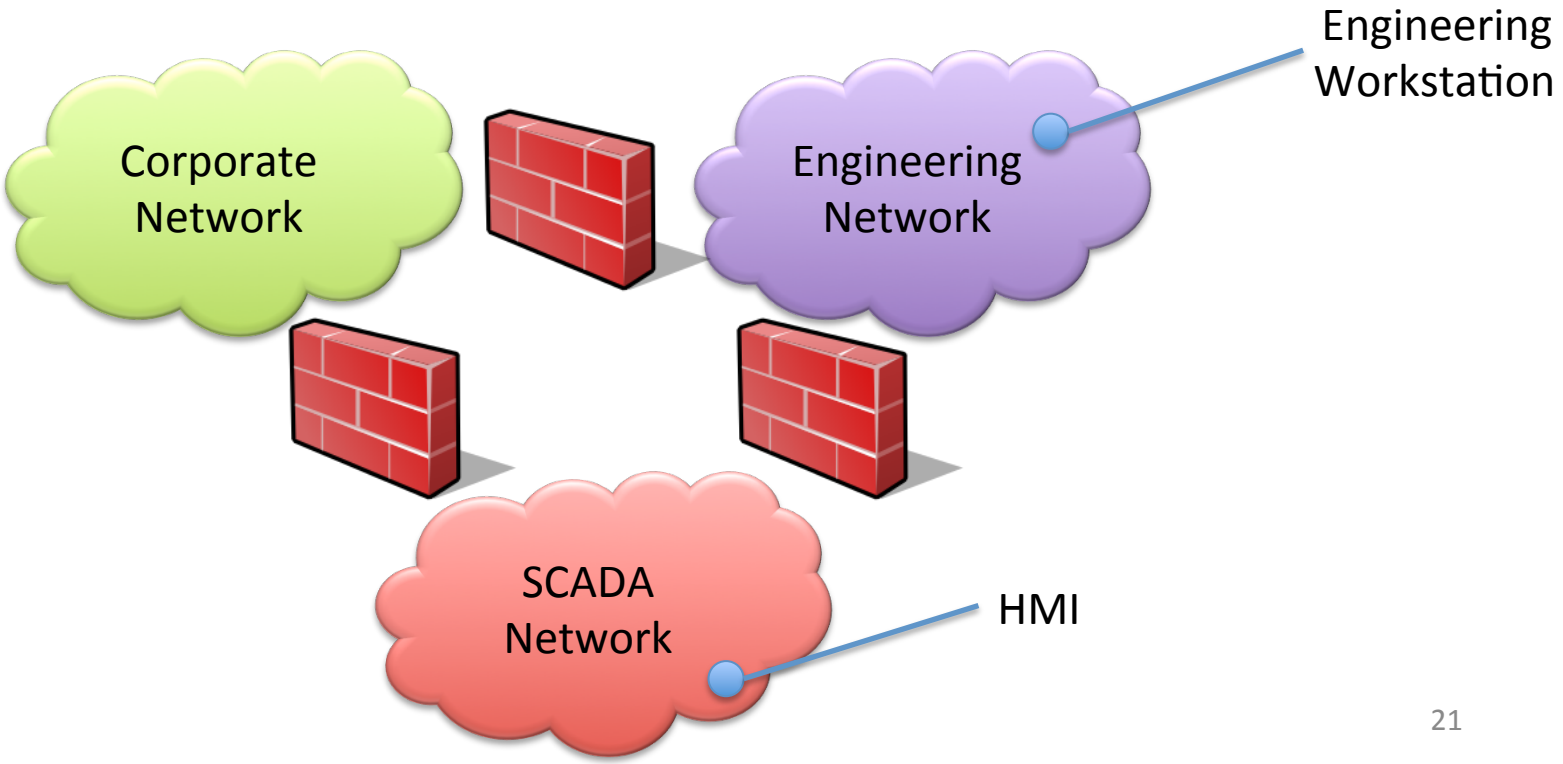
- Attributes
  - Properties associated with a component.
  - For example, a component might use a specific type of authentication mechanism.
  - Attributes are listed in the "Details" of the component.



Step 2 – Model Systems

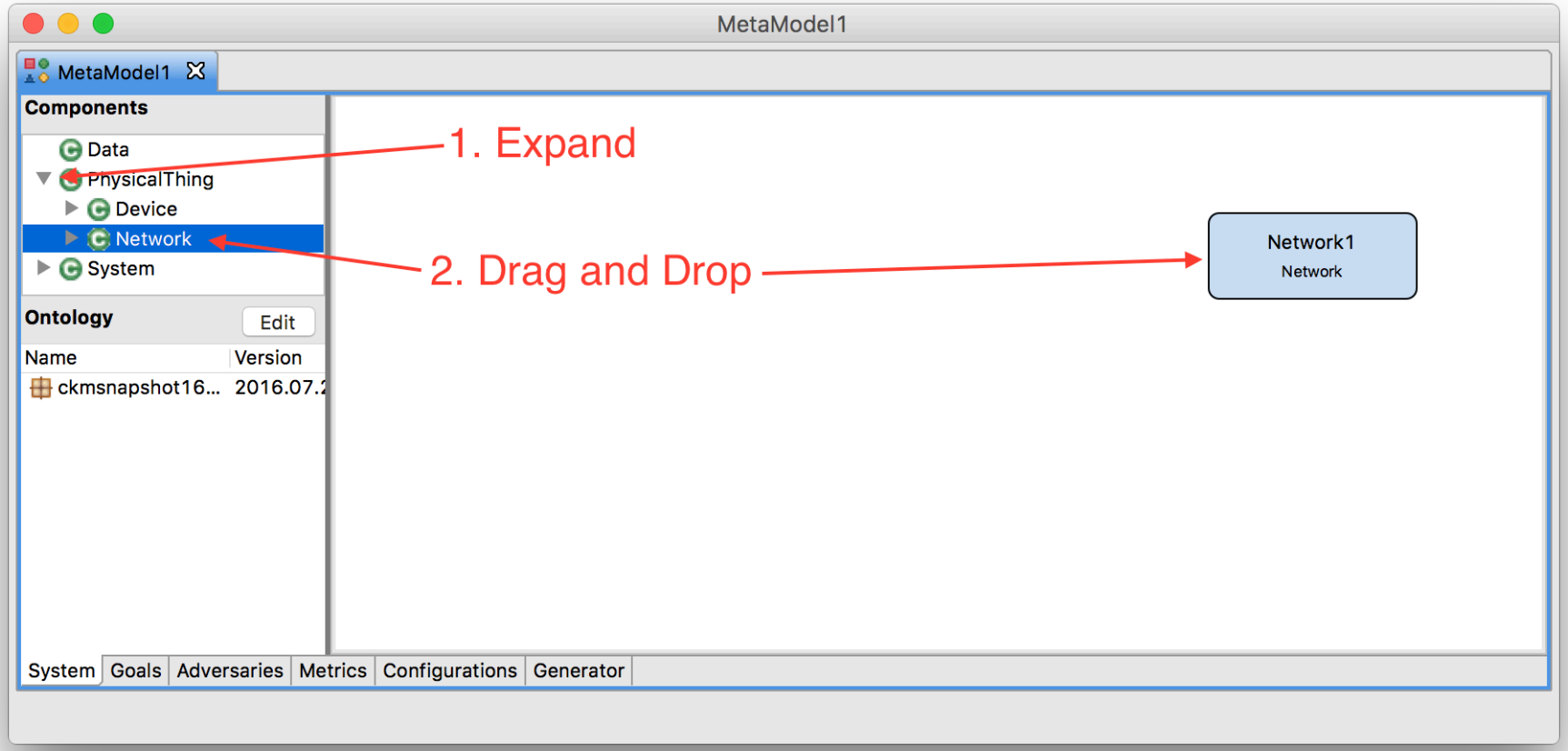
Our simple example consists of:

- SCADA Network with a local terminal (HMI)
- Engineering Network with a local Linux workstation running an SSH server
- Corporate LAN
- All networks are interconnected through firewalls



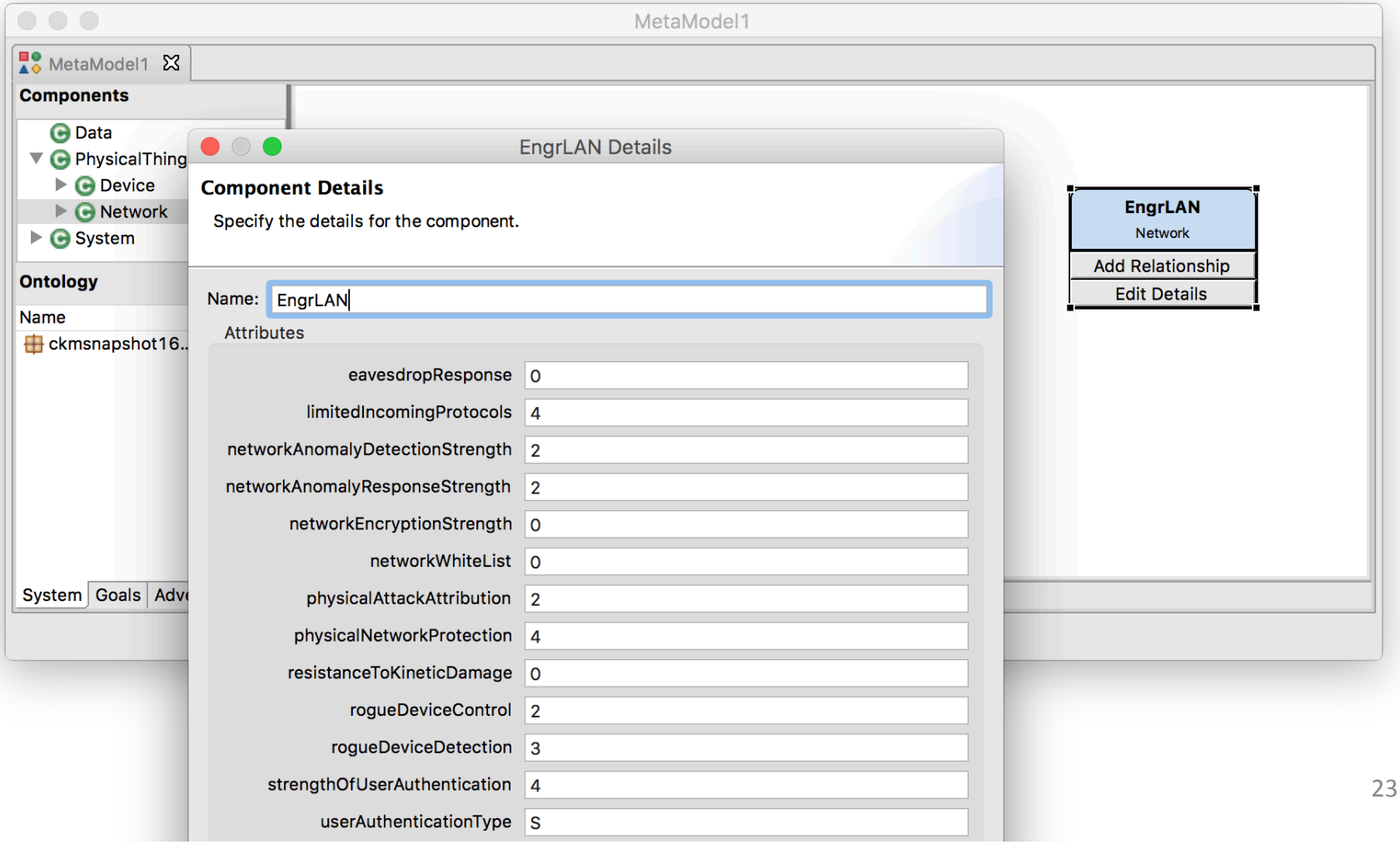
Step 2 – Model Systems

1. Expand the **PhysicalThing** node in the available components tree.
2. Drag and drop an instance of a **Network** onto the canvas.



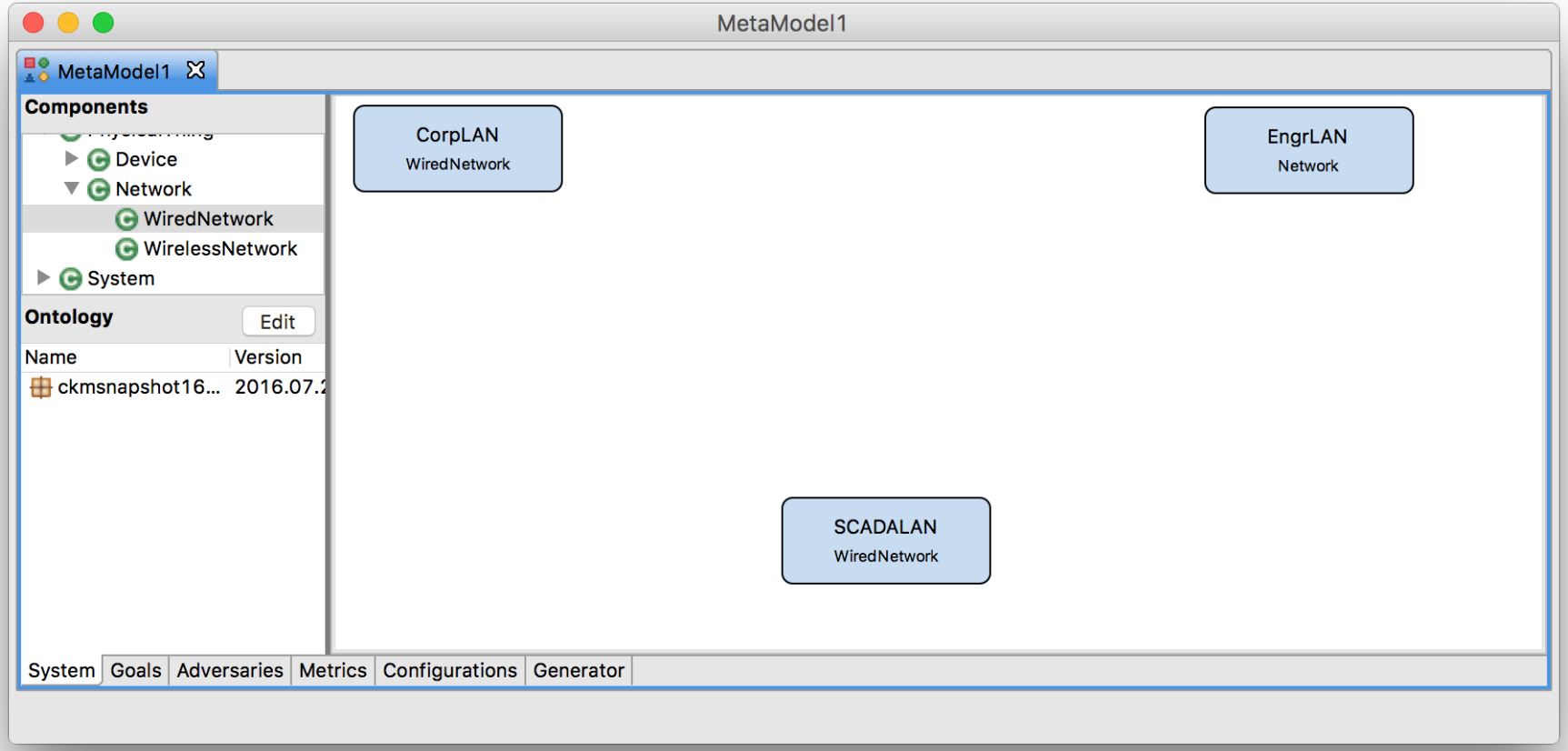
Step 2 – Model Systems

1. Select the **Network1** component and click the Edit Details button.
2. Change the name to **EngrLAN** and click Finish.



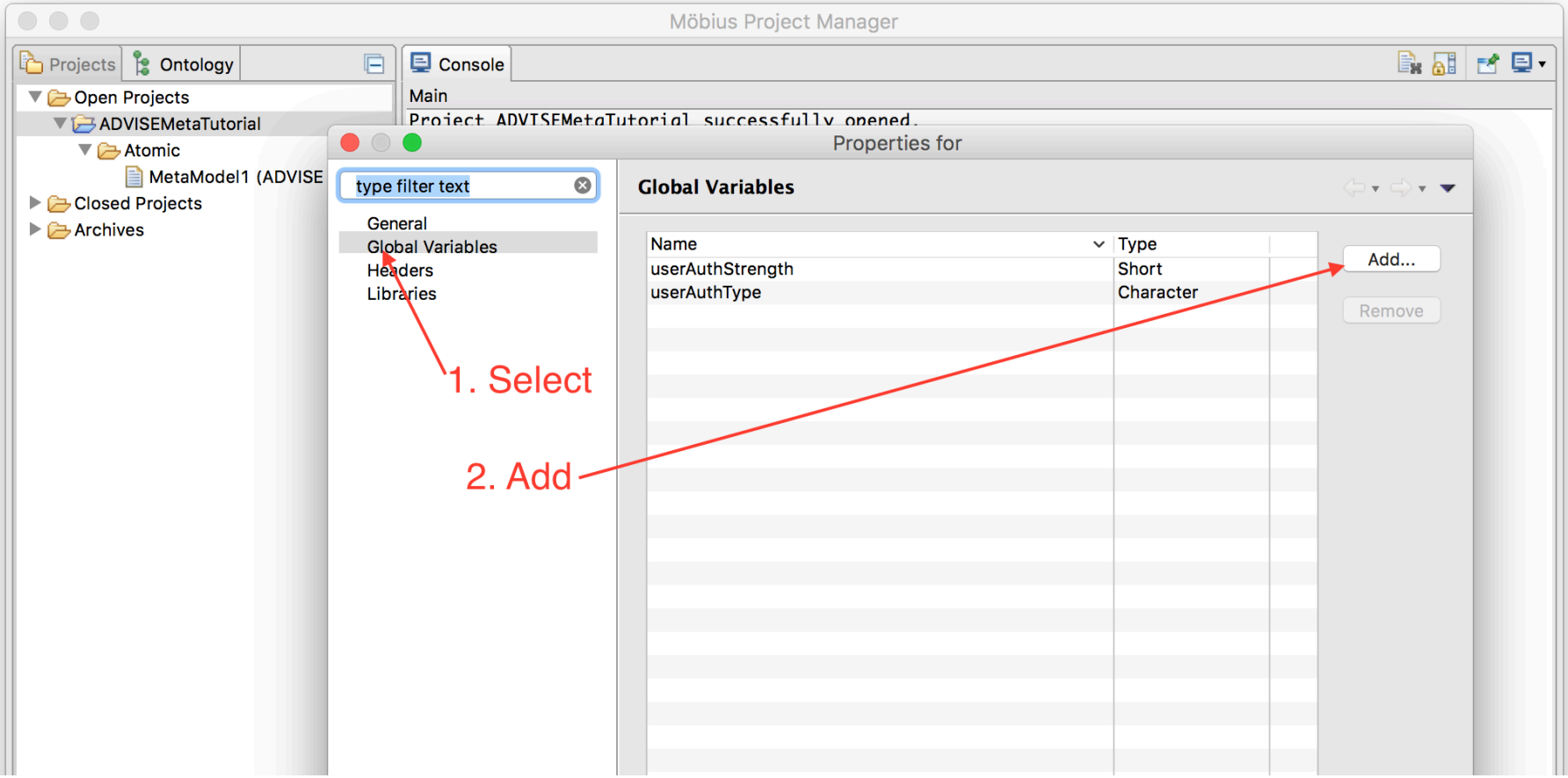
Step 2 – Model Systems

1. Create a **WiredNetwork** called **CorpLAN**
2. Create a **WiredNetwork** called **SCADALAN**



Step 2 – Model Systems

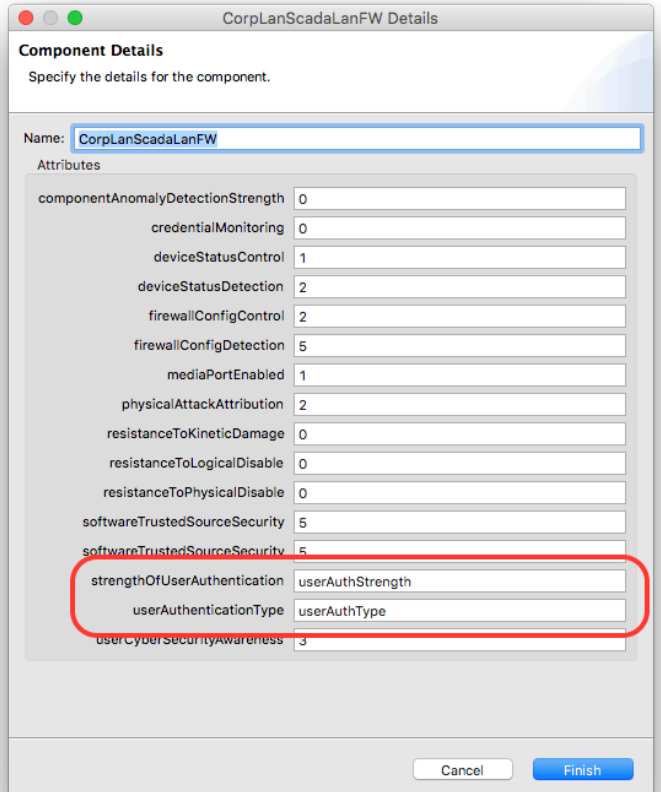
1. Right click the project **ADVISEMetaTutorial** and select **Properties**…
2. Select the Global Variables section.
3. Add a new variable called **userAuthType** with type **Character**.
4. Add a new variable called **userAuthStrength** with type **Short**.



