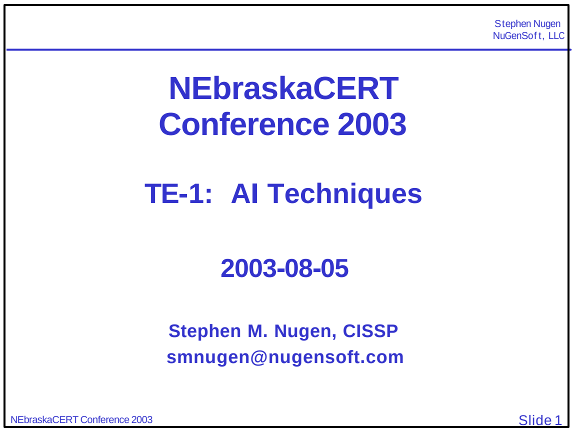

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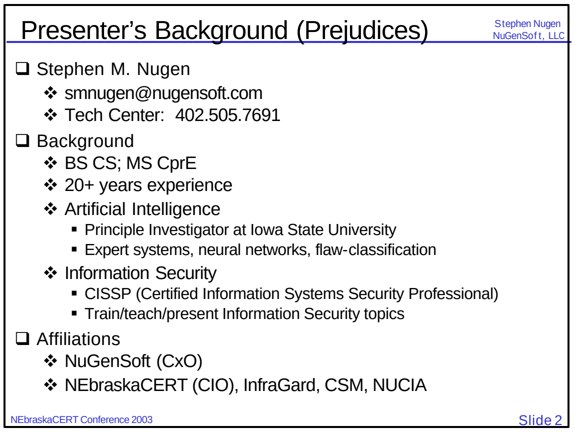
TE-1: AI Techniques

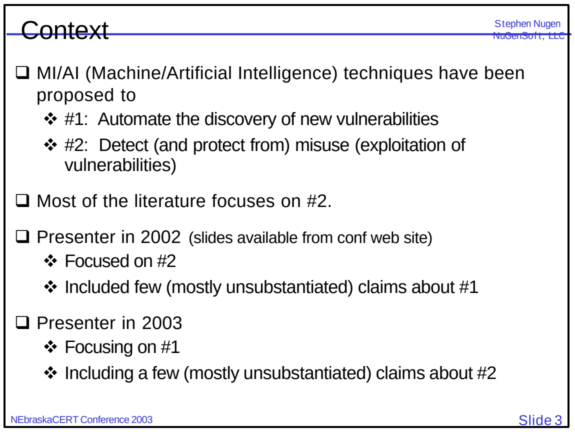
2003-08-05

Stephen M. Nugen, CISSP
smnugen@nugensoft.com



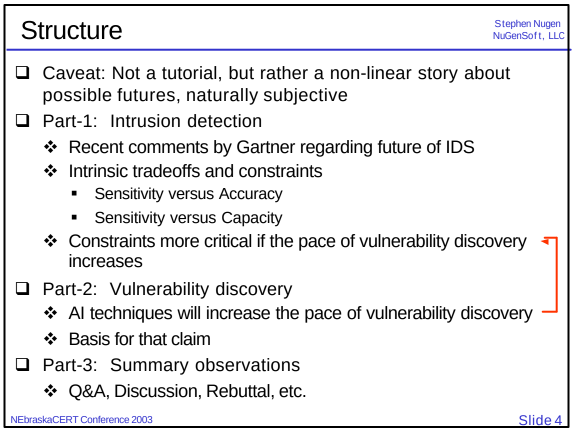
Presenter’s Background (Prejudices)

- ❑ Stephen M. Nugen
  - ❖ smnugen@nugensoft.com
  - ❖ Tech Center: 402.505.7691
- ❑ Background
  - ❖ BS CS; MS CprE
  - ❖ 20+ years experience
  - ❖ Artificial Intelligence
    - Principle Investigator at Iowa State University
    - Expert systems, neural networks, flaw-classification
  - ❖ Information Security
    - CISSP (Certified Information Systems Security Professional)
    - Train/teach/present Information Security topics
- ❑ Affiliations
  - ❖ NuGenSoft (CxO)
  - ❖ NEbraskaCERT (CIO), InfraGard, CSM, NUCIA



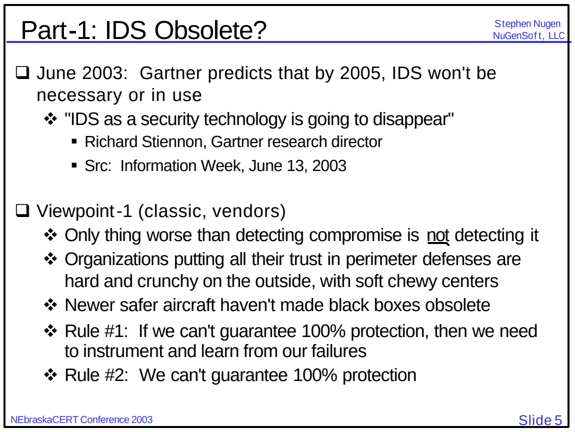
Context

- ❑ MI/AI (Machine/Artificial Intelligence) techniques have been proposed to
  - ❖ #1: Automate the discovery of new vulnerabilities
  - ❖ #2: Detect (and protect from) misuse (exploitation of vulnerabilities)
- ❑ Most of the literature focuses on #2.
- ❑ Presenter in 2002 (slides available from conf web site)
  - ❖ Focused on #2
  - ❖ Included few (mostly unsubstantiated) claims about #1
- ❑ Presenter in 2003
  - ❖ Focusing on #1
  - ❖ Including a few (mostly unsubstantiated) claims about #2



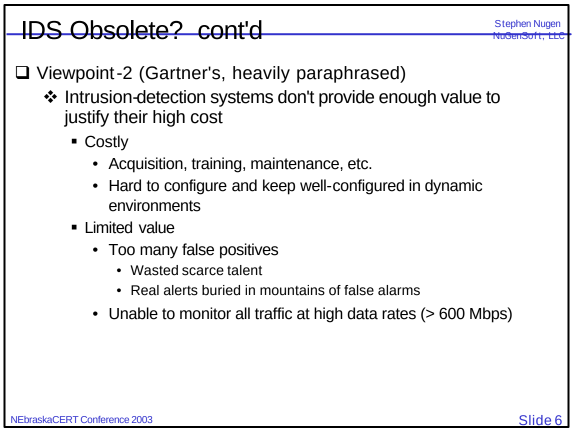
Structure

- ❑ Caveat: Not a tutorial, but rather a non-linear story about possible futures, naturally subjective
- ❑ Part-1: Intrusion detection
  - ❖ Recent comments by Gartner regarding future of IDS
  - ❖ Intrinsic tradeoffs and constraints
    - ▪ Sensitivity versus Accuracy
    - ▪ Sensitivity versus Capacity
  - ❖ Constraints more critical if the pace of vulnerability discovery increases
- ❑ Part-2: Vulnerability discovery
  - ❖ AI techniques will increase the pace of vulnerability discovery
  - ❖ Basis for that claim
- ❑ Part-3: Summary observations
  - ❖ Q&A, Discussion, Rebuttal, etc.