Step 2 – Model Systems

1. Create a **FirewallHosted** and define its attributes like so:

Attribute	Value
Name	CorpLanScadaLanFW
strengthOfUserAuthentication	userAuthStrength
userAuthenticationType	userAuthType



Step 2 – Model Systems

1. Create another **FirewallHosted**

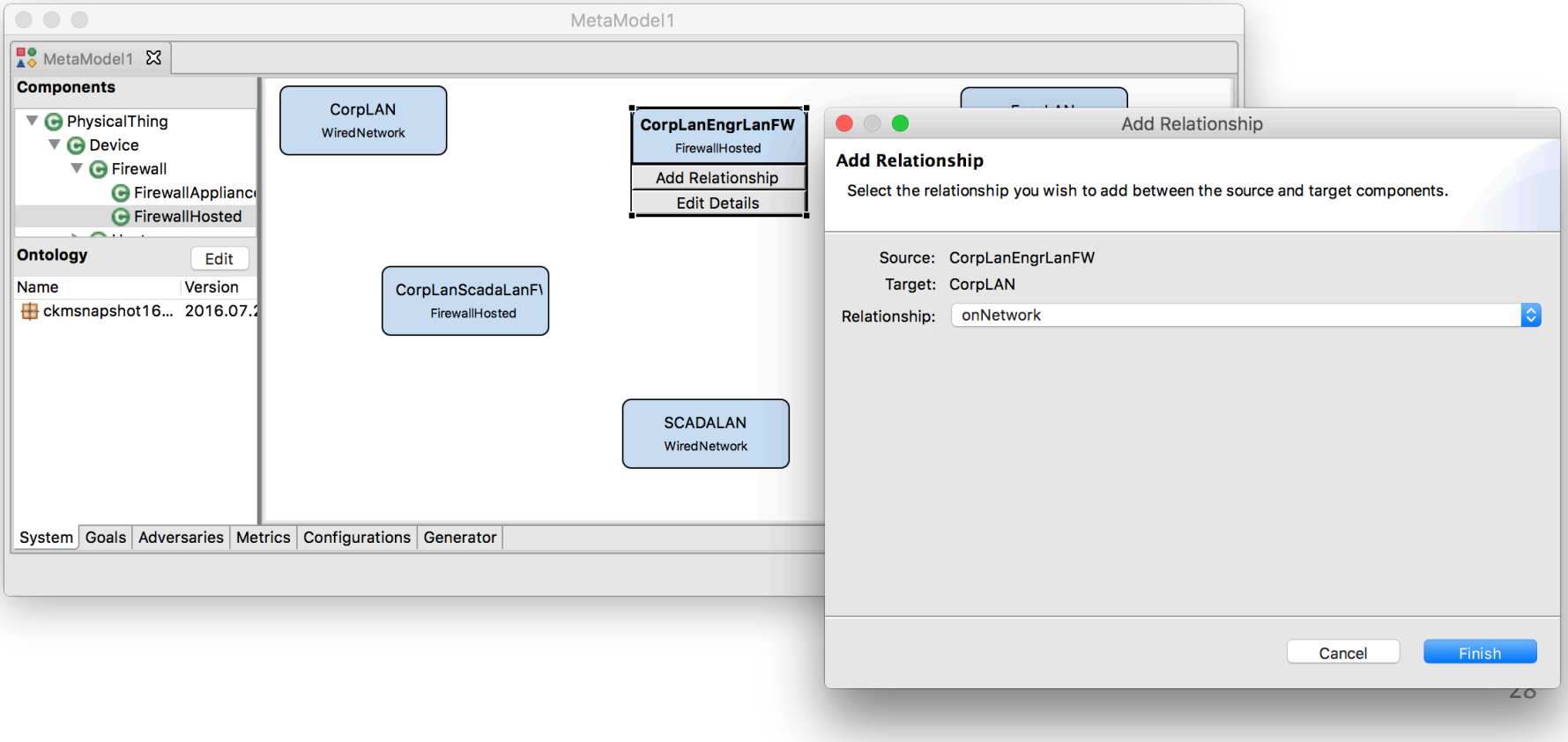
Attribute	Value
Name	CorpLanEngrLanFW
strengthOfUserAuthentication	userAuthStrength
userAuthenticationType	userAuthType

2. Create another **FirewallHosted**

Attribute	Value
Name	EngrLanScadaLanFW
strengthOfUserAuthentication	userAuthStrength
userAuthenticationType	userAuthType

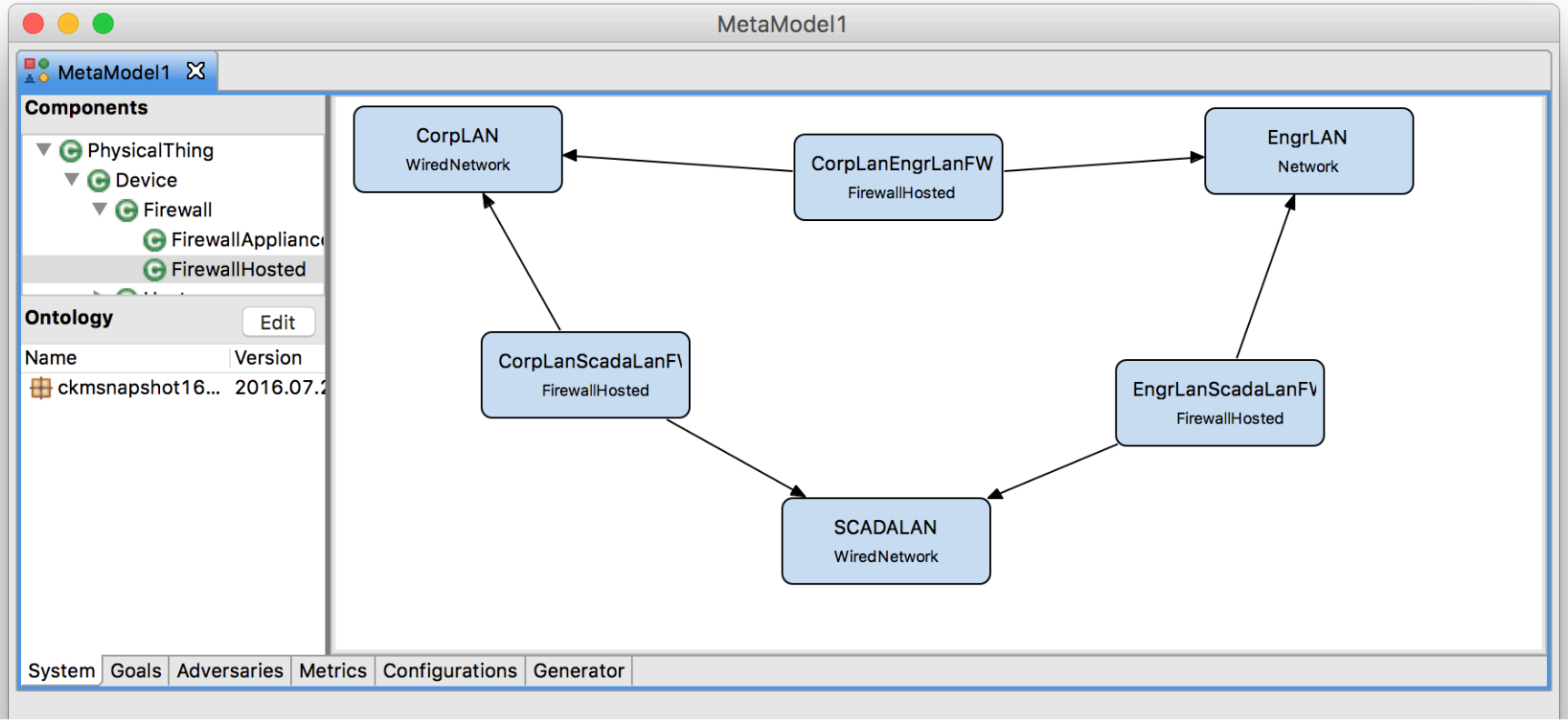
Step 2 – Model Systems

1. Select the **CorpLanEngrLanFW** component and click the Add Relationship button.
2. Select the **CorpLan** component.
3. Check that the **onNetwork** relationship is selected and click Finish.



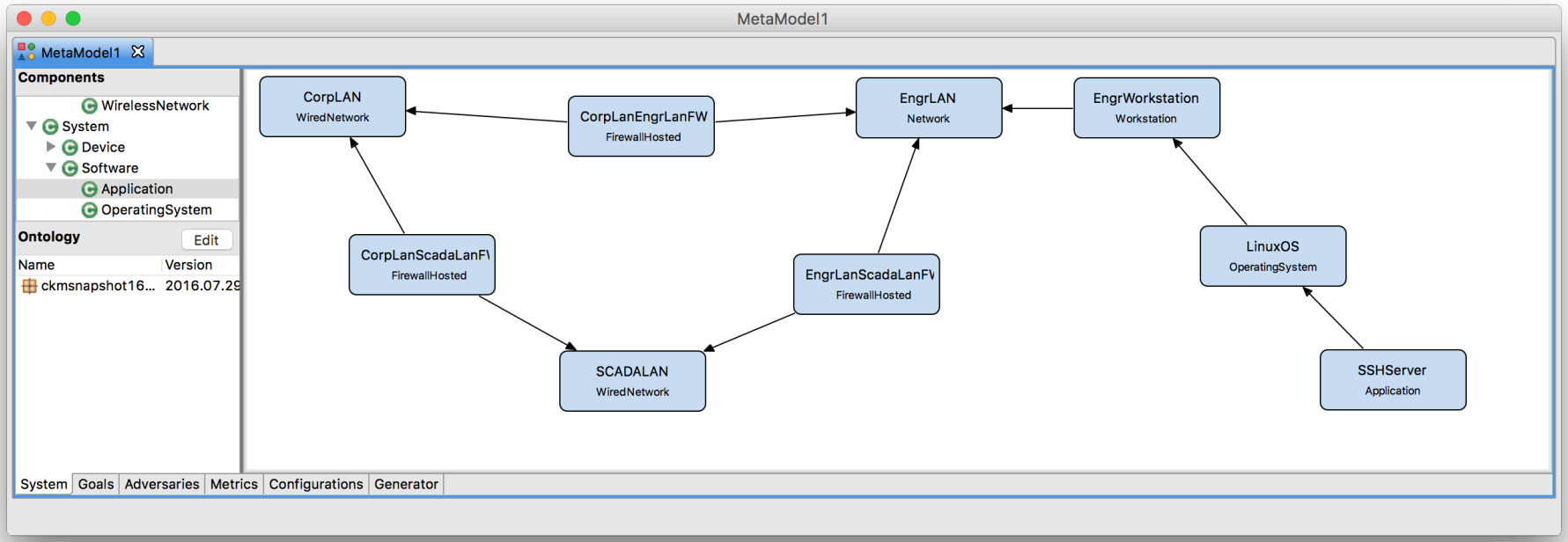
Step 2 – Model Systems

1. Create additional **onNetwork** relationships between:
   - **CorpLanEngrLanFW** to **EngrLAN**
   - **CorpLanScadaLanFW** to **CorpLAN**
   - **CorpLanScadaLanFW** to **SCADALAN**
   - **EngrLanScadaLanFW** to **EngrLAN**
   - **EngrLanScadaLanFW** to **SCADALAN**



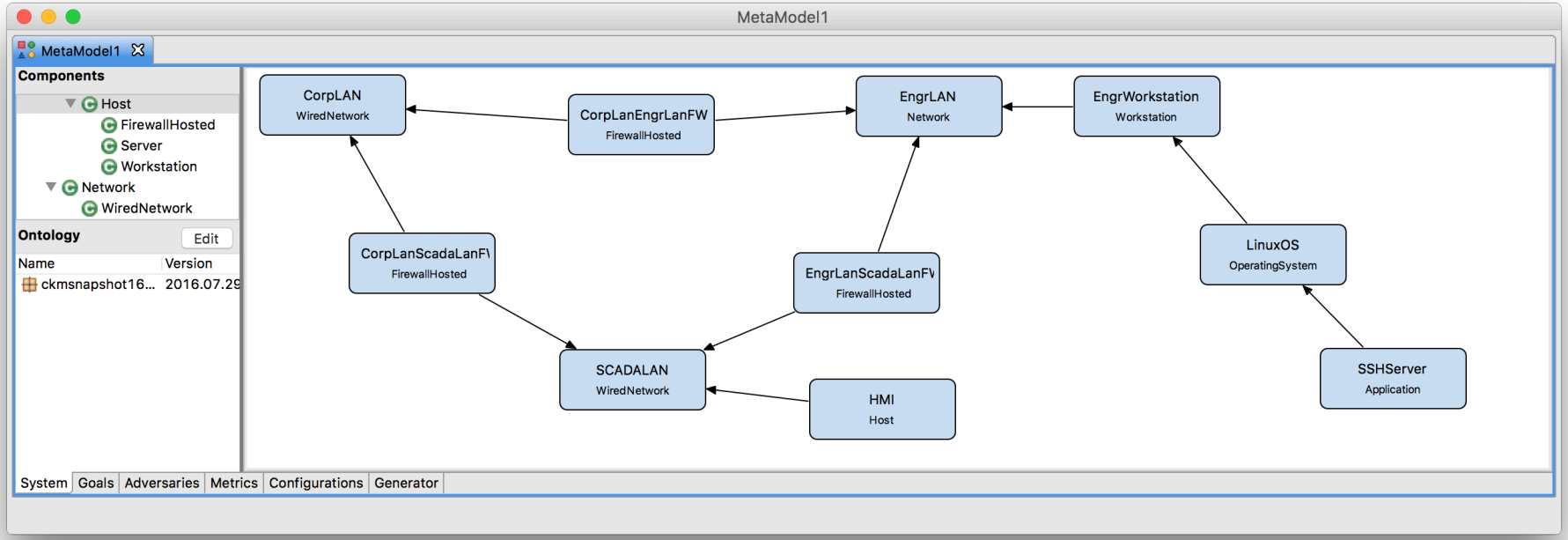
Step 2 – Model Systems

1. Create a **Workstation** called **EngrWorkstation**
2. Define an **onNetwork** relationship from **EngrWorkstation** to **EngrLAN**.
3. Create an **OperatingSystem** called **LinuxOS**.
4. Define a **hardwarePlatform** relationship from **LinuxOS** to **EngrWorkstation.**
5. Create an **Application** called **SSHServer**.
6. Define an **applicationOS** relationship from the **SSHServer** to **LinuxOS**.