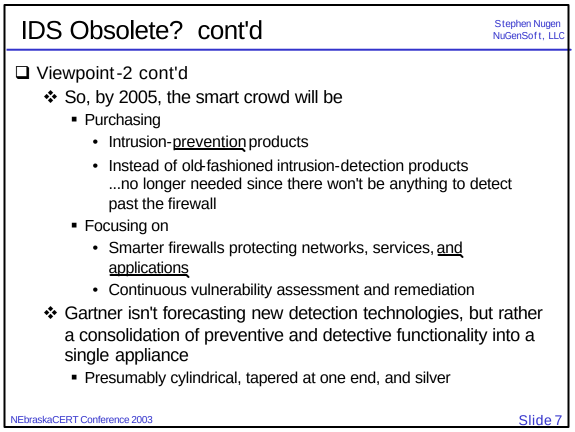
Part-1: IDS Obsolete?

- ❑ June 2003: Gartner predicts that by 2005, IDS won't be necessary or in use
  - ❖ "IDS as a security technology is going to disappear"
    - ▪ Richard Stiennon, Gartner research director
    - ▪ Src: Information Week, June 13, 2003
- ❑ Viewpoint-1 (classic, vendors)
  - ❖ Only thing worse than detecting compromise is <u>not</u> detecting it
  - ❖ Organizations putting all their trust in perimeter defenses are hard and crunchy on the outside, with soft chewy centers
  - ❖ Newer safer aircraft haven't made black boxes obsolete
  - ❖ Rule #1: If we can't guarantee 100% protection, then we need to instrument and learn from our failures
  - ❖ Rule #2: We can't guarantee 100% protection



IDS Obsolete? cont'd

- ❑ Viewpoint-2 (Gartner's, heavily paraphrased)
  - ❖ Intrusion-detection systems don't provide enough value to justify their high cost
    - ▪ Costly
      - Acquisition, training, maintenance, etc.
      - Hard to configure and keep well-configured in dynamic environments
    - ▪ Limited value
      - Too many false positives
        - Wasted scarce talent
        - Real alerts buried in mountains of false alarms
      - Unable to monitor all traffic at high data rates (> 600 Mbps)



IDS Obsolete? cont'd

Stephen Nugen
NuGenSoft, LLC

- ❑ Viewpoint-2 cont'd
  - ❖ So, by 2005, the smart crowd will be
    - ▪ Purchasing
      - Intrusion-prevention products
      - Instead of old-fashioned intrusion-detection products ...no longer needed since there won't be anything to detect past the firewall
    - ▪ Focusing on
      - Smarter firewalls protecting networks, services, and applications
      - Continuous vulnerability assessment and remediation
  - ❖ Gartner isn't forecasting new detection technologies, but rather a consolidation of preventive and detective functionality into a single appliance
    - ▪ Presumably cylindrical, tapered at one end, and silver

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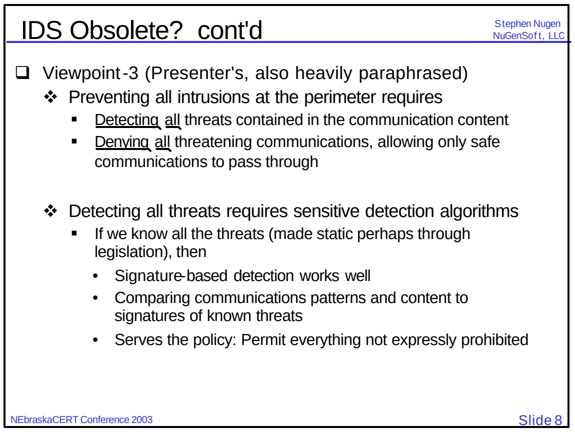

IDS Obsolete? cont'd

Stephen Nugen
NuGenSoft, LLC

- ❑ Viewpoint-3 (Presenter's, also heavily paraphrased)
  - ❖ Preventing all intrusions at the perimeter requires
    - ▪ Detecting all threats contained in the communication content
    - ▪ Denying all threatening communications, allowing only safe communications to pass through
  - ❖ Detecting all threats requires sensitive detection algorithms
    - ▪ If we know all the threats (made static perhaps through legislation), then
      - Signature-based detection works well
      - Comparing communications patterns and content to signatures of known threats
      - Serves the policy: Permit everything not expressly prohibited

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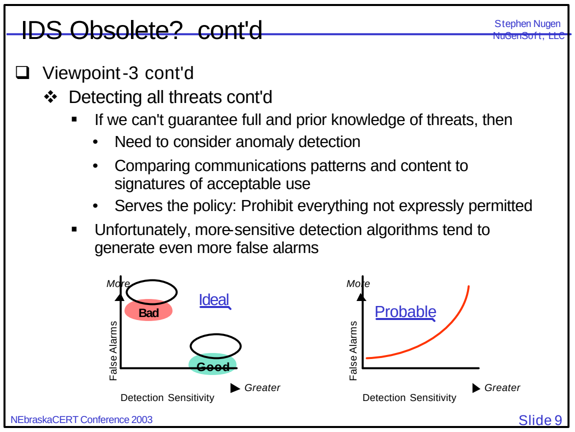

IDS Obsolete? cont'd

Stephen Nugen
NuGenSoft, LLC

- ❑ Viewpoint-3 cont'd
  - ❖ Detecting all threats cont'd
    - ▪ If we can't guarantee full and prior knowledge of threats, then
      - Need to consider anomaly detection
      - Comparing communications patterns and content to signatures of acceptable use
      - Serves the policy: Prohibit everything not expressly permitted
    - ▪ Unfortunately, more-sensitive detection algorithms tend to generate even more false alarms

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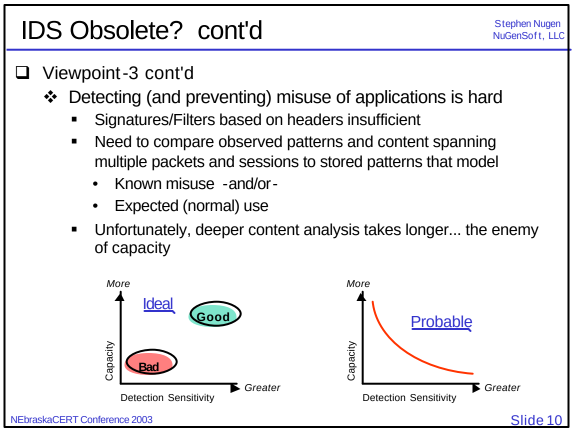

IDS Obsolete? cont'd

Stephen Nugen
NuGenSoft, LLC

- ❑ Viewpoint-3 cont'd
  - ❖ Detecting (and preventing) misuse of applications is hard
    - ▪ Signatures/Filters based on headers insufficient
    - ▪ Need to compare observed patterns and content spanning multiple packets and sessions to stored patterns that model
      - Known misuse -and/or-
      - Expected (normal) use
    - ▪ Unfortunately, deeper content analysis takes longer... the enemy of capacity