Step 2 – Model Systems

1. Create a **Host** called **HMI**.
2. Define an **onNetwork** relationship from **HMI** to **SCADALAN**



Step 2 – Model Systems – Feedback

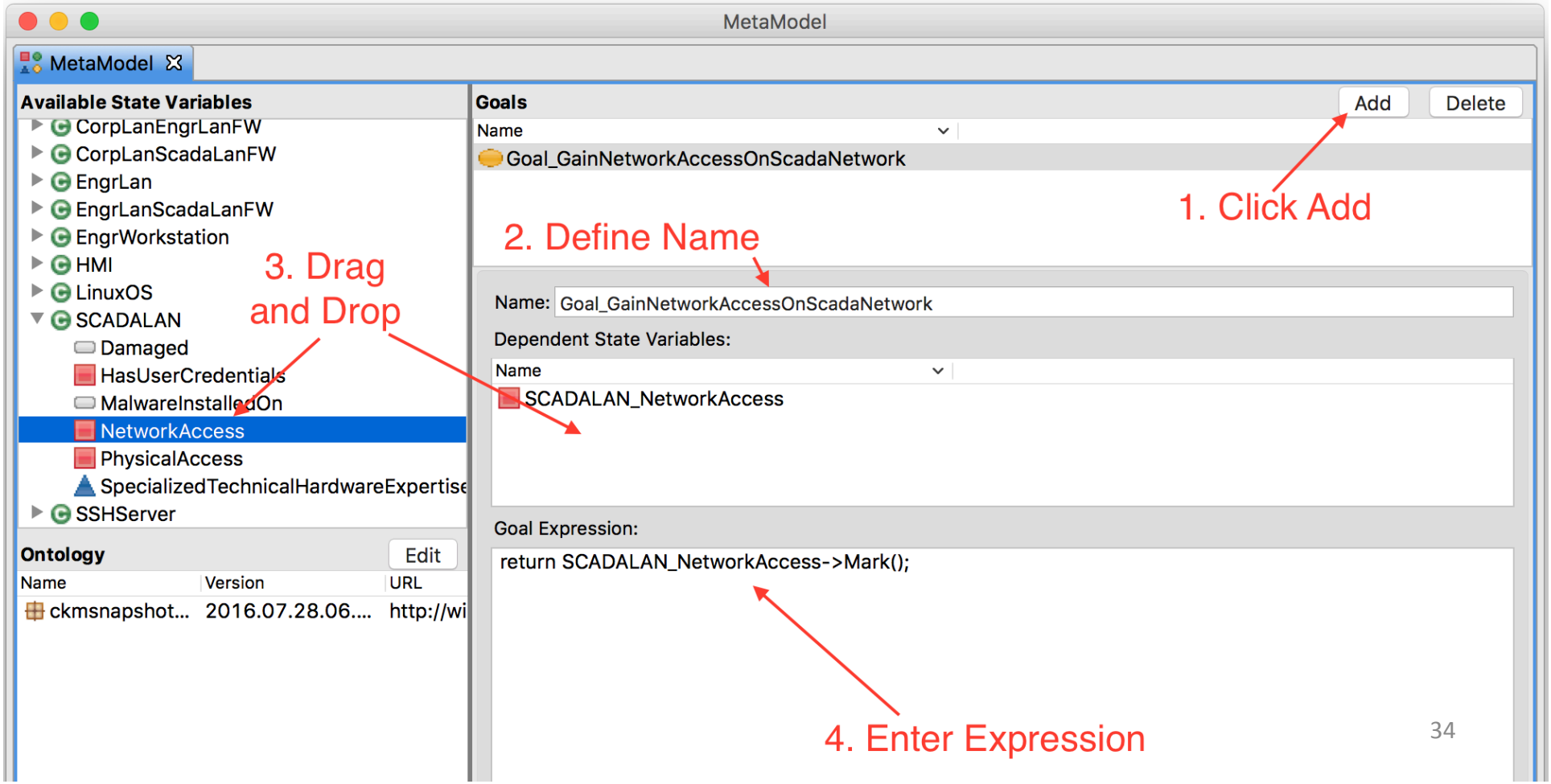
- How challenging was this step?
- Was adding components, creating relationships, and defining attributes easy?
- Could this part of the tool be useful for designing system diagrams for uses outside of the tool?
- How would you handle larger, more complex models? How would you expect the tool to help you with those models?
- Was the available components tree intuitive?

Step 3 – Attack Goals, Adversaries, and Generation

- Possible attack goals are dependent on the system diagram
  - Choose a set of state variables (Access, Skill, Knowledge, SSV) the goal state is a function of.
  - Define the functional expression that indicates whether the goal has been achieved.

Small SCADA Networks – Step 3

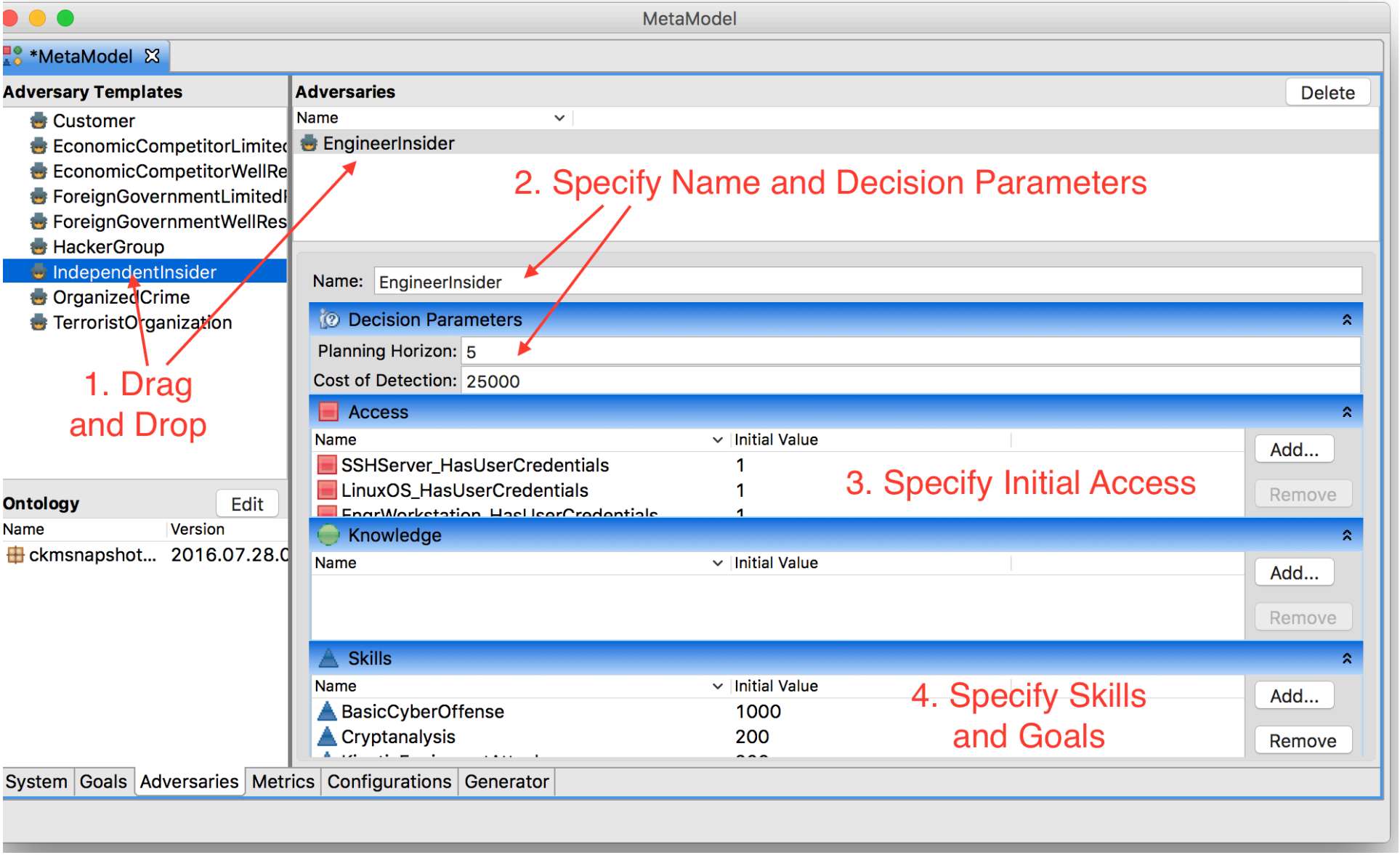
```
return SCADALAN_NetworkAccess->Mark();
```



Step 3 – Attack Goals, Adversaries, and Generation

- Adversaries are created from Adversary Templates (defined in the ontology)
  - Attributes are customizable
  - Possible initial state depends on system diagram

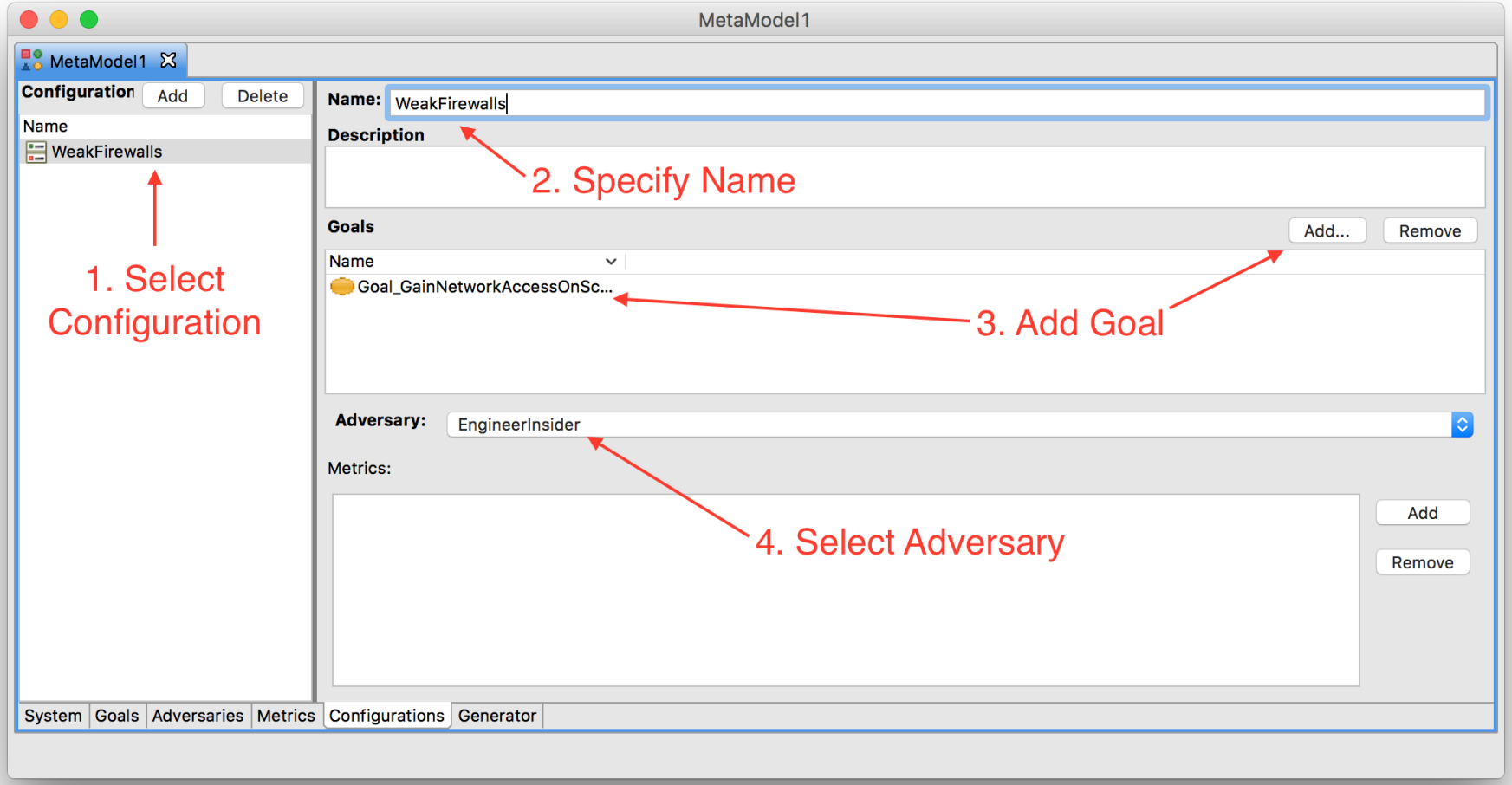
Small SCADA Networks – Step 3



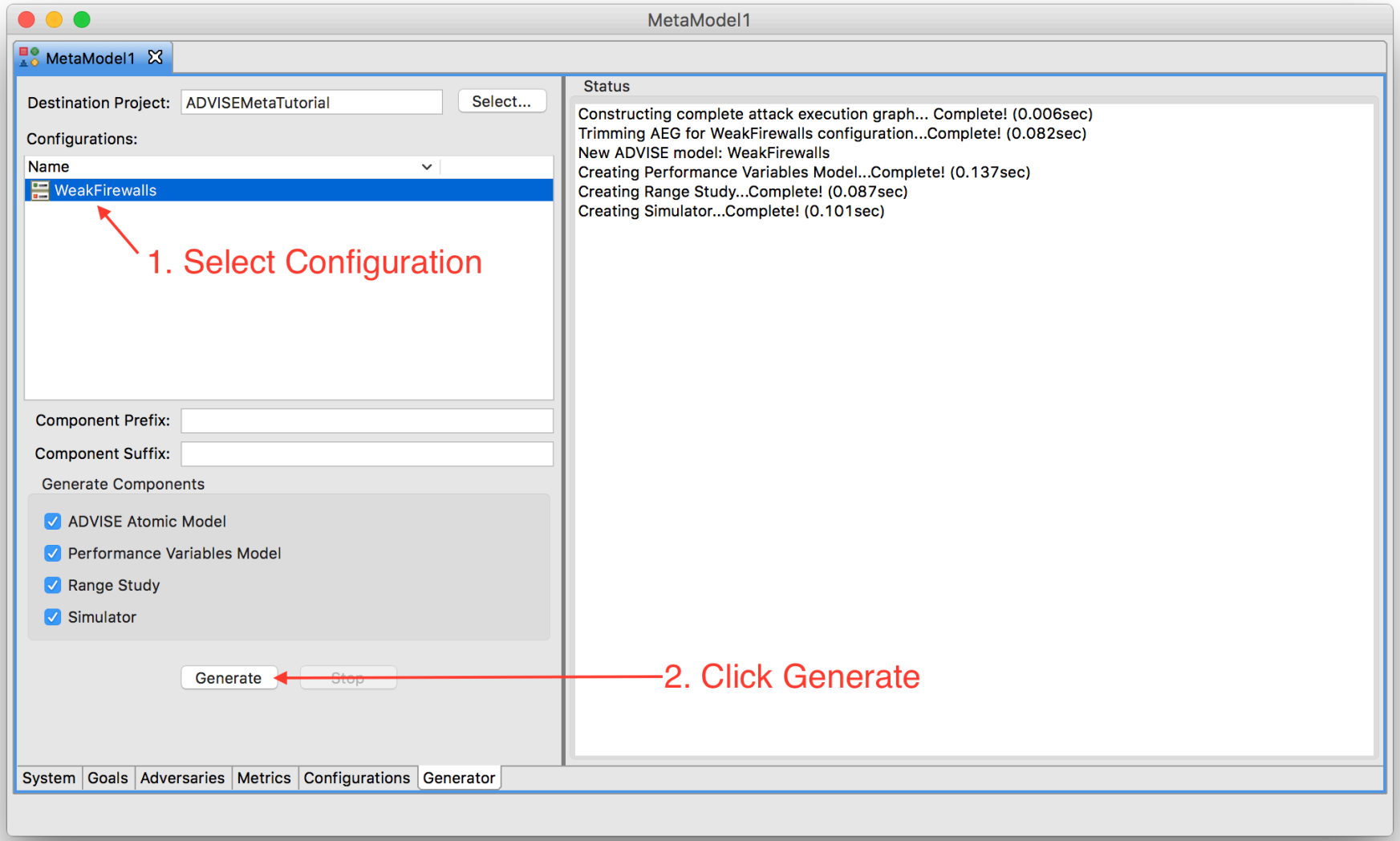
Small SCADA Networks – Step 3

1. Independent Insider
2. Name: EngineerInsider
   Planning Horizon: 5
   Cost of Detection: 20000
3. Access: CorpLAN_PhysicalAccess
   CorpLanEngrLanFW_PhysicalAccess
   CorpLanScadaLanFW_PhysicalAccess
   EngrLAN_NetworkAccess
   EngrLAN_PhysicalAccess
   EngrLanScadaLanFW_PhysicalAccess
   EngrWorkstation_HasUserCredentials
   EngrWorkstation_LogicalAccess
   EngrWorkstation_PhysicalAccess
   EngrWorkstation_UIAccess
   InsiderAccess
   HMI_PhysicalAccess
   LinuxOS_HasUserCredentials
   LinuxOS_LogicalAccess
   LinuxOS_UIAccess
   SCADALAN_PhysicalAccess
   SSHServer_HasUserCredentials
   SSHServer_LogicalAccess
   SSHServer_UIAccess
4. Goal: Goal_GainNetworkAccessOnScadaNetwork 80000

Small SCADA Networks – Step 3



Small SCADA Networks – Step 3



Step 3 – Attack Goals, Adversaries, and Generation – Feedback

- How challenging was this step?
- Did the goal definition seem intuitive?
- What other adversary templates would you look for?
- Does the configuration of an adversary's attributes make sense?

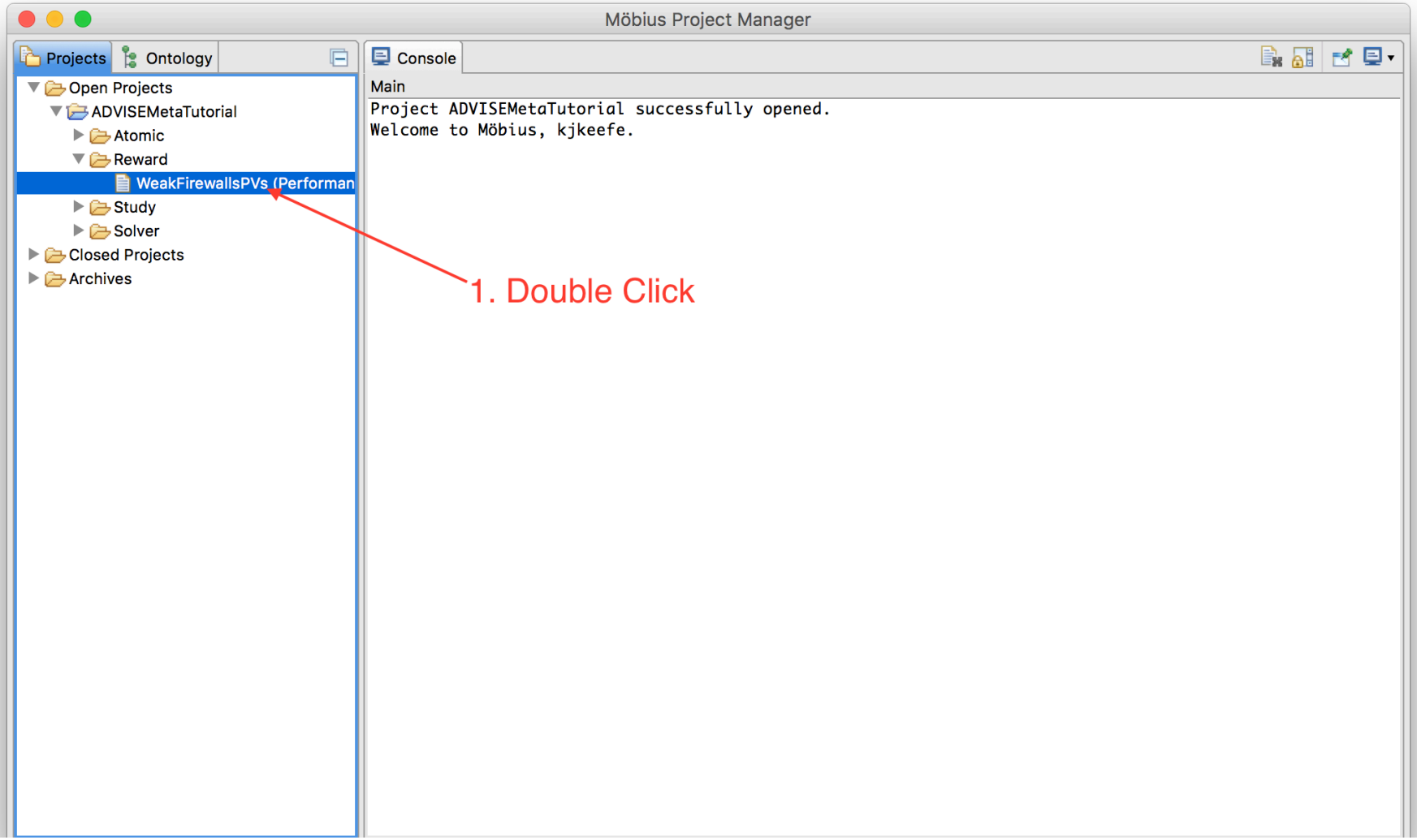
Step 4 – Metrics and Experiments

- Performance Variables
  - Rate-based
  - Event-based
  - Time instants, intervals, and steady state
- Example Metrics
  - Goal Achieved – Gain Network Access on SCADA Net
  - Time – Instants (0, 10, 20, 30, 40, 50, 60)
- Study
  - Set of experiments
  - Varying global variable values (initial model parameters)