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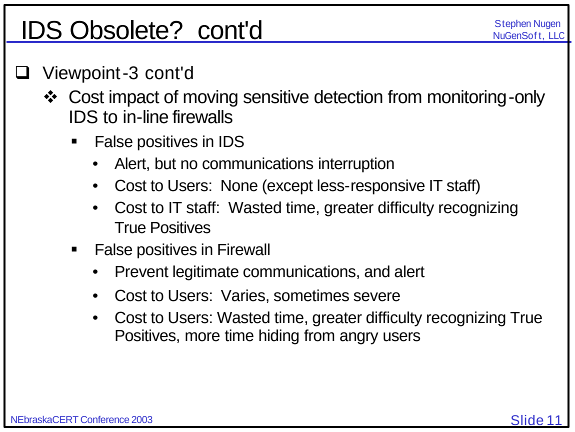
Slide 10



IDS Obsolete? cont'd

Stephen Nugen
NuGenSoft, LLC

- ❑ Viewpoint-3 cont'd
  - ❖ Cost impact of moving sensitive detection from monitoring-only IDS to in-line firewalls
    - ▪ False positives in IDS
      - Alert, but no communications interruption
      - Cost to Users: None (except less-responsive IT staff)
      - Cost to IT staff: Wasted time, greater difficulty recognizing True Positives
    - ▪ False positives in Firewall
      - Prevent legitimate communications, and alert
      - Cost to Users: Varies, sometimes severe
      - Cost to Users: Wasted time, greater difficulty recognizing True Positives, more time hiding from angry users

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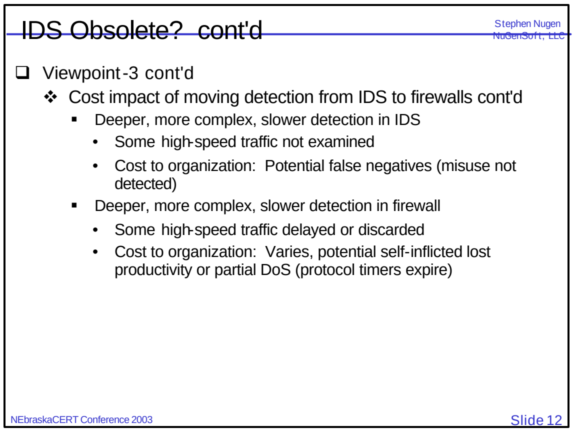
Slide 11



IDS Obsolete? cont'd

Stephen Nugen
NuGenSoft, LLC

- ❑ Viewpoint-3 cont'd
  - ❖ Cost impact of moving detection from IDS to firewalls cont'd
    - ▪ Deeper, more complex, slower detection in IDS
      - Some high-speed traffic not examined
      - Cost to organization: Potential false negatives (misuse not detected)
    - ▪ Deeper, more complex, slower detection in firewall
      - Some high-speed traffic delayed or discarded
      - Cost to organization: Varies, potential self-inflicted lost productivity or partial DoS (protocol timers expire)

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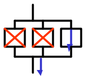
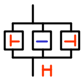
Slide 12

Claim-A

- ❑ Regardless of where the detection function resides, utility depends on
  - ❖ Capacity (how much of the traffic is examined) ... primarily function of speed since parallel processing
    - ▪ Not feasible for in-line firewalls



    - ▪ Not feasible for IDS when hostile activity spans multiple sessions



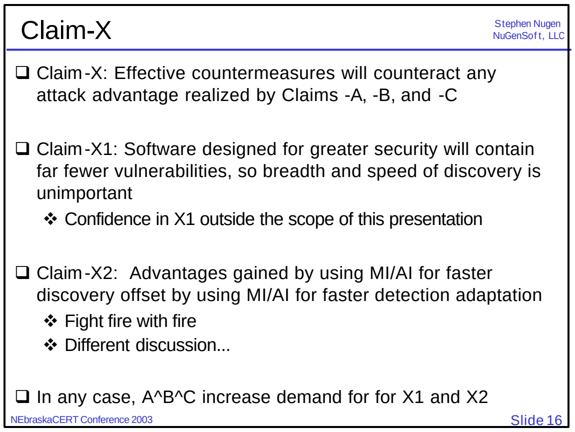
  - ❖ Accuracy, permitting no more than acceptable number of confidence-lowering
    - ▪ False positives (legitimate content detected as hostile)
    - ▪ False negatives (hostile content not detected as hostile)
  - ❖ Confidence in Claim-A is near-universal.

Claim-B cont'd

- ❑ Detection utility also depends on:
  - ❖ How quickly our detection methods and implementations adapt/evolve, relative to speed at which attacks evolve
    - ▪ Quickness of adaptation directly impacts accuracy
  - ❖ How efficiently our detection methods and implementations adapt/evolve in response to evolving attacks
    - ▪ Efficiency of adaptation directly impacts capacity
- ❑ Confidence in Claim-B less universal, but growing in response to
  - ❖ Multi-vector attacks like NIMDA
  - ❖ Evolving malware like SoBig
  - ❖ Quick-to-market exploits like ShadowCode and RPC/DCOM exploits from Xfocus and Metasploit

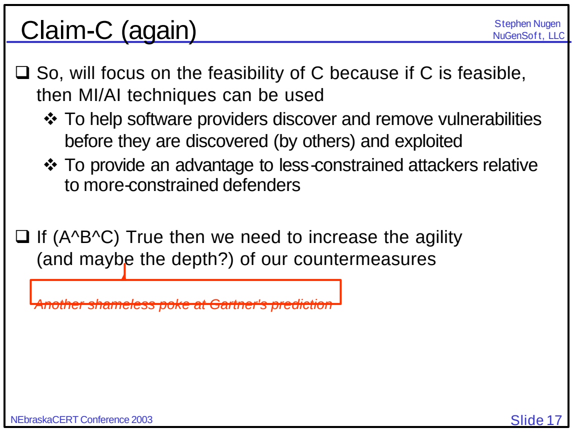
Claim-C

- ❑ MI/AI techniques can and will be used to assist in the discovery of new vulnerabilities in commercial and custom software
  - ❖ Increasing the number of exploitable vulnerabilities
  - ❖ Increasing the speed at which attacks can evolve
- ❑ Importance: If (Claim-A True <u>and</u> Claim-B True <u>and</u> Claim-C True <u>and</u> Claim-X False) Then
  - ▪ Speed at which attacks evolve will increase relative to speed of detection adaptations
  - ▪ More vulnerabilities and corresponding exploits increase the difficulty of vendors
    - Updating misuse signatures
    - Patching the vulnerability
  - ▪ More attacks succeed



Claim-X

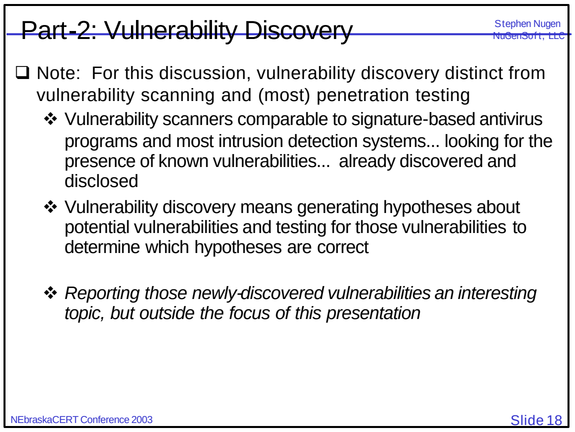
- Claim-X: Effective countermeasures will counteract any attack advantage realized by Claims -A, -B, and -C
- Claim-X1: Software designed for greater security will contain far fewer vulnerabilities, so breadth and speed of discovery is unimportant
  - Confidence in X1 outside the scope of this presentation
- Claim-X2: Advantages gained by using MI/AI for faster discovery offset by using MI/AI for faster detection adaptation
  - Fight fire with fire
  - Different discussion...
- In any case, A^B^C increase demand for for X1 and X2



Claim-C (again)

- So, will focus on the feasibility of C because if C is feasible, then MI/AI techniques can be used
  - To help software providers discover and remove vulnerabilities before they are discovered (by others) and exploited
  - To provide an advantage to less-constrained attackers relative to more-constrained defenders
- If (A^B^C) True then we need to increase the agility (and maybe the depth?) of our countermeasures

Another shameless poke at Gartner's prediction



Part-2: Vulnerability Discovery

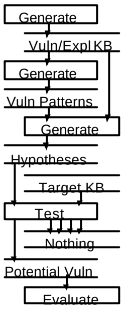
- Note: For this discussion, vulnerability discovery distinct from vulnerability scanning and (most) penetration testing
  - Vulnerability scanners comparable to signature-based antivirus programs and most intrusion detection systems... looking for the presence of known vulnerabilities... already discovered and disclosed
  - Vulnerability discovery means generating hypotheses about potential vulnerabilities and testing for those vulnerabilities to determine which hypotheses are correct
  - *Reporting those newly-discovered vulnerabilities an interesting topic, but outside the focus of this presentation*

Basis For Claim-C

❑ Approach for discussing the feasibility of Claim-C

- ❖ Break large claim into smaller pieces
- ❖ Show larger Claim-C feasible by showing all the (required) pieces are feasible

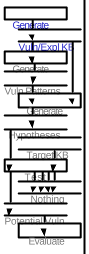
❑ *Note: This discussion is notional, conjecture... not a discussion of anyone's specific architecture or any proposed architecture*



Vulnerability KB

❑ Content

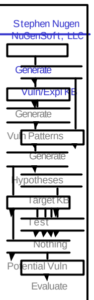
- ❖ Known, reported vulnerabilities and exploits
- ❖ Example
  - ▪ Preconditions
    - • Access Type (e.g., External, Internal, Inserted)
    - • Privilege Level (e.g., Anonymous, Auth-User, Root)
    - • Operating Environment (e.g., Vendor, Software version, etc.)
    - • Predecessors (for chained exploits)
  - ▪ Operations
    - • Exploit Method (e.g., Malformed Input, Impersonation, etc.)
    - • Known Exploits (the messy details)
    - • Comments (e.g., weakness associated with vulnerability, when announced/mitigated, etc.)



Vulnerability KB cont'd

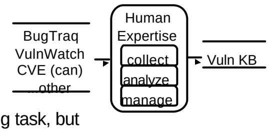
❑ Content cont'd

- ❖ Example cont'd
  - ▪ Postconditions
    - • Result (e.g., Remote Control, DoS, File Access, etc.)
    - • Successors (for chained exploits)
  - ▪ Mitigations
    - • Operational (e.g., port filtering, terminate service, etc.)
    - • Updates (e.g., patches, new software versions, etc.)
  - ▪ Other...



Vulnerability KB cont'd

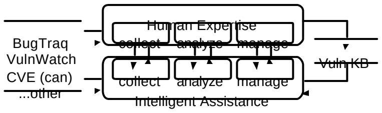
- □ Generating Vuln KB



  - ❖ Rather tedious, continuing task, but
    - Effort can be distributed over multiple experts
    - Results can be shared
  - ❖ Technical challenges include
    - Analyzing and structuring the information for pattern development and generating hypotheses
  - ❖ Management challenges include
    - Agreeing on common definitions, data exchange formats, etc.
    - Coordinating efforts of multiple experts
    - Possible legal constraints on full-disclosure

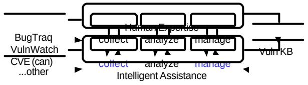
Vulnerability KB cont'd

- □ Feasibility
  - ❖ Relief: No strict minimums thresholds for scope or performance
  - ❖ Human-feasible: Yes
    - With or without MI/AI technologies
    - (Partial) Examples: Vendors and open source communities defining vulnerability signatures; CVE
- □ MI/AI opportunities: Augment human expertise with intelligent assistance



Vulnerability KB cont'd

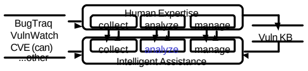
- □ MI/AI opportunities cont'd



  - ❖ Distributed agents may be employed to
    - Collect information... avoiding duplication
      - Cooperating agents, resolving duplicates between themselves with direct communications or shared blackboard
      - Hierarchical control
    - Help coordinate collection and analysis tasks between different human experts
      - Example
        - Raw Info -> three suitable experts
        - Wait for at least two responses (analyses)... Nag as required
        - Send responses to suitable moderator (to resolve differences)

Vulnerability KB cont'd

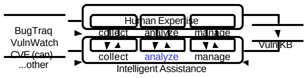
❑ MI/AI opportunities cont'd



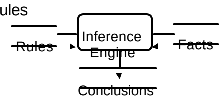
- ❖ Natural Language Processing (NLP) techniques may be used for first-level content parsing
  - ▪ Some sources easier to parse than others...
  - ▪ First-level might be sufficient to recognize
    - Duplicates
    - Partial-Duplicates, distinguishing just the information added or changed

Vulnerability KB cont'd

❑ MI/AI opportunities cont'd



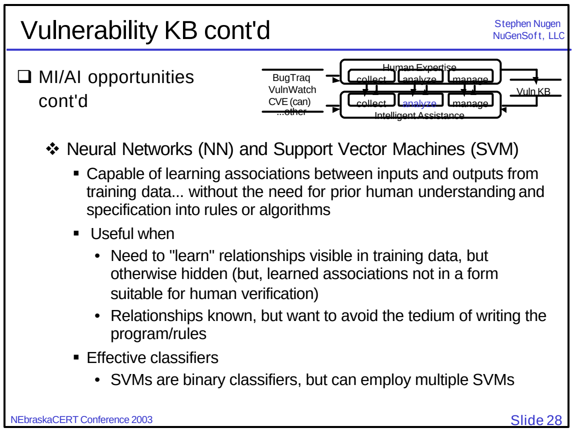
- ❖ Expert system
  - ▪ Rules may be employed to express heuristic knowledge (easier than code to review/change)
  - ▪ Inference engines evaluate (fire) the rules (goal-directed, forward-chaining)
  - ▪ Conclusions may
    - Invoke a new action
    - Increase belief or disbelief in a specific hypothesis (beliefs accumulate)