Small SCADA Networks – Step 4

Open the Reward Model

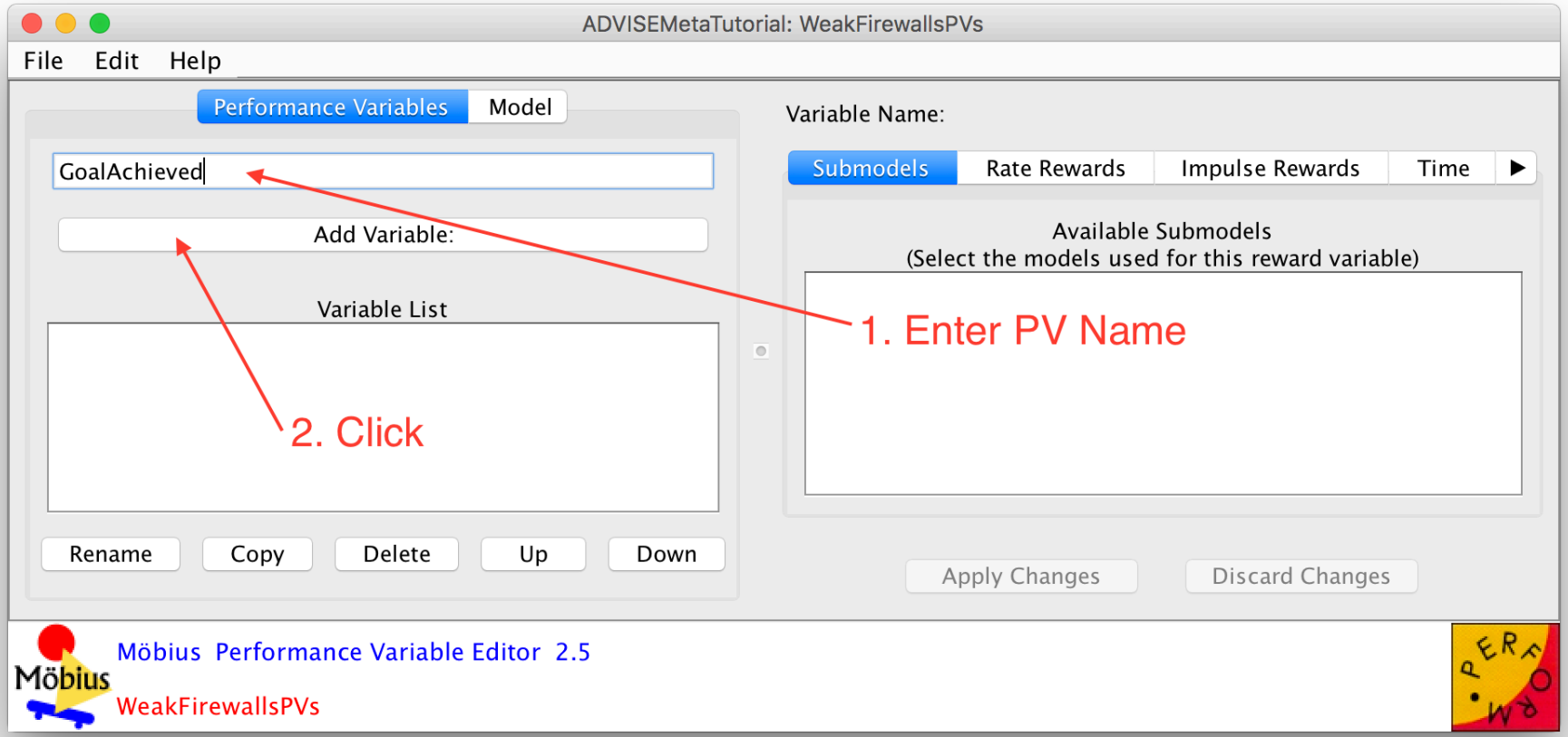
- Double click **WeakFirewallsPVs**



Small SCADA Networks – Step 4

Create a new Performance Variable

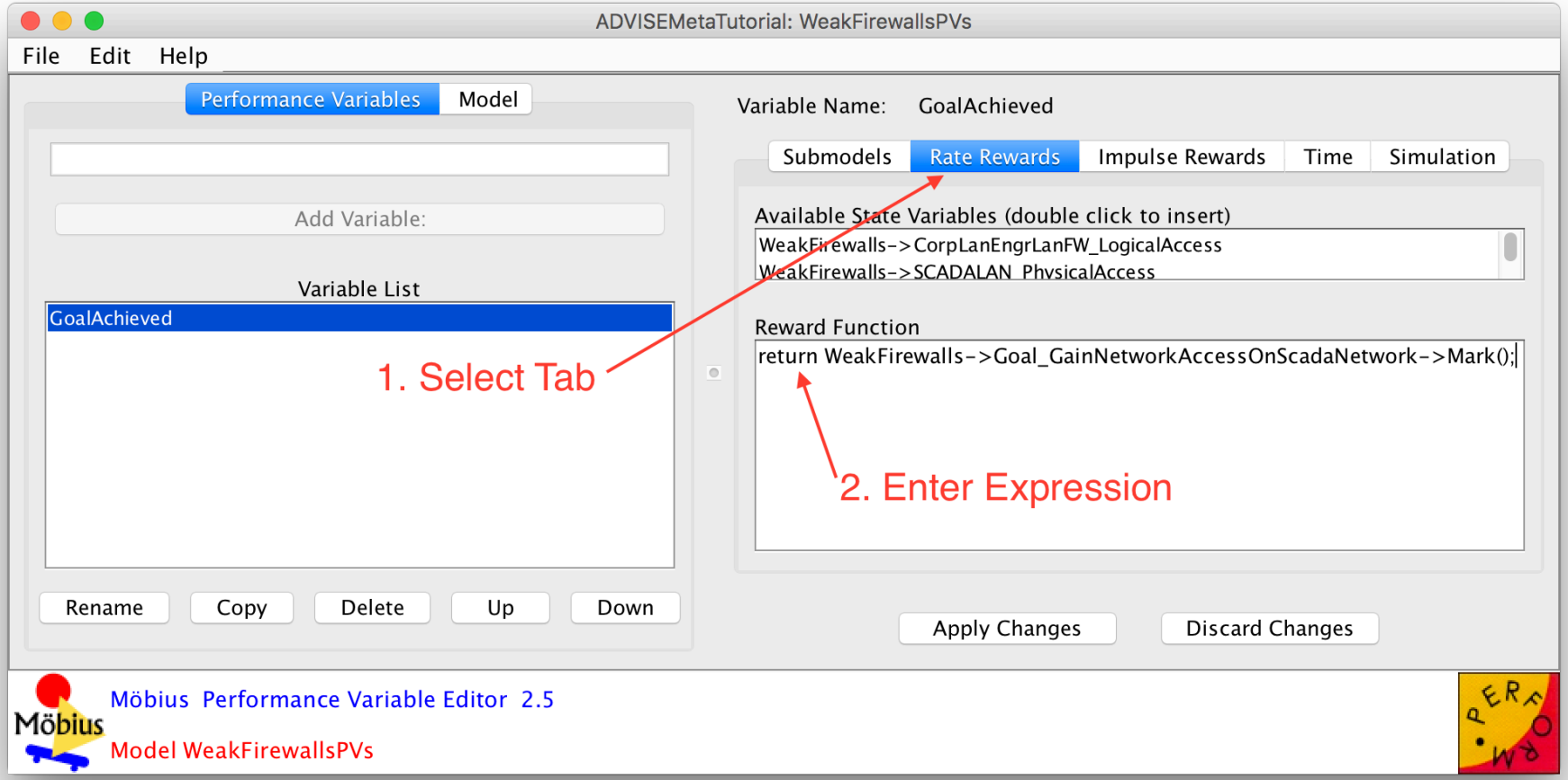
- Enter the variable name **GoalAchieved**, click Add Variable



Small SCADA Networks – Step 4

Enter Rate Reward Expression

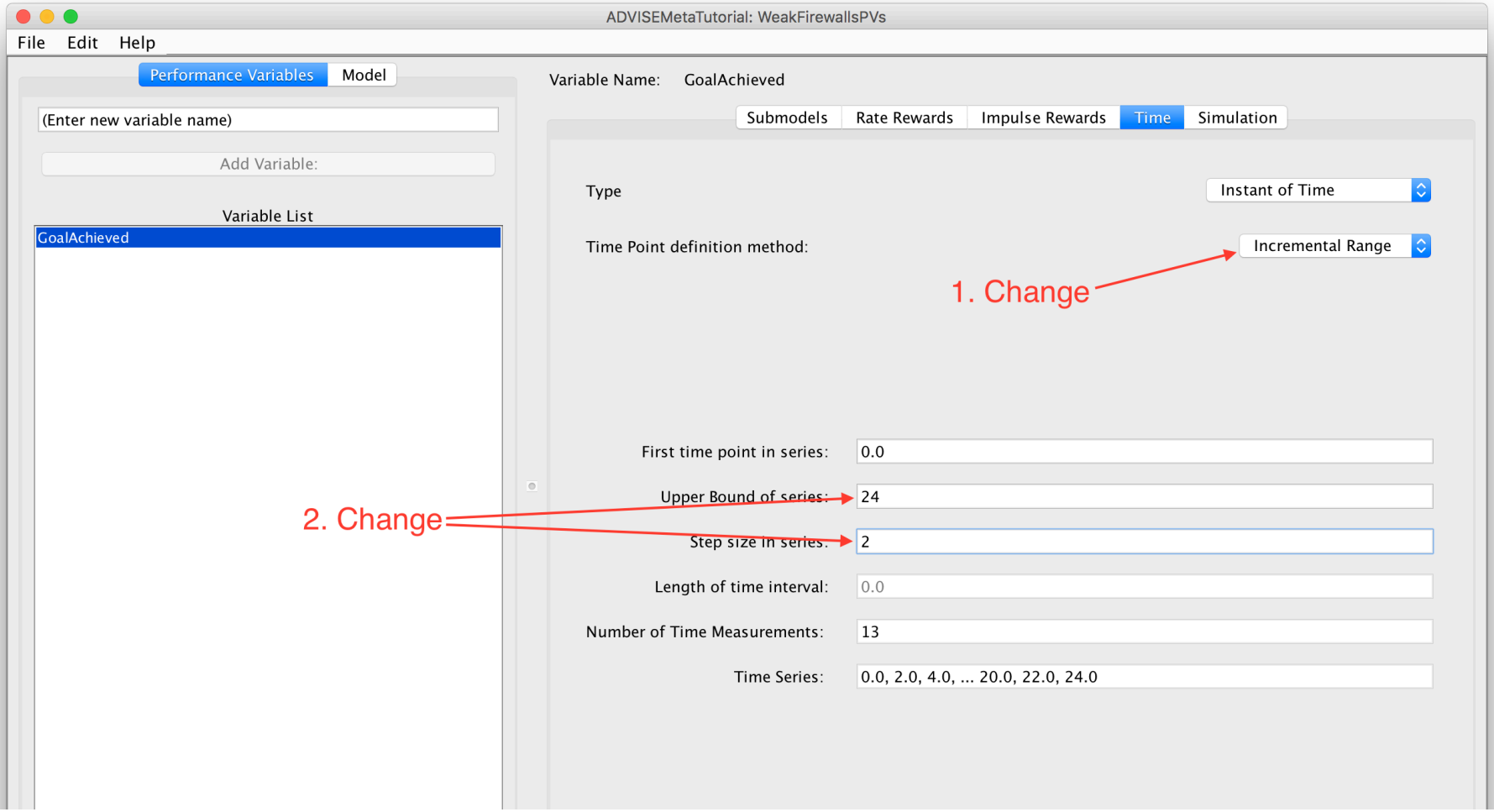
- Click the Rate Rewards tab
- Enter the expression:
  - `return WeakFirewalls->Goal_GainNetworkAccessOnScadaNetwork->Mark();`



Small SCADA Networks – Step 4

Define Timing Instants

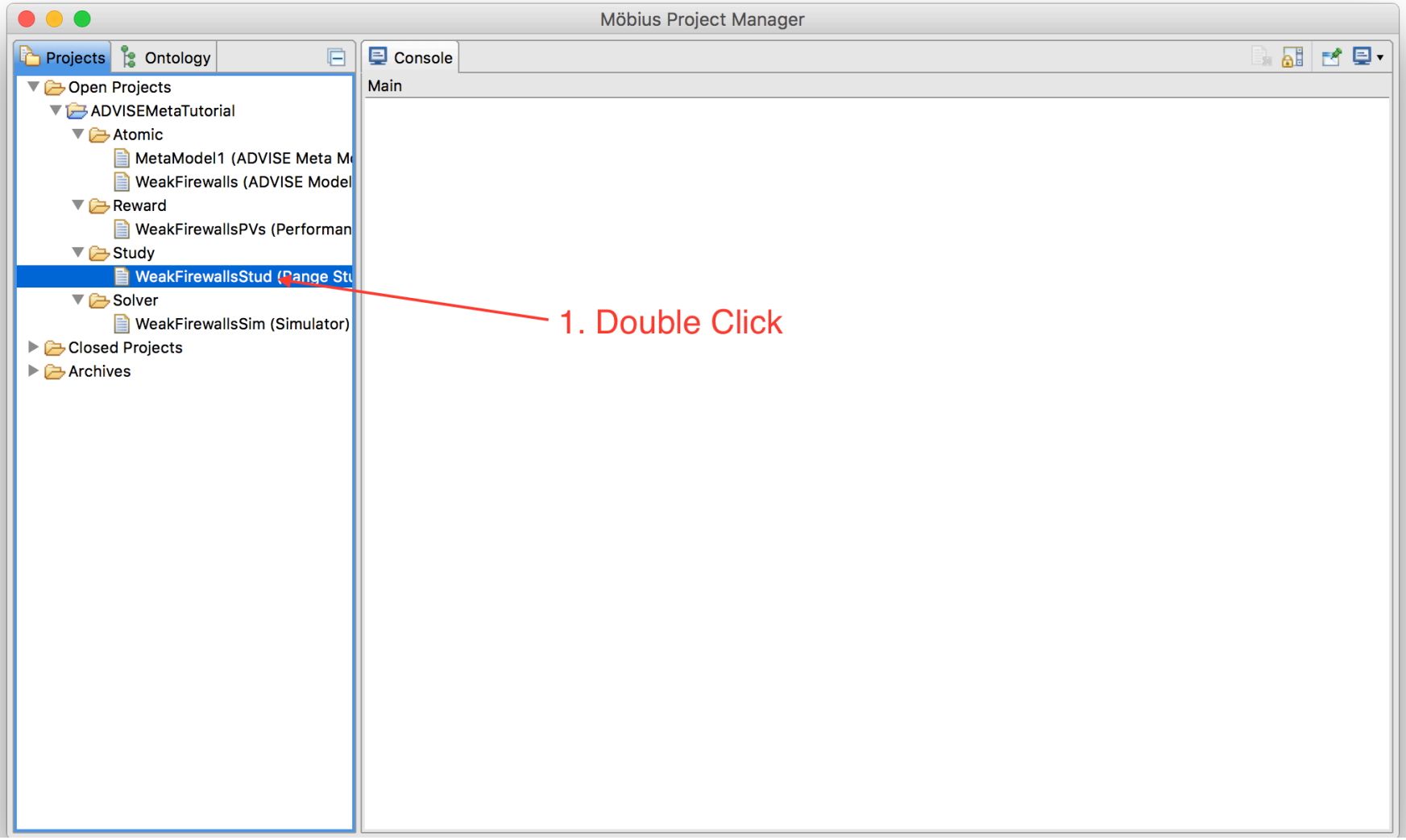
- Click the Time tab, Change the method to Incremental Range, Set Upper Bound to 24 and Step Size to 2.



Small SCADA Networks – Step 4

Open the study

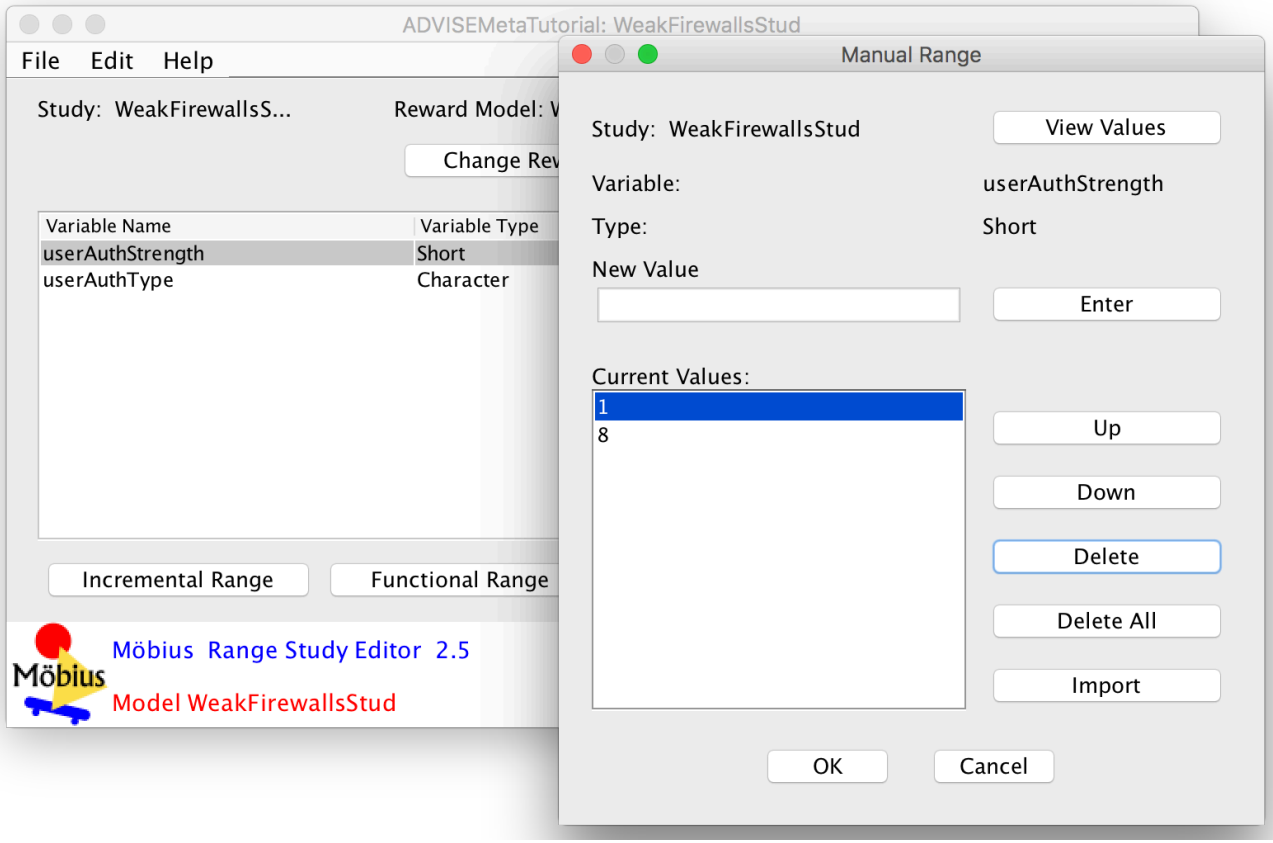
1. Double click **WeakFirewallsStud.**



Small SCADA Networks – Step 4

Change the values for **userAuthStrength**.

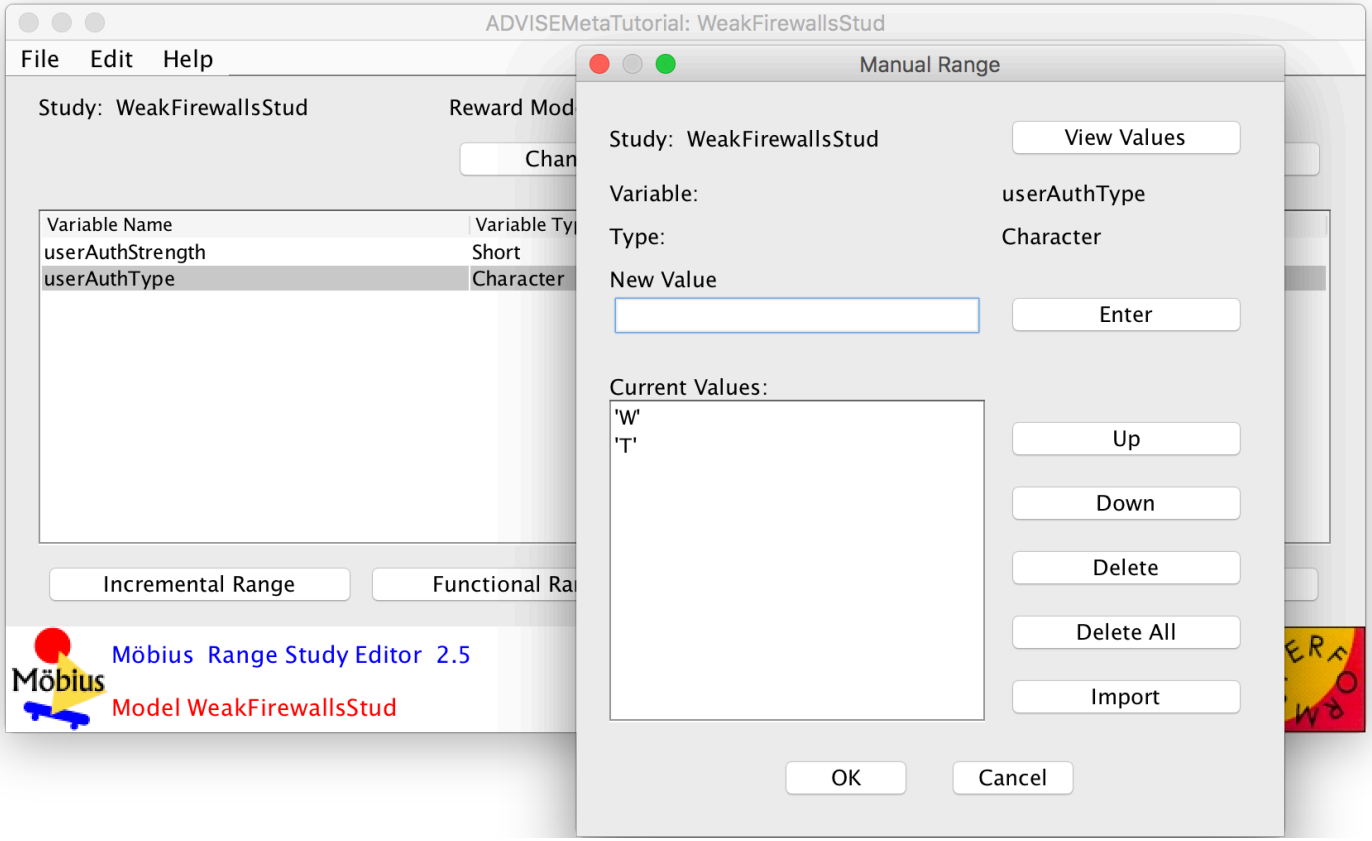
1. Select **userAuthStrength** and click Manual Range.
2. Input **1** in the New Value box and click Enter.
3. Input **8** in the New Value box and click Enter.
4. Select the default **0** and click Delete.



Small SCADA Networks – Step 4

Change the values for **userAuthType**.

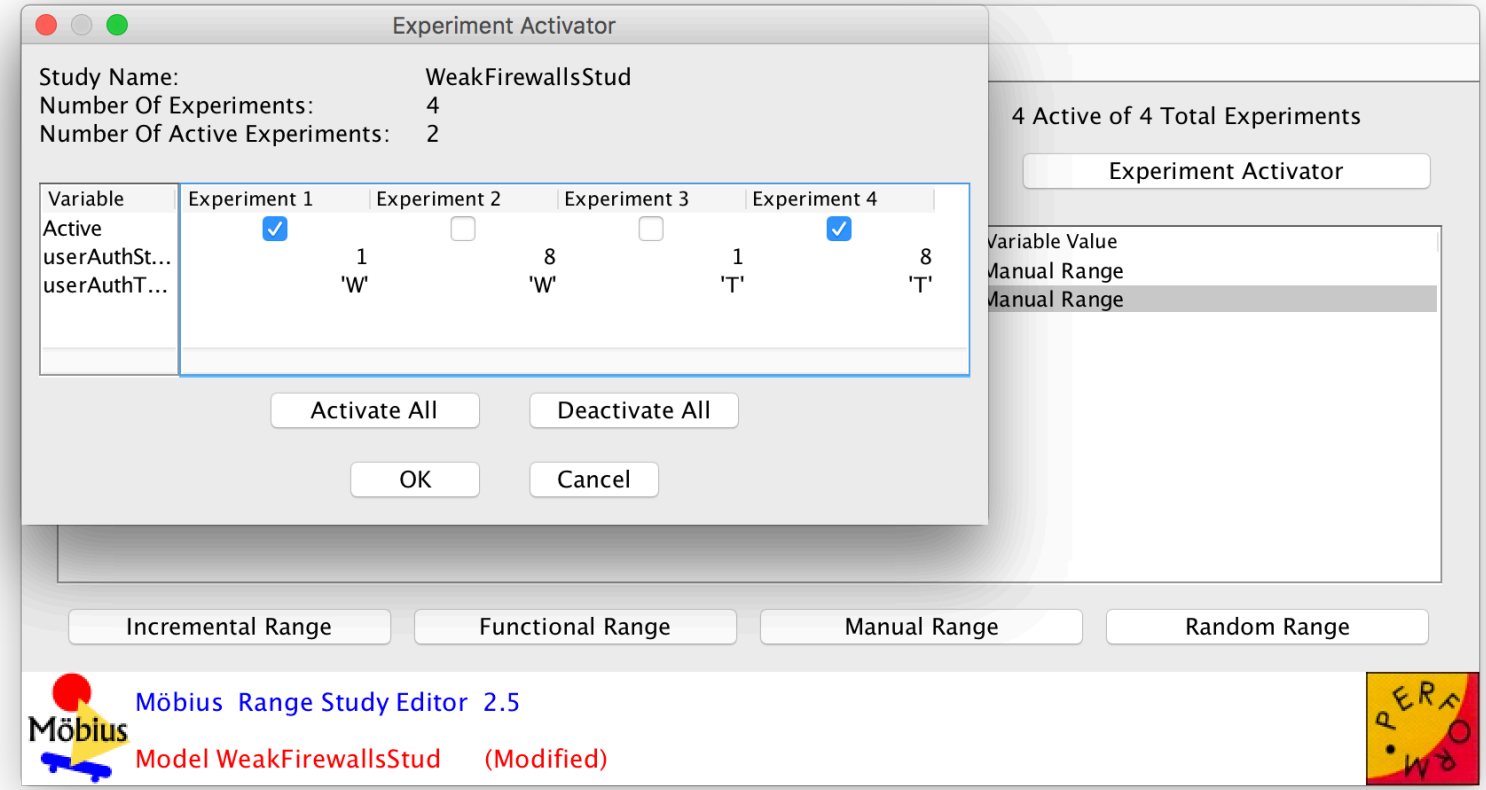
1. Select **userAuthType** and click Manual Range.
2. Input **'W'** in the New Value box and click Enter.
3. Input **'T'** in the New Value box and click Enter.
4. Select the default **0** and click Delete.



Small SCADA Networks – Step 4

Deactivate Unnecessary Experiments

1. Click the Experiment Activator button.
2. Uncheck experiments 2 and 3.
3. Click OK.

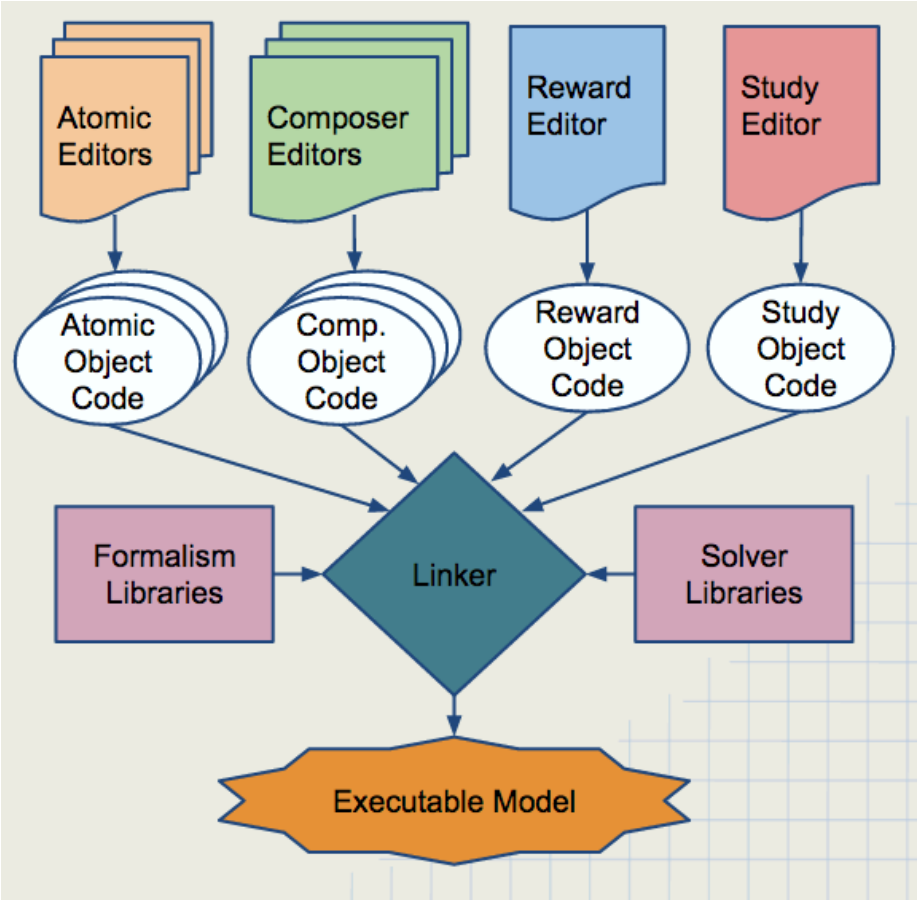


Step 4 – Metrics and Experiments – Feedback

- How challenging was this step?
- What kind of metrics would you want to define in a system?
- How could you define it as a performance variable?
- What results do you expect to see once the model executes?
- Do you understand how you can develop many experiments?

Step 5 – Execute Models

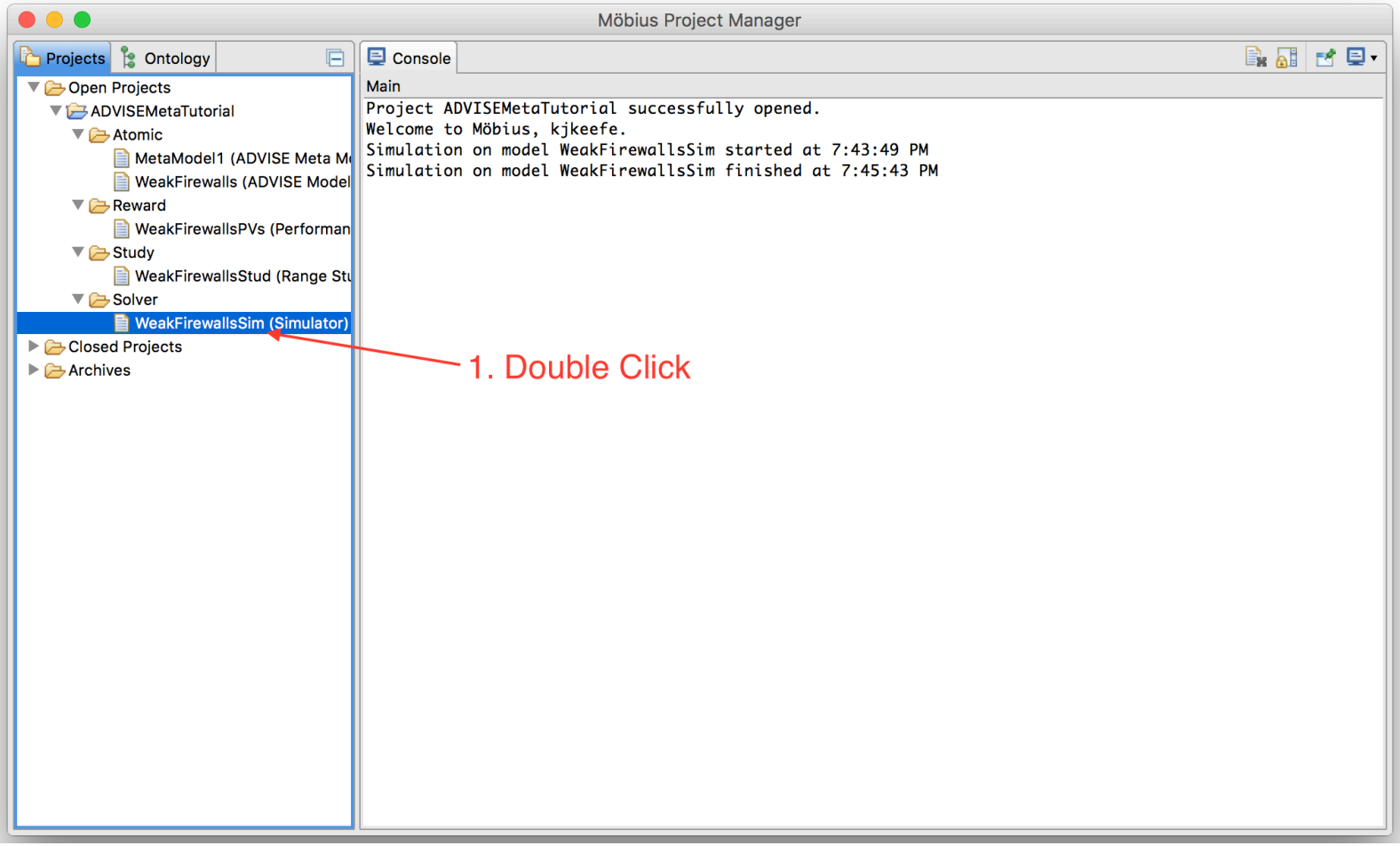
- Möbius creates an executable model by:
  - Generating C++ code representations of project models
  - Compiling the code and linking formalism and solver libraries
  - Executing the binary to gather observations and calculate statistics



Small SCADA Networks – Step 5

Open Simulator

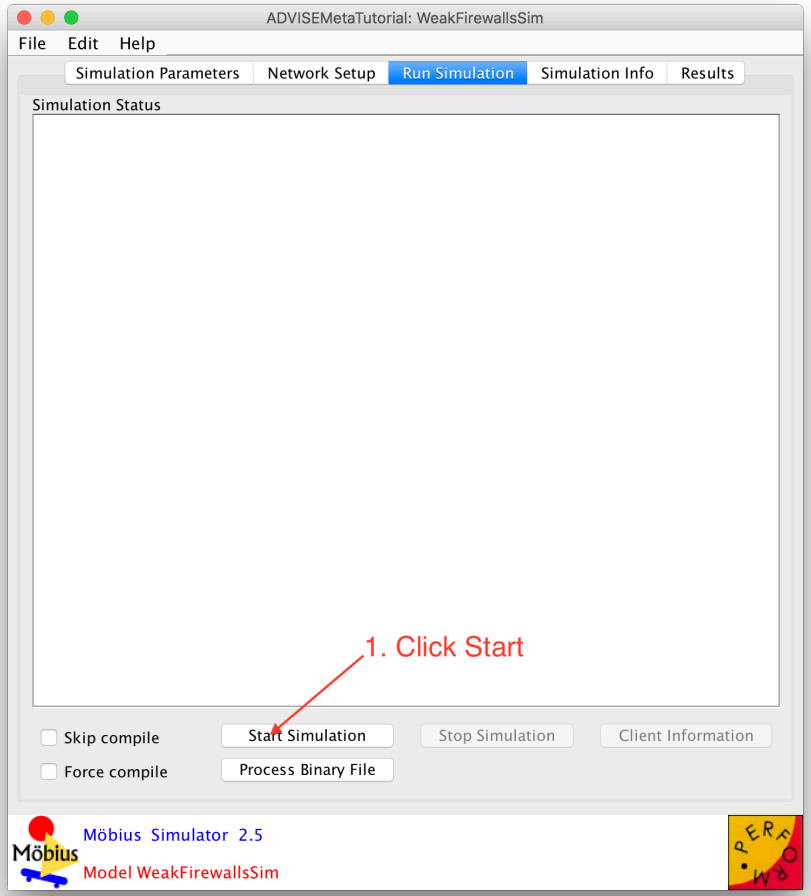
1. Double click the **WeakFirewallsSim**.