Vulnerability KB cont'd

❑ MI/AI opportunities cont'd

- ❖ Expert system cont'd
  - ▪ Example
    - IF (MS Sec Bulletin) AND (Vuln-Text includes the phrase "Microsoft thanks <X> "for reporting this issue to us and working with us to protect customers")
    - THEN (Collection-Task = Collect more information from <X>)
  - ▪ Example
    - IF (Vuln-Text includes the phrase "run code of attacker's choice")
    - THEN
      - Assert strong belief (Post.Expl-Result, DoS,,)
      - Assert strong belief(Post.Expl-Result, Rem-Control,,)
      - Assert moderate belief (Post.Expl-Result, File-Access,RWX)
      - Assert moderate belief (Post.Succ, *multiple,,)



Vulnerability KB cont'd

- ❑ MI/AI opportunities cont'd

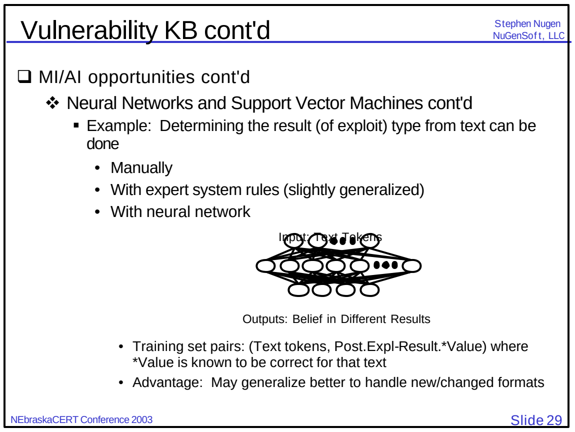
BugTraq
VulnWatch
CVE (can)
...other

Human Expertise
collect
analyze
manage

collect
analyze
manage
Intelligent Assistance

Vuln KB

- ❖ Neural Networks (NN) and Support Vector Machines (SVM)
  - ▪ Capable of learning associations between inputs and outputs from training data... without the need for prior human understanding and specification into rules or algorithms
  - ▪ Useful when
    - Need to "learn" relationships visible in training data, but otherwise hidden (but, learned associations not in a form suitable for human verification)
    - Relationships known, but want to avoid the tedium of writing the program/rules
  - ▪ Effective classifiers
    - SVMs are binary classifiers, but can employ multiple SVMs



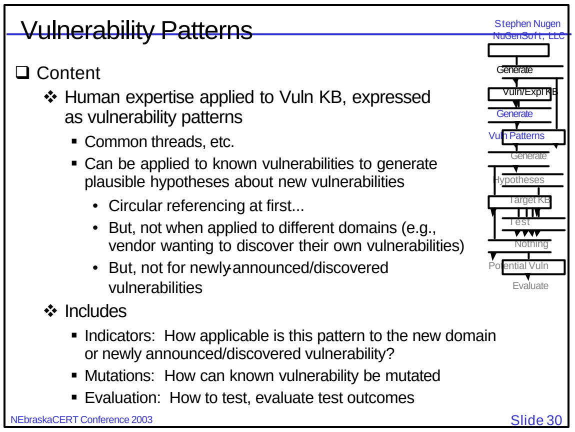
Vulnerability KB cont'd

- ❑ MI/AI opportunities cont'd
  - ❖ Neural Networks and Support Vector Machines cont'd
    - ▪ Example: Determining the result (of exploit) type from text can be done
      - Manually
      - With expert system rules (slightly generalized)
      - With neural network

Inputs: Text Tokens

Outputs: Belief in Different Results

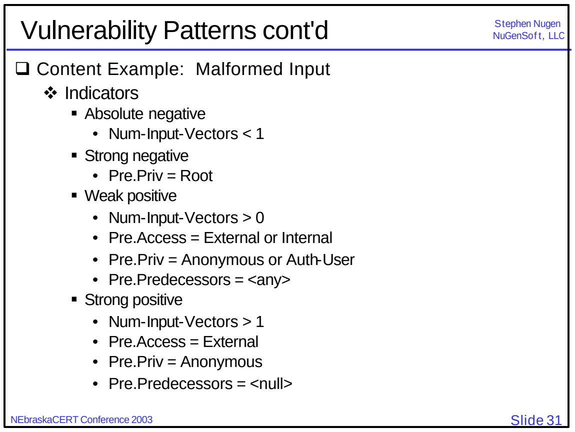
- Training set pairs: (Text tokens, Post.Expl-Result.*Value) where *Value is known to be correct for that text
- Advantage: May generalize better to handle new/changed formats



Vulnerability Patterns

Generate
Vuln/Expl KB
Generate
Vuln Patterns
Generate
Hypotheses
Target KB
Test
Nothing
Potential Vuln
Evaluate

- ❑ Content
  - ❖ Human expertise applied to Vuln KB, expressed as vulnerability patterns
    - ▪ Common threads, etc.
    - ▪ Can be applied to known vulnerabilities to generate plausible hypotheses about new vulnerabilities
      - Circular referencing at first...
      - But, not when applied to different domains (e.g., vendor wanting to discover their own vulnerabilities)
      - But, not for newly-announced/discovered vulnerabilities
  - ❖ Includes
    - ▪ Indicators: How applicable is this pattern to the new domain or newly announced/discovered vulnerability?
    - ▪ Mutations: How can known vulnerability be mutated
    - ▪ Evaluation: How to test, evaluate test outcomes



Vulnerability Patterns cont'd

Stephen Nugen
NuGenSoft, LLC

❑ Content Example: Malformed Input
- ❖ Indicators
  - Absolute negative
    - Num-Input-Vectors < 1
  - Strong negative
    - Pre.Priv = Root
  - Weak positive
    - Num-Input-Vectors > 0
    - Pre.Access = External or Internal
    - Pre.Priv = Anonymous or Auth-User
    - Pre.Predecessors = <any>
  - Strong positive
    - Num-Input-Vectors > 1
    - Pre.Access = External
    - Pre.Priv = Anonymous
    - Pre.Predecessors = <null>

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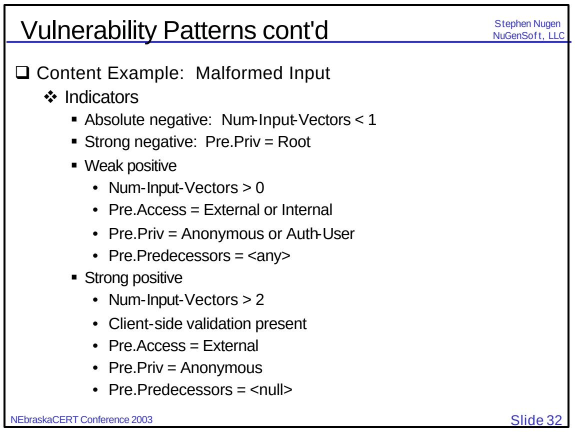
Slide 31