Small SCADA Networks – Step 5

Run Simulation

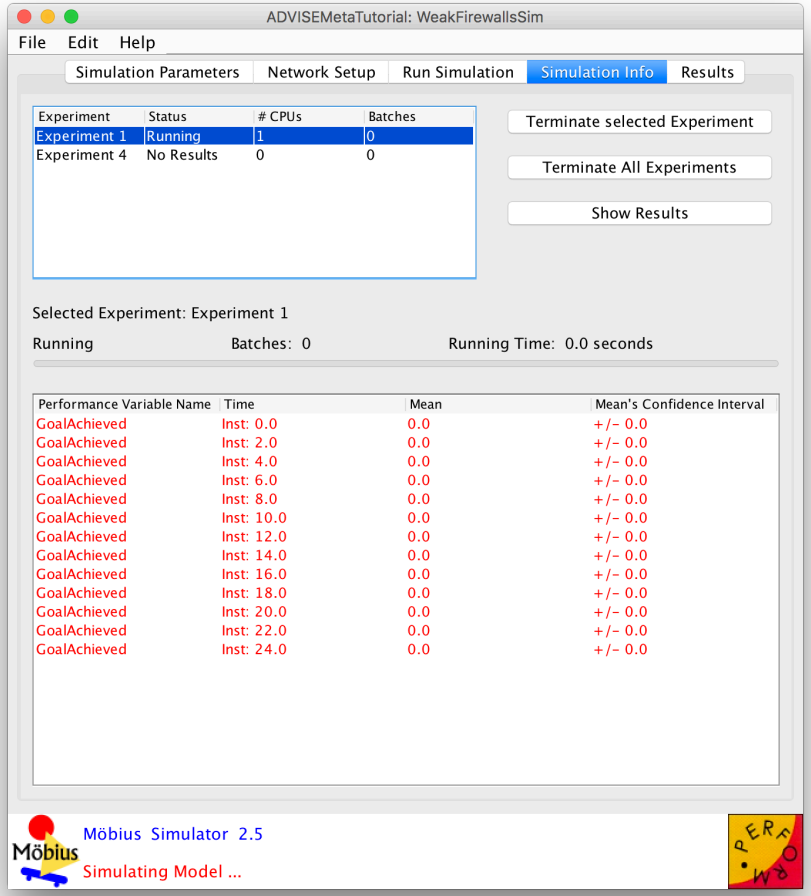
1. Click the Start Simulation button.



Small SCADA Networks – Step 5

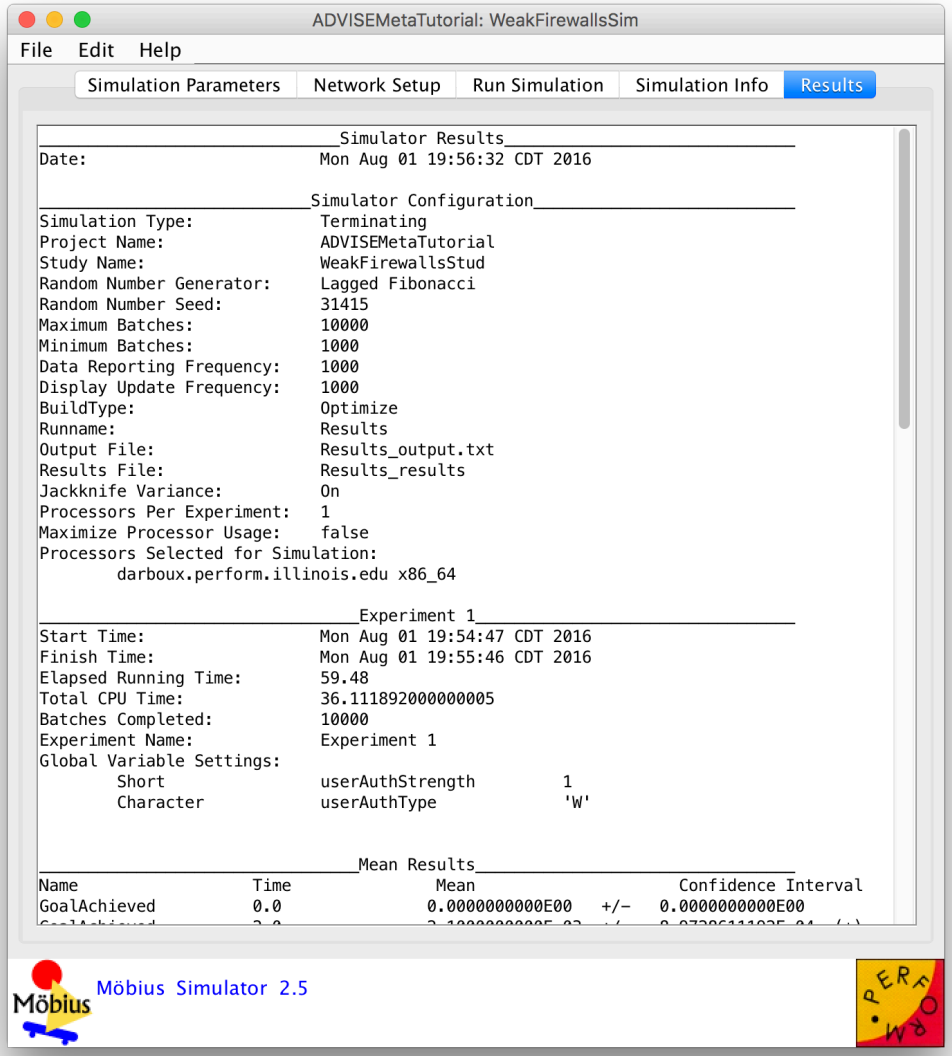
Simulation Info

1. Wait.



Small SCADA Networks – Step 5

Simulation Is Complete



Step 5 – Execute Models – Feedback

- How challenging was this step?
- Did the simulation run faster/slower than you expected?
- Were the steps to execute the simulation too complex?

Step 6 – Interpret Results

- We will examine…
  - Numerical results from the simulation
  - A visual presentation of the model's behavior

Small SCADA Networks – Step 6

Numerical Results

- Adversary was more successful, more quickly when firewalls were hardened.

Batches Completed: 10000
Experiment Name: Experiment 1
Global Variable Settings:

Short	userAuthStrength	1
Character	userAuthType	'W'

Mean Results

Name	Time	Mean		Confidence Interval	
GoalAchieved	0.0	0.0000000000E00	+/-	0.0000000000E00	
GoalAchieved	2.0	2.1000000000E-03	+/-	8.9728611192E-04	(*)
GoalAchieved	4.0	2.8200000000E-02	+/-	3.2448213338E-03	(*)
GoalAchieved	6.0	9.8300000000E-02	+/-	5.8356008775E-03	
GoalAchieved	8.0	1.8260000000E-01	+/-	7.5726082533E-03	
GoalAchieved	10.0	2.5560000000E-01	+/-	8.5499070658E-03	
GoalAchieved	12.0	3.2230000000E-01	+/-	9.1606582755E-03	
GoalAchieved	14.0	3.7860000000E-01	+/-	9.5072237807E-03	
GoalAchieved	16.0	4.3560000000E-01	+/-	9.7188577416E-03	
GoalAchieved	18.0	4.8330000000E-01	+/-	9.7950219940E-03	
GoalAchieved	20.0	5.3120000000E-01	+/-	9.7813910489E-03	
GoalAchieved	22.0	5.7350000000E-01	+/-	9.6940223358E-03	
GoalAchieved	24.0	6.1140000000E-01	+/-	9.5541466358E-03	

Batches Completed: 10000
Experiment Name: Experiment 4
Global Variable Settings:

Short	userAuthStrength	8
Character	userAuthType	'T'

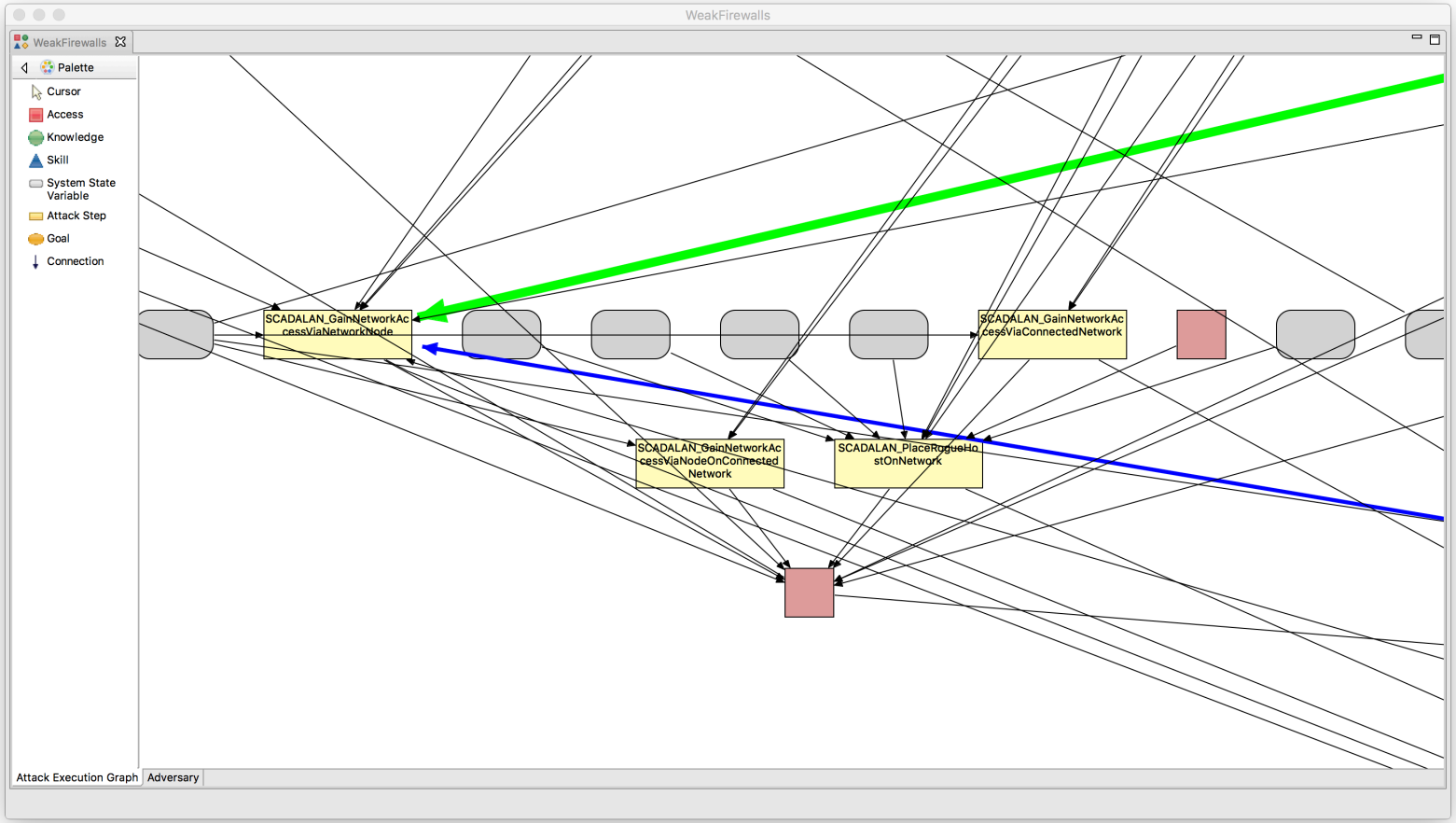
Mean Results

Name	Time	Mean		Confidence Interval
GoalAchieved	0.0	0.0000000000E00	+/-	0.0000000000E00
GoalAchieved	2.0	5.1500000000E-01	+/-	3.0991872098E-02
GoalAchieved	4.0	9.7000000000E-01	+/-	1.0578396025E-02
GoalAchieved	6.0	1.0000000000E00	+/-	0.0000000000E00
GoalAchieved	8.0	1.0000000000E00	+/-	0.0000000000E00
GoalAchieved	10.0	1.0000000000E00	+/-	0.0000000000E00
GoalAchieved	12.0	1.0000000000E00	+/-	0.0000000000E00
GoalAchieved	14.0	1.0000000000E00	+/-	0.0000000000E00
GoalAchieved	16.0	1.0000000000E00	+/-	0.0000000000E00
GoalAchieved	18.0	1.0000000000E00	+/-	0.0000000000E00
GoalAchieved	20.0	1.0000000000E00	+/-	0.0000000000E00
GoalAchieved	22.0	1.0000000000E00	+/-	0.0000000000E00
GoalAchieved	24.0	1.0000000000E00	+/-	0.0000000000E00

Small SCADA Networks – Step 6

Visual Results

- Adversary chose to directly compromise the HMI, rather than go through the firewalls when the firewalls were hardened.



Step 6 – Interpret Results – Feedback

- Were you surprised by the results?
- Do you believe unexpected results could be useful?
- What more would you like to know about the model to make design decisions based on what you've learned?
- How could the results presentation be improved?

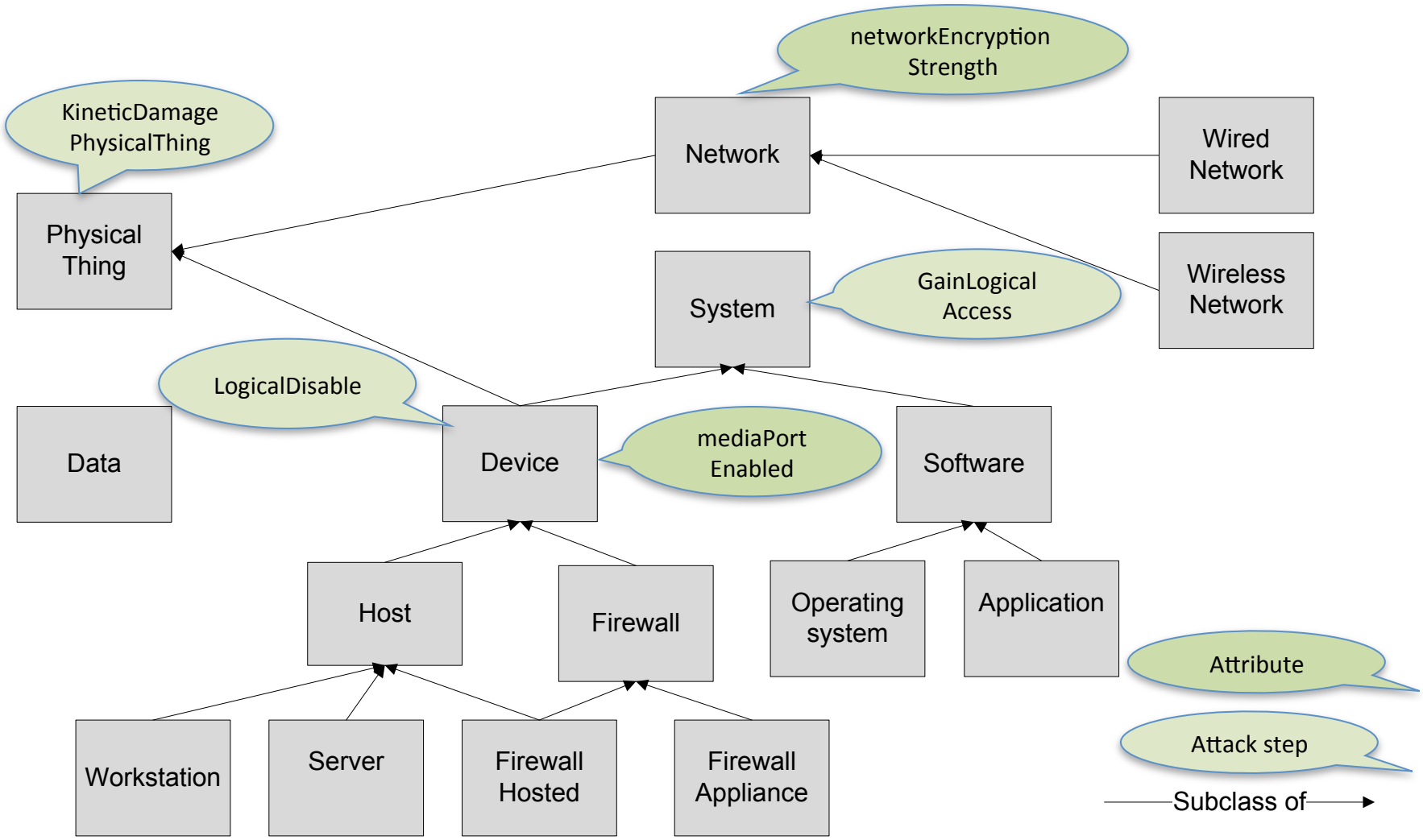
Agenda

- Registration and Continental Breakfast
- Welcome
- Goals
  - Tool
  - Workshop
- Steps to Use ADVISE Meta
- Hands on Sessions
- Case Studies and Custom Ontologies
- Wrap Up