Vulnerability Patterns cont'd

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❑ Content Example: Malformed Input
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  - Strong negative: Pre.Priv = Root
  - Weak positive
    - Num-Input-Vectors > 0
    - Pre.Access = External or Internal
    - Pre.Priv = Anonymous or Auth-User
    - Pre.Predecessors = <any>
  - Strong positive
    - Num-Input-Vectors > 2
    - Client-side validation present
    - Pre.Access = External
    - Pre.Priv = Anonymous
    - Pre.Predecessors = <null>

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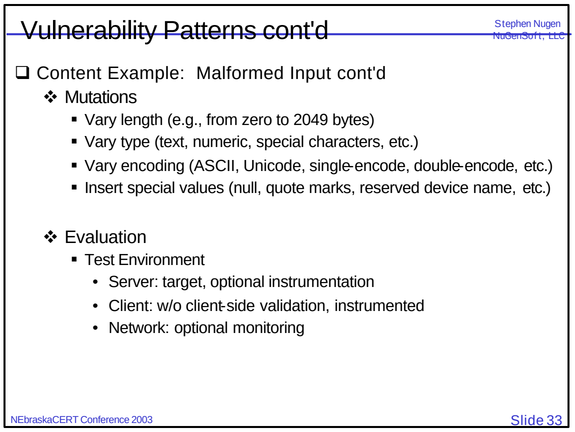
Slide 32



Vulnerability Patterns cont'd

Stephen Nugen
NuGenSoft, LLC

❑ Content Example: Malformed Input cont'd
- ❖ Mutations
  - Vary length (e.g., from zero to 2049 bytes)
  - Vary type (text, numeric, special characters, etc.)
  - Vary encoding (ASCII, Unicode, single-encode, double-encode, etc.)
  - Insert special values (null, quote marks, reserved device name, etc.)
- ❖ Evaluation
  - Test Environment
    - Server: target, optional instrumentation
    - Client: w/o client-side validation, instrumented
    - Network: optional monitoring

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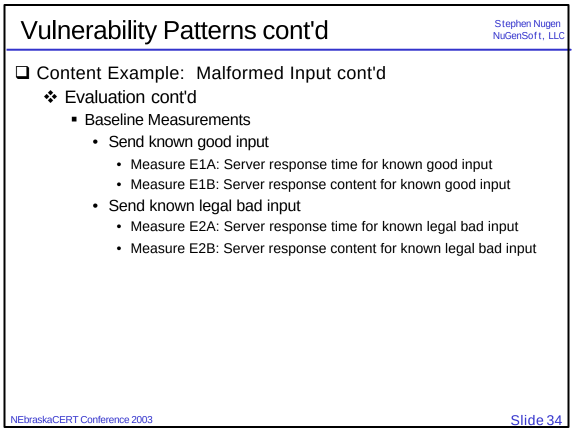

Vulnerability Patterns cont'd

Stephen Nugen
NuGenSoft, LLC

- ❑ Content Example: Malformed Input cont'd
  - ❖ Evaluation cont'd
    - ▪ Baseline Measurements
      - Send known good input
        - Measure E1A: Server response time for known good input
        - Measure E1B: Server response content for known good input
      - Send known legal bad input
        - Measure E2A: Server response time for known legal bad input
        - Measure E2B: Server response content for known legal bad input

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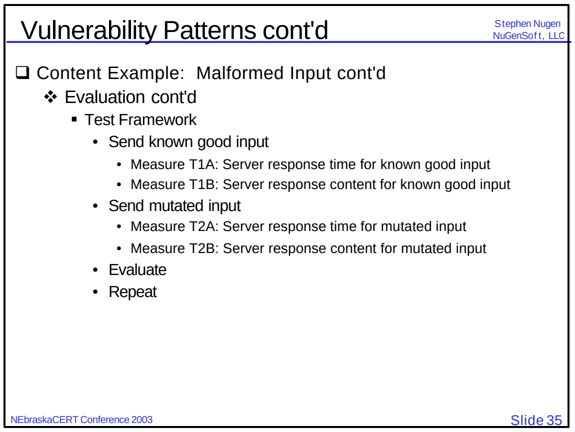

Vulnerability Patterns cont'd

Stephen Nugen
NuGenSoft, LLC

- ❑ Content Example: Malformed Input cont'd
  - ❖ Evaluation cont'd
    - ▪ Test Framework
      - Send known good input
        - Measure T1A: Server response time for known good input
        - Measure T1B: Server response content for known good input
      - Send mutated input
        - Measure T2A: Server response time for mutated input
        - Measure T2B: Server response content for mutated input
      - Evaluate
      - Repeat

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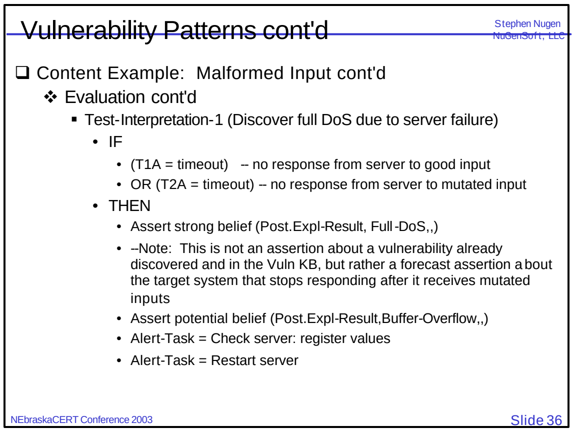
Slide 35



Vulnerability Patterns cont'd

Stephen Nugen
NuGenSoft, LLC

- ❑ Content Example: Malformed Input cont'd
  - ❖ Evaluation cont'd
    - ▪ Test-Interpretation-1 (Discover full DoS due to server failure)
      - IF
        - (T1A = timeout)   -- no response from server to good input
        - OR (T2A = timeout) -- no response from server to mutated input
      - THEN
        - Assert strong belief (Post.Expl-Result, Full-DoS,,)
        - --Note: This is not an assertion about a vulnerability already discovered and in the Vuln KB, but rather a forecast assertion about the target system that stops responding after it receives mutated inputs
        - Assert potential belief (Post.Expl-Result,Buffer-Overflow,,)
        - Alert-Task = Check server: register values
        - Alert-Task = Restart server

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Slide 36

Vulnerability Patterns cont'd

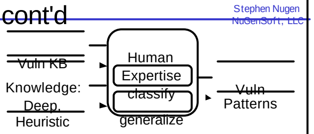
- ❑ Content Example: Malformed Input cont'd
  - ❖ Evaluation cont'd
    - ▪ Test-Interpretation-2 (Discover partial DoS due to Server error/exception processing)
      - IF
        - (T1A >> E1A) – server has slowed down, even for good inputs
        - OR (T2A >> E2A) – server responds slower to mutated inputs
      - THEN
        - Assert moderate belief (Post.Expl-Result, Partial-DoS,,)
        - Continue