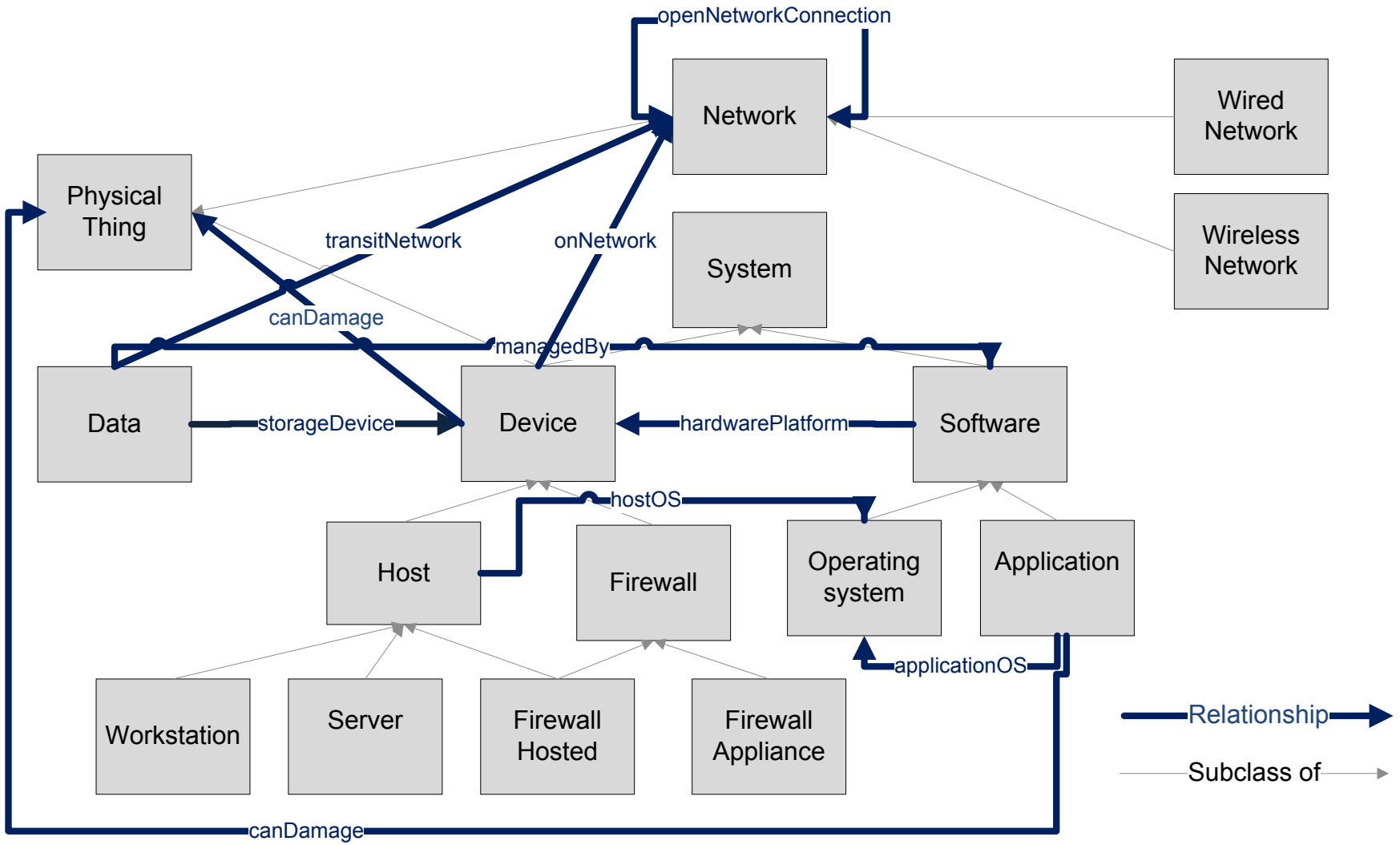
Base Ontology

- Used for hands-on exercise
- Representative of tool capabilities
- Grounded by:
  - Research on attack methods
  - Study of example analysis previously done with a hand-created AEG
- Not yet a "complete" or vetted dataset

Base Component Ontology and Inheritance



Base Ontology Relationships



Types of Access

- PhysicalAccess(X), where X is a PhysicalThing
  - Not achievable via any attack step, must be given as initial condition
- NetworkAccess(X), where X is a Network
  - Able to read and write bits on the network
- UIAccess(X), where X is a Device or Software
  - Able to touch the login function (if any)
- HasUserCredentials(X), where X is a Device or Software
  - Has the password, token, key, or other credential required to access user functions provided by X
- LogicalAccess(X), where X is a Device or Software
  - Able to access user functions provided by X

Skills

- See list of skills on ontology tab with symbol 
- Adversary templates define default skill proficiencies
- Most skills are generic
- Reason for adding system specific skills ("Specialized")
  - Model the tremendous advantage they provide to adversary
- Reason for using broad skill categories
  - Represents how real adversaries accumulate skills
  - Fine grained skill proficiencies (e.g. at stealing passwords or breaking VPNs) unlikely to be known or even guessable in an actual case
  - Haven't seen reason yet for increasing data input requirements and complexity in attack step models

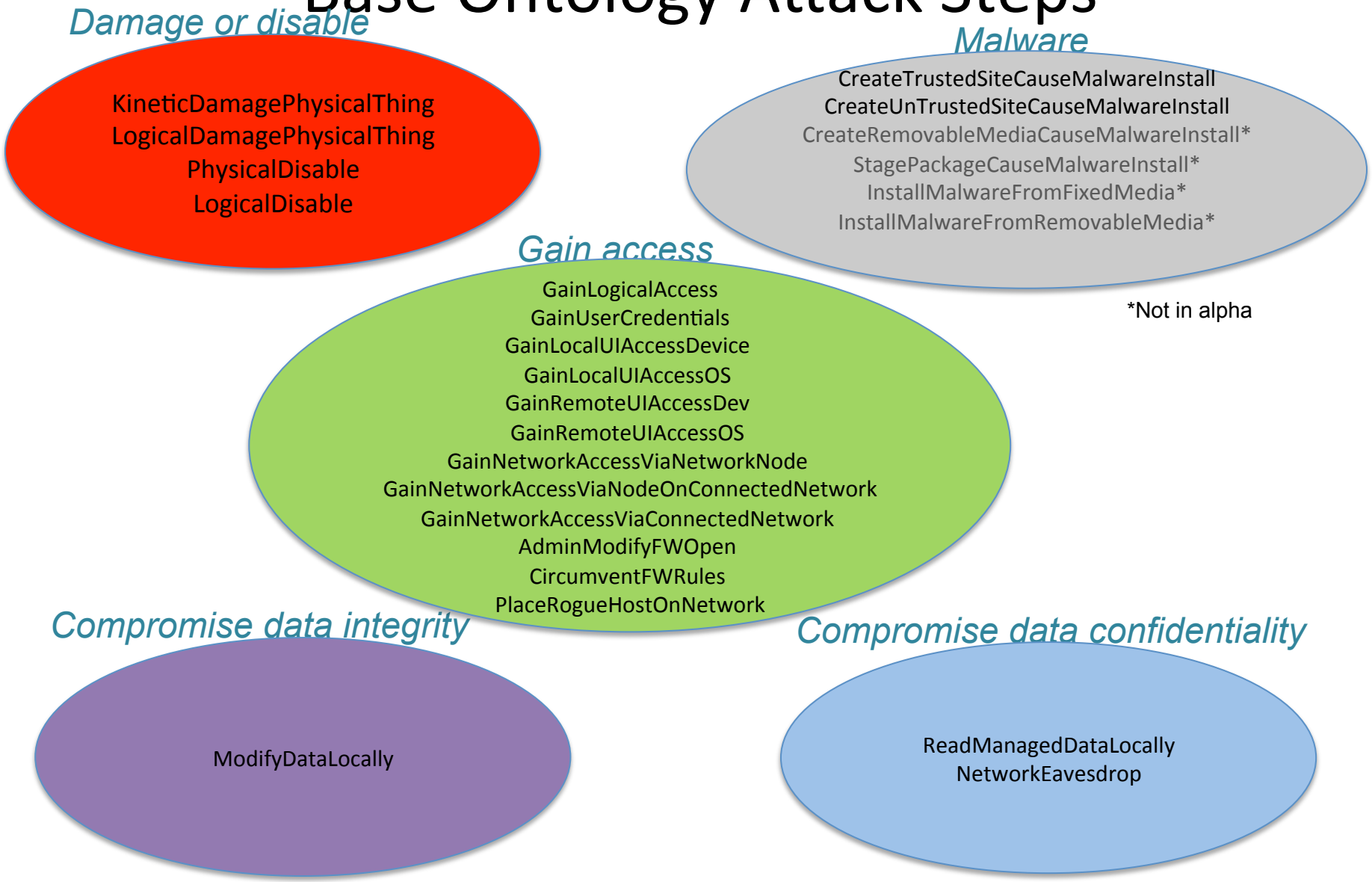
What does skill proficiency mean?

Basic cyber offense	This is a set of skills not further distinguished, some level of which are available via relatively inexpensive tools to any adversary. These include the following elements from the Ethical Hacking Certification Syllabus at https://www.eccouncil.org/Certification/professional-series/ceh-course-outline : scanning, enumeration, phishing attack, password cracking based on external information (guessing, replay), privilege escalation, hijacking web servers, hacking web applications, SQL injection, buffer overflow, straightforward DoS attacks, network sniffing, social engineering without human contact (for which phishing is an example).	1000	Lead individual employed by a nation state to conduct cyber attacks
		800	Individual with broad skills including stealth, which would earn admirers in the hacking community
		600	Individual with solid skills that could be employed to perform ethical hacking engagements
		400	Individual with solid skills in many areas listed, but weak in a few
		50	Individual can perform simple script-based attacks

In the base ontology, probability of success/failure of an attack step often has a linear relationship with one or two skills

- e.g. a generic skill OR a specialized skill impacts outcome

Base Ontology Attack Steps



*Not in alpha

Attack Steps: Example Probability Calculation

Coded in the Ontology tab->*NetworkEavesdrop* ->Failure:

Probability of the adversary outcome Failure for *NetworkEavesdrop* on a Data element is the probability that the adversary can't break the crypto (if any) on a *network which the data transits*, or that they can break it, but are kicked off the network before harm is done. (transitNetwork, relationship of Data to Network)

The probability they can't break the crypto increases with:

- Application layer encryption strength (attribute of data)
- Network layer encryption strength (attribute of network)

and decreases with:

- Cryptanalysis skill proficiency of the adversary (adversary parameter)

The probability that they are kicked off the network increases with:

- the strength of countermeasures on the network to detect and respond to eavesdropping (attribute of network)
- attribute defaulted to zero because this is extremely difficult to do

Features for Future Base Ontology

- Component ontology
  - Types of networks (LAN, WAN, VLAN)
  - VPN connections
  - Routers
  - Gateways
  - Device authentication
  - User roles

Features for Future Base Ontology (cont.)

- Attack steps
  - Disable or Damage
    - PhysicalDisconnect
    - NetworkFlood
  - Malware
    - CreateRemovableMediaCauseMalwareInstall
    - Stage PackageCauseMalwareInstall
    - InstallMalwareFromRemovableMedia
    - InstallMalwareFromFixedMedia
  - Data Confidentiality
    - Exfiltrate data
  - Network Infrastructure
    - Router and switch attacks
  - 0 - days

Custom Ontologies

- The base ontology is data, it is not baked into the tool
- A "library designer" may on the ontology tab:
  - Add to or modify base ontology
  - Define a new ontology
- This includes all ontology elements including:
  - Components
    - Relationships
    - Attributes
  - Attack steps
  - Adversaries

Examples for Custom Ontologies

- Add component types with unique defaults, attributes, and/or attack steps
  - Virtual OS – build model of data center
  - ATM machine – build model of banking organization
  - Smartmeter – build model of planned smart grid architecture
- Add a customized adversary type (e.g. contractor with specific skills)
- Modify formulas used to calculate attack step characteristics
  - Probability of success/failure of attack step
  - Detectability of an attack step outcome
  - Cost of attack step
  - Time to execute attack step
- Build ontology to model internal architecture of a modern electric vehicle together with associated charging stations
- See tutorial to try out creating an ontology https://www.mobius.illinois.edu/wiki/index.php/ADVISE_Meta_Two_Nets_Tutorial

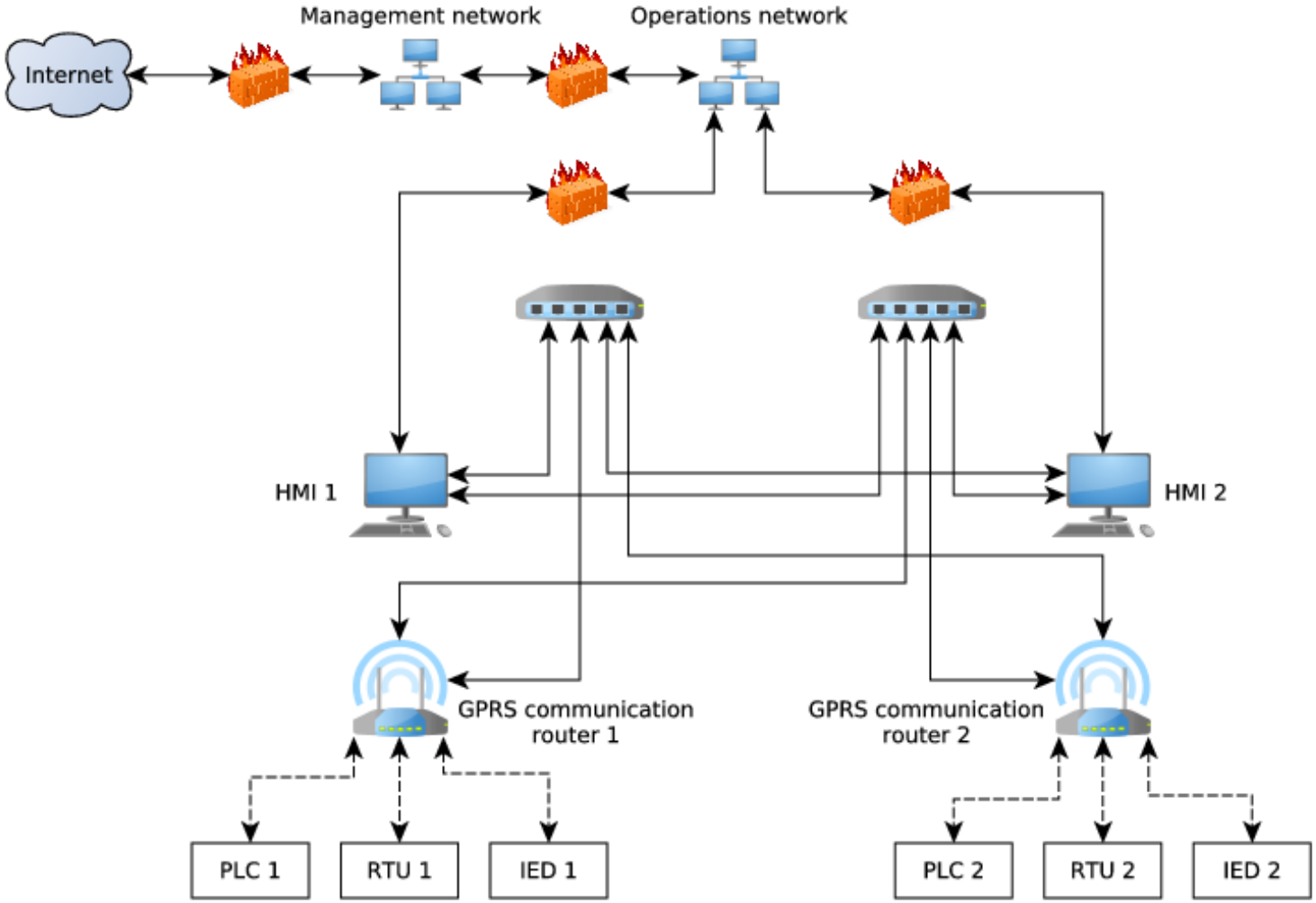
River Zonal Dispatcher Case Study

Purpose of analysis

- Investigate the effects on system security of architectural changes to a river zonal dispatcher system with multiple SCADA subsystems.
- In particular, analyze the security impact of intrusion detection systems (IDSes) and isolation, as well as multiple subsystems.
  - How does the behavior of an attacker change when adding IDSes or isolating SCADA subsystems?
  - What key factors would motivate an attacker to choose one SCADA subsystem over another?

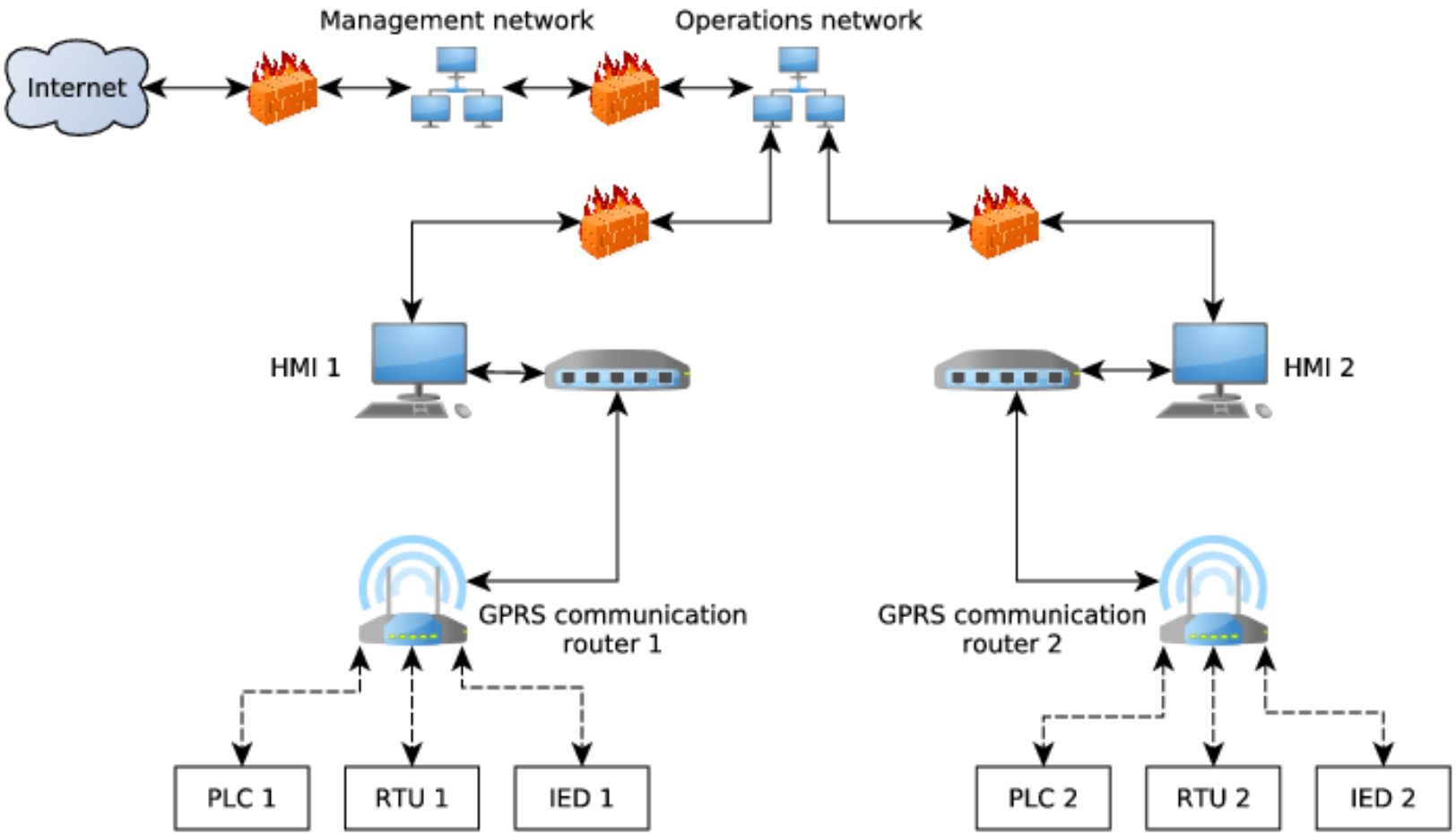
River Zonal Dispatcher Case Study

Without Isolation



River Zonal Dispatcher Case Study

With Isolation



River Zonal Dispatcher Case Study

Model Systems

- Two systems: with and without isolation
- Highlights of models:
  - Four regular networks
  - Devices on two Modbus networks
  - An OPC daemon on an HMI sends commands to the devices controlling the dams
  - Used global variables to control whether IDSes and isolation exist

River Zonal Dispatcher Case Study

Model Attack Goals and Adversaries

- Install malware on HMI, compromise system via router, compromise system via devices
- Five adversaries are:
  - Foreign government
    - Primarily concerned with installing backdoors on the HMIs and cares little about costs.
  - Hacker
    - Interested in most of the possible goals and is highly skilled, but must consider a balance of concern regarding cost, payoff, and detection.
  - Hostile Organization
    - Highly skilled, but is interested only in compromising the supervisory LANs and is mostly seeking best payoff.
  - Insider Engineer
    - Interested in all goals, but is poorly skilled in attacks.
  - Insider Operator
    - Has access to many parts of the system already, is highly skilled, and is primarily concerned with reprogramming the devices.