Vulnerability Patterns cont'd

- ❑ Content Example: Partial DoS -> Full DoS
  - ❖ Indicators
    - ▪ Absolute negative
      - (Belief (Post.Expl-Result, Partial-DoS,,) < unknown)
    - ▪ Strong negative
      - (Belief (Post.Expl-Result, Partial-DoS,,) = unknown)
    - ▪ Weak positive
      - Belief (Post.Expl-Result, Partial-DoS,,) > unknown
    - ▪ Strong positive
      - Belief (Post.Expl-Result, Partial-DoS,,) > weak
  - ❖ Mutations
    - ▪ Vary single-client volume (just blast, without waiting for response)
    - ▪ Vary number of clients (use multiple clients for discover DDoS)
  - ❖ Evaluation... similar to previous example

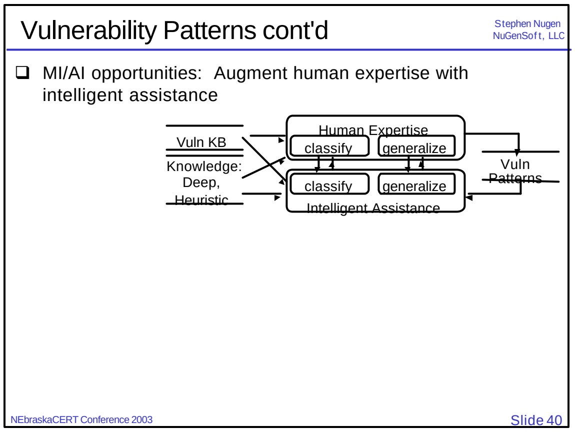
Vulnerability Patterns cont'd

- ❑ Generating Vuln Patterns



Less tedious, less continual than populating the Vuln KB
- ▪ Efforts distributable, results shareable

- ❑ Feasibility
  - ❖ Relief: No strict minimums thresholds for scope or performance
  - ❖ Human-feasible: Yes
    - ▪ With fewer, but more skilled, human experts
    - ▪ With or without MI/AI technologies
    - ▪ Examples: White-hat and Black-hat hackers



Vulnerability Patterns cont'd

Stephen Nugen
NuGenSoft, LLC

❑ MI/AI opportunities: Augment human expertise with intelligent assistance

Vuln KB
Knowledge: Deep, Heuristic
Human Expertise
classify
generalize
classify
generalize
Intelligent Assistance
Vuln Patterns

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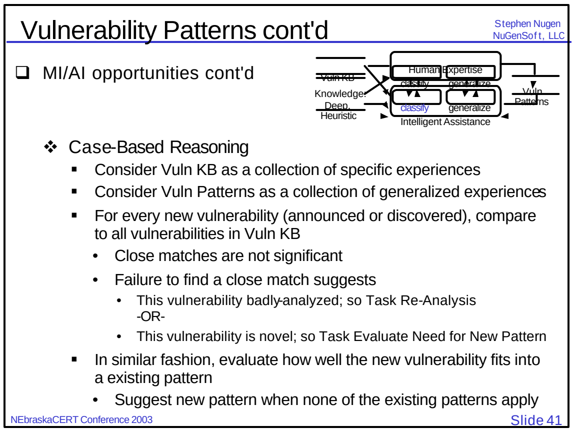

Vulnerability Patterns cont'd

Stephen Nugen
NuGenSoft, LLC

❑ MI/AI opportunities cont'd

Vuln KB
Knowledge: Deep, Heuristic
Human Expertise
classify
generalize
classify
generalize
Intelligent Assistance
Vuln Patterns

- ❖ Case-Based Reasoning
  - ▪ Consider Vuln KB as a collection of specific experiences
  - ▪ Consider Vuln Patterns as a collection of generalized experiences
  - ▪ For every new vulnerability (announced or discovered), compare to all vulnerabilities in Vuln KB
    - Close matches are not significant
    - Failure to find a close match suggests
      - This vulnerability badly-analyzed; so Task Re-Analysis -OR-
      - This vulnerability is novel; so Task Evaluate Need for New Pattern
  - ▪ In similar fashion, evaluate how well the new vulnerability fits into a existing pattern
    - Suggest new pattern when none of the existing patterns apply

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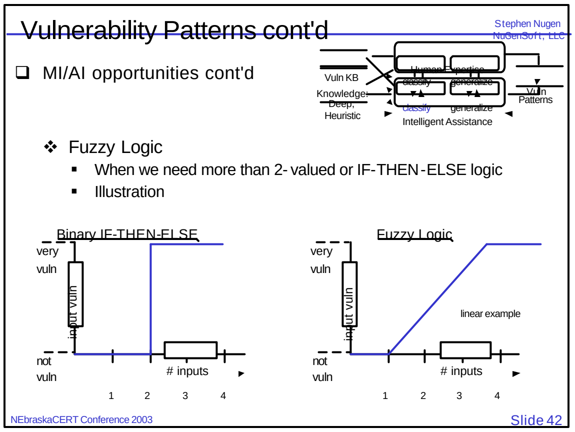
Slide 41



Vulnerability Patterns cont'd

Stephen Nugen
NuGenSoft, LLC

❑ MI/AI opportunities cont'd

Vuln KB
Knowledge: Deep, Heuristic
Human Expertise
classify
generalize
classify
generalize
Intelligent Assistance
Vuln Patterns

- ❖ Fuzzy Logic
  - ▪ When we need more than 2-valued or IF-THEN-ELSE logic
  - ▪ Illustration

Binary IF-THEN-ELSE
very vuln
input vuln
not vuln
# inputs
1
2
3
4
Fuzzy Logic
very vuln
input vuln
linear example
not vuln
# inputs
1
2
3
4

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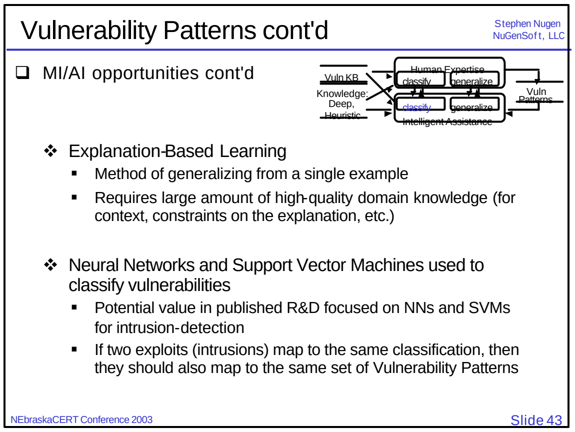
Slide 42



Vulnerability Patterns cont'd

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NuGenSoft, LLC

❑ MI/AI opportunities cont'd

Vuln KB
Knowledge: Deep, Heuristic
Human Expertise
classify
generalize
Vuln Patterns
classify
generalize
Intelligent Assistance