River Zonal Dispatcher Case Study

Select Metrics (all standard available metrics)

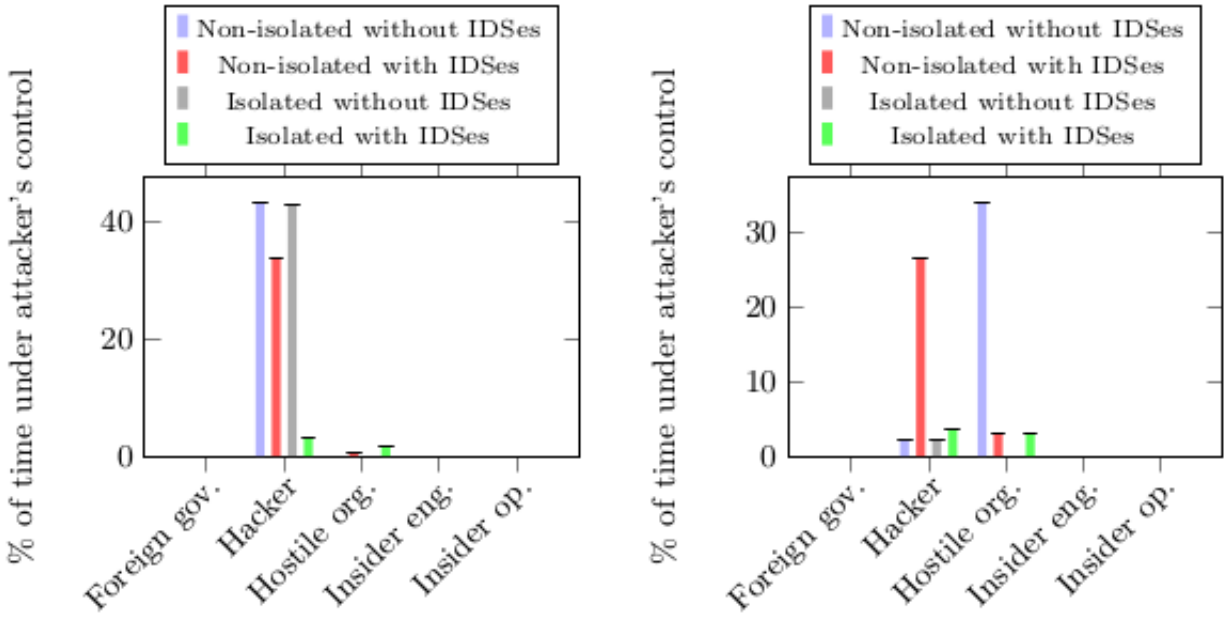
- **Average Number of Attempts**
  - Report for each attack step (maybe not all)
  - Gives insight on preferred attack path of adversary
- **Probability of Attack Goal Achieved at End Time**
  - Report for each attack goal
  - Gives insight on what goals the adversary is actively pursuing and reaching
- **Average Time-To-Achieve-Goal**
  - For attack goals where the above probability metric is 1 (or close to 1)
  - Gives insight on the speed of the adversary's attack

River Zonal Dispatcher Case Study

Generate and Execute Models

- Set up 20 configurations for execution
  - Each of 5 adversaries X 4 system models
  - Calculate all metrics
- Simulation run time set to 8760 seconds
- Ran 1,000 to 10,000 iterations
  - Confidence interval set to 90%
  - Results representing rare events (typically values close to zero) failed to converge

River Zonal Dispatcher Case Study

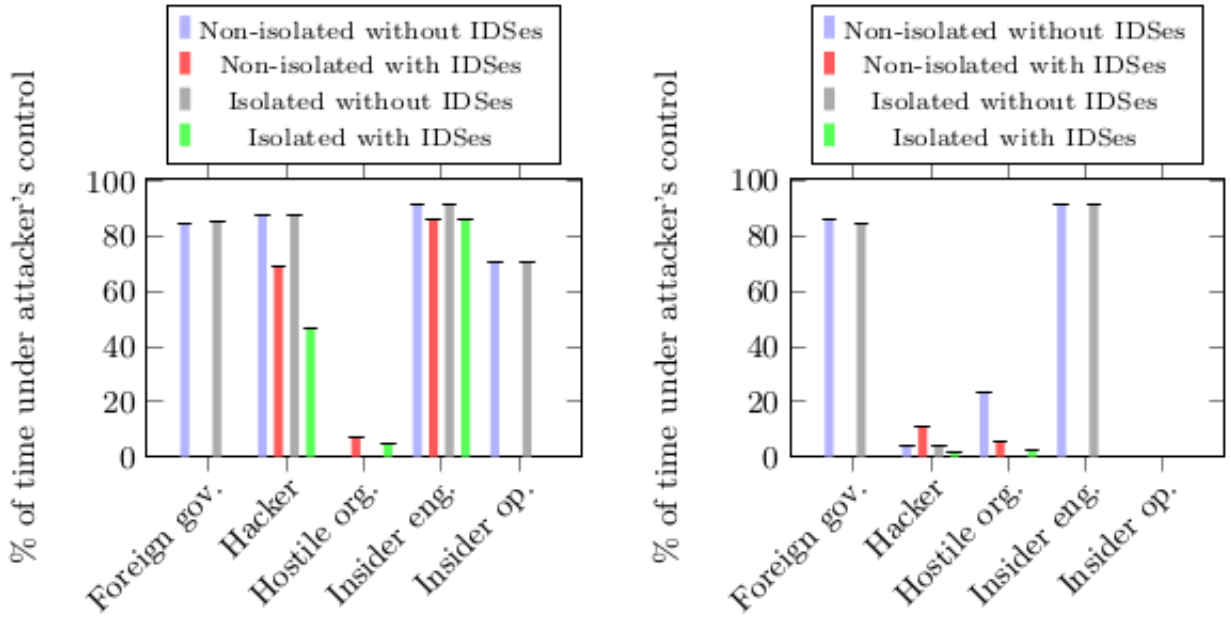


(a) Supervisory LAN 1.

(b) Supervisory LAN 2.

Fig. 6: Average percentages of time in which the attacker has control of a GPRS communication router on a particular supervisory network

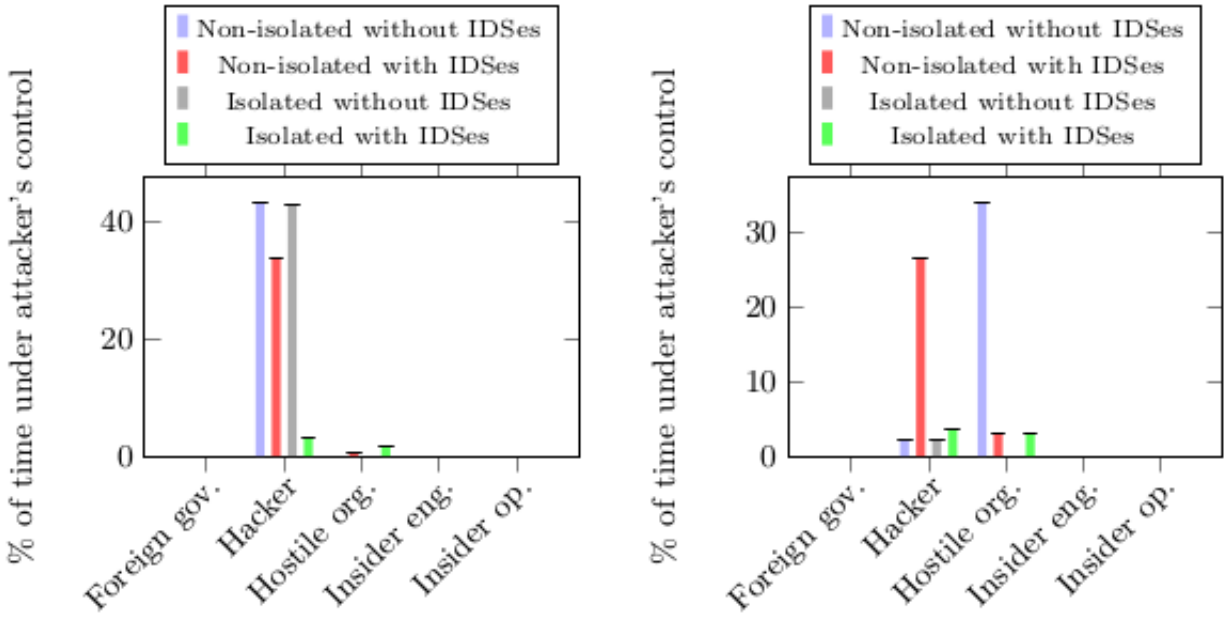
River Zonal Dispatcher Case Study



(a) Supervisory LAN 1. (b) Supervisory LAN 2.

Fig. 7: Average percentages of time that an HMI on a particular network has backdoor software installed.

River Zonal Dispatcher Case Study



(a) Supervisory LAN 1.

(b) Supervisory LAN 2.

Fig. 6: Average percentages of time in which the attacker has control of a GPRS communication router on a particular supervisory network

River Zonal Dispatcher Case Study

Interpret Results

- How does the behavior of an attacker change when adding IDSes or isolating SCADA subsystems?
  - Attacker behavior changes as outcome probabilities and global variables change, affecting the preconditions and attractiveness of attack steps
- What key factors would motivate an attacker to choose one SCADA subsystem over another?
  - Payoff differences (seen by duration of mean time that backdoor SW is installed on HMI)

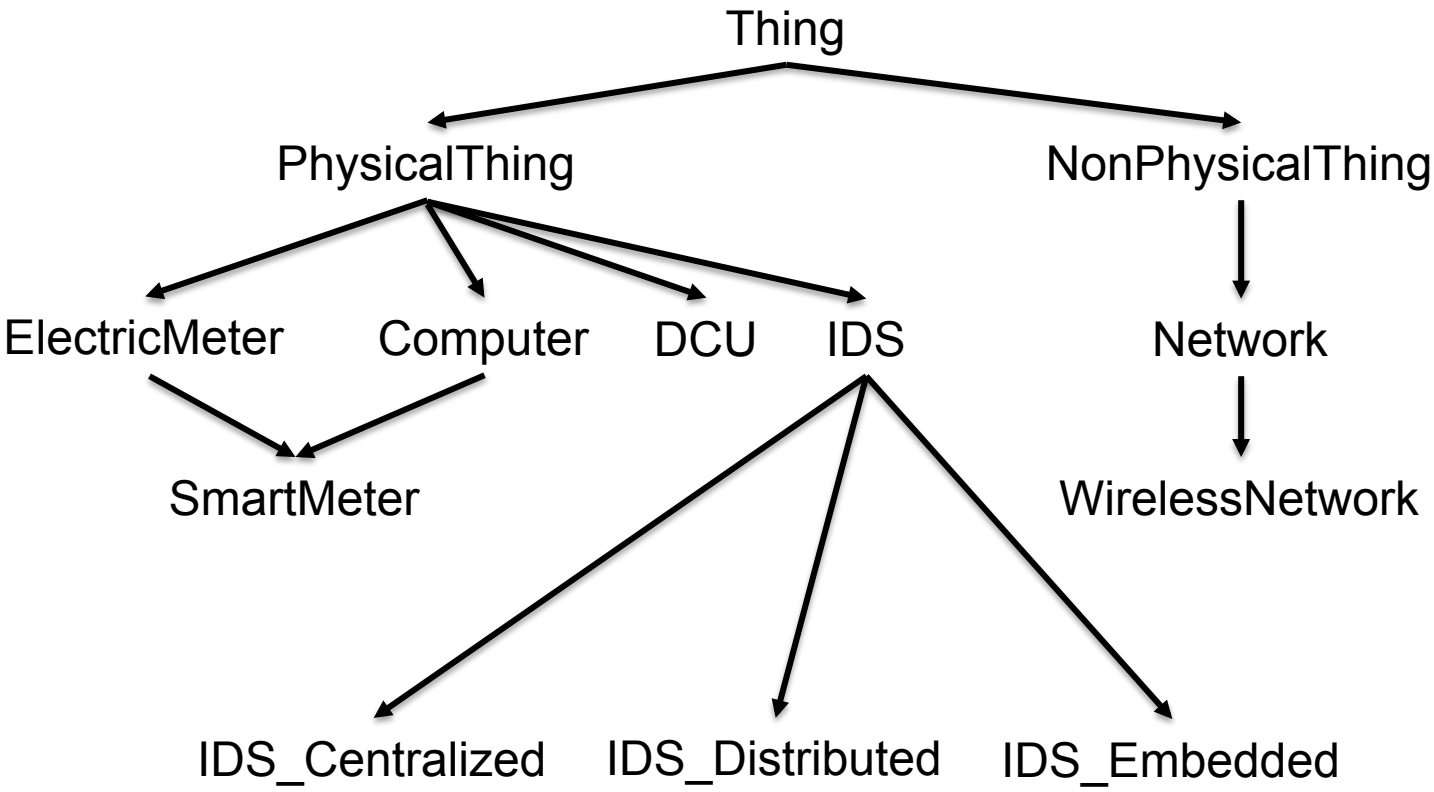
Advanced Metering Infrastructure Case Study

Define purpose of analysis

- Determine the cost-effectiveness of different intrusion detection systems (IDSes) in an Advanced Metering Infrastructure (AMI) network.
- In particular, compare
  - Centralized IDS,
  - Distributed IDS, and
  - Embedded IDS.

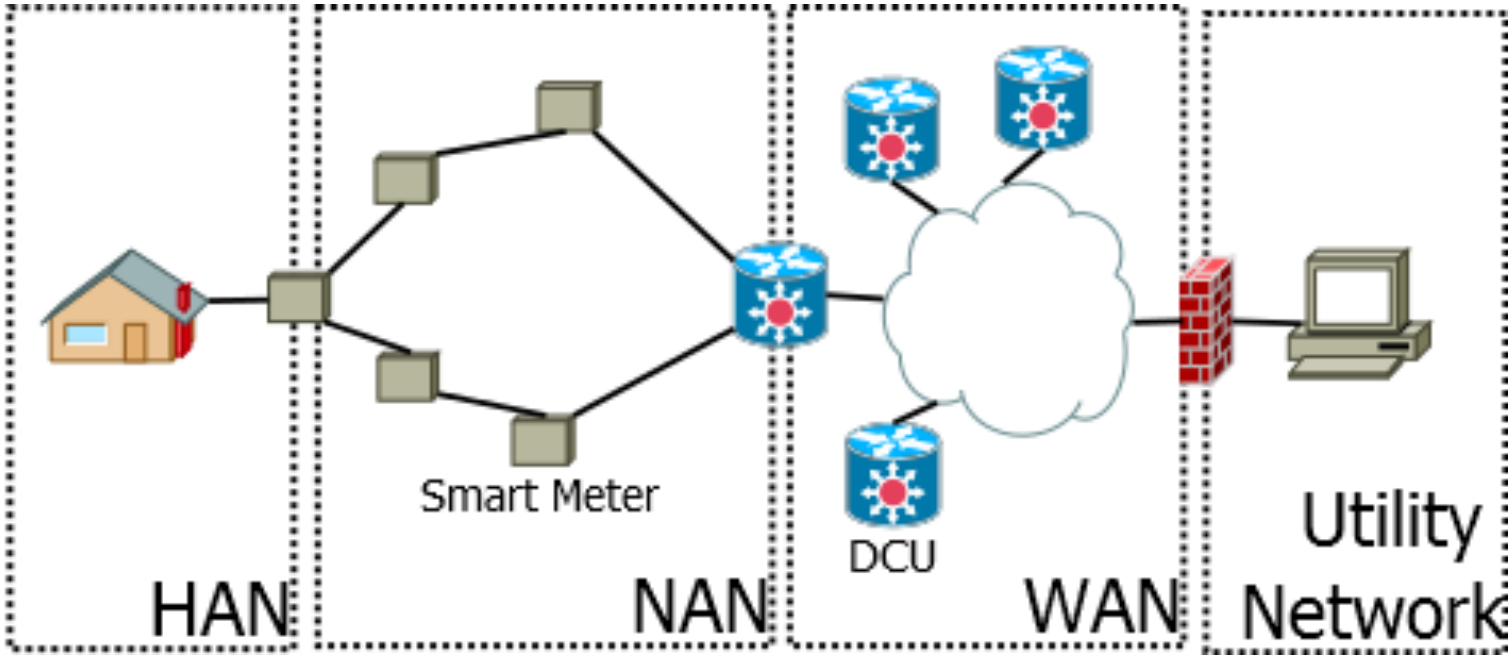
Advanced Metering Infrastructure Case Study

Define system components, relationship and attributes



Advanced Metering Infrastructure Case Study

Define system components, relationship and attributes



Advanced Metering Infrastructure Case Study

Model Attack Goals and Adversaries

- Compromise availability and integrity of the AMI, or steal electricity, depending on adversary.
- Adversaries include
  - Malicious customers
  - Insider
  - Nation-State
  - Terrorist

Advanced Metering Infrastructure Case Study

Select Metrics

- Damage to System
- Probability of Detecting Adversary
- Attack Path

Advanced Metering Infrastructure Case Study

Simulate Model

- Execute ADVISE models to determine how each of the three IDSes may fare when faced with attacks from the four adversary types, when compared on
  - Likelihood of detection,
  - Attack path chosen by adversary, and
  - Damage to the system.
- Calculate cost-effectiveness of each IDS

Agenda

- Registration and Continental Breakfast
- Welcome
- Goals
  - Tool
  - Workshop
- Steps to Use ADVISE Meta
- Hands on Sessions
- Case Studies and Custom Ontologies
- Wrap Up

Wrap Up

- General feedback
  - Was this tool useful?
  - How could you and your organization use it?
  - What areas need work?
- The Near Future
  - Improvements to ADVISE/Actor Model
  - Expanded Ontology
  - System to Easily Share Ontology Packages
  - Ontology Editor Improvements / Validation

Thank You!

- Contact Info
  - staff@mobius.illinois.edu
  - http://www.mobius.illinois.edu