- ❖ Explanation-Based Learning
  - Method of generalizing from a single example
  - Requires large amount of high-quality domain knowledge (for context, constraints on the explanation, etc.)
- ❖ Neural Networks and Support Vector Machines used to classify vulnerabilities
  - Potential value in published R&D focused on NNs and SVMs for intrusion-detection
  - If two exploits (intrusions) map to the same classification, then they should also map to the same set of Vulnerability Patterns

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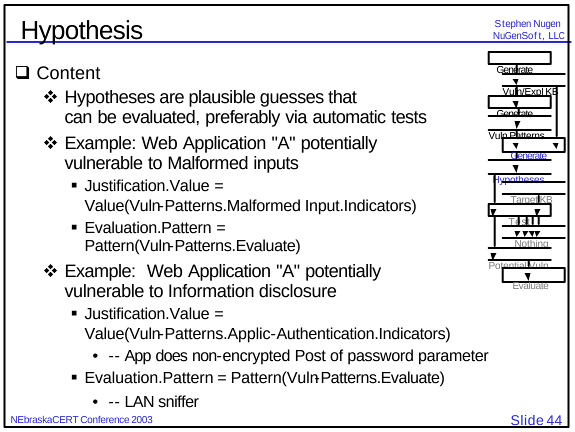

Hypothesis

Stephen Nugen
NuGenSoft, LLC

Generate
Vuln/Expl KB
Generate
Vuln Patterns
Generate
Hypotheses
Target KB
Test
Nothing
Potential Vuln
Evaluate

❑ Content

- ❖ Hypotheses are plausible guesses that can be evaluated, preferably via automatic tests
- ❖ Example: Web Application "A" potentially vulnerable to Malformed inputs
  - Justification.Value = Value(Vuln-Patterns.Malformed Input.Indicators)
  - Evaluation.Pattern = Pattern(Vuln-Patterns.Evaluate)
- ❖ Example: Web Application "A" potentially vulnerable to Information disclosure
  - Justification.Value = Value(Vuln-Patterns.Applic-Authentication.Indicators)
    - -- App does non-encrypted Post of password parameter
  - Evaluation.Pattern = Pattern(Vuln-Patterns.Evaluate)
    - -- LAN sniffer

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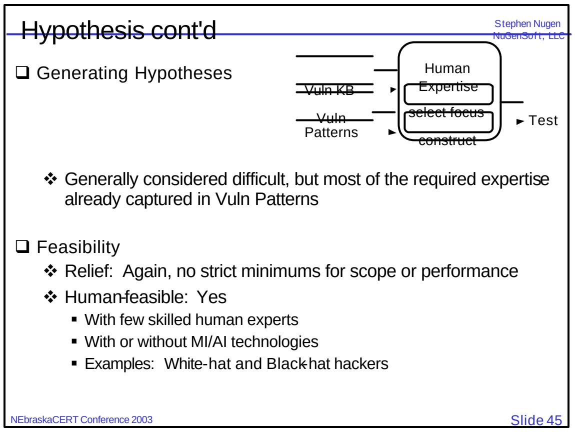

Hypothesis cont'd

Stephen Nugen
NuGenSoft, LLC

❑ Generating Hypotheses

Vuln KB
Vuln Patterns
Human Expertise
select focus
construct
Test

- ❖ Generally considered difficult, but most of the required expertise already captured in Vuln Patterns

❑ Feasibility

- ❖ Relief: Again, no strict minimums for scope or performance
- ❖ Human-feasible: Yes
  - With few skilled human experts
  - With or without MI/AI technologies
  - Examples: White-hat and Black-hat hackers

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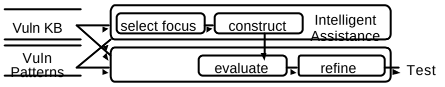
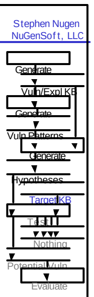
Hypothesis cont'd

- ❑ MI/AI opportunities: Augment human expertise by reassigning some of the iterative tasks to software
  - ❖ Advantage comes from use abundant machine cycles to test a very wide range of hypotheses (and mutations)
  - ❖ Use relatively simple programs to iteratively generate the different combinations of hypotheses
    - Keep track of the justifications for human expert confirmation



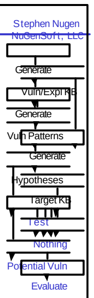
Target KB

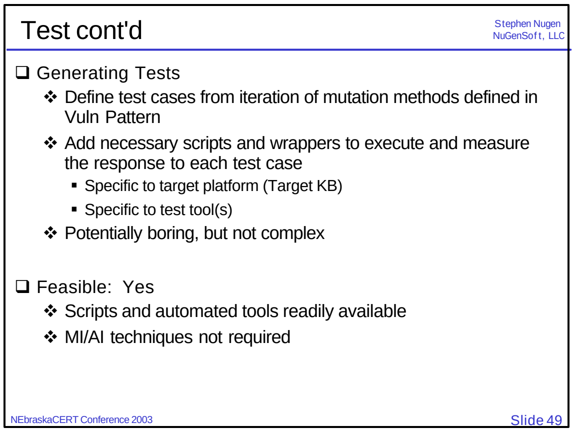
- ❑ Content
  - ❖ Meta-knowledge describing the environment vulnerability discovery is focused on
  - ❖ Example
    - Target Attributes
      - IP address,
      - URLs,
      - Post Form parameters
    - Constraints
- ❑ Feasible: Yes, low-risk



Test

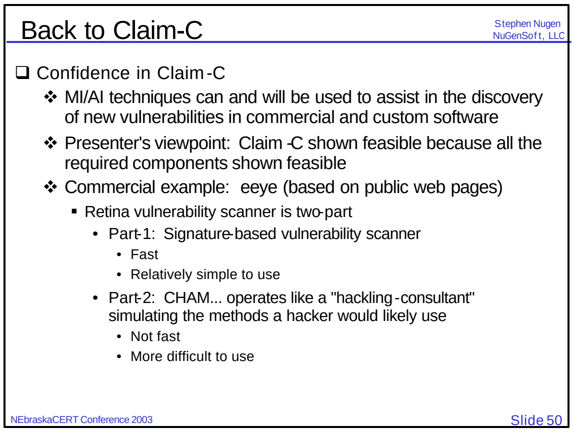
- ❑ Content
  - ❖ For each Hypothesis, generate test cases that reflect all or a significant subset of all possible mutations as defined in the applicable Vuln Pattern
  - ❖ Example for one Hypothesis
    - Assume
      - Known good input: "A"
      - Mutation-Method-1: Vary input-1 length: [1 - 1025]
      - Mutation-Method-2: Insert special characters: [<null>, <%>, <'>, <–>]
    - Test-1: Input = "A"
    - Test-2: Input = "AA"
    - Test-1025: Input = "A.....A" (1025 bytes)
    - Test-1026 = <null>
    - Test-1027 = "A<null>"
    - ...and so forth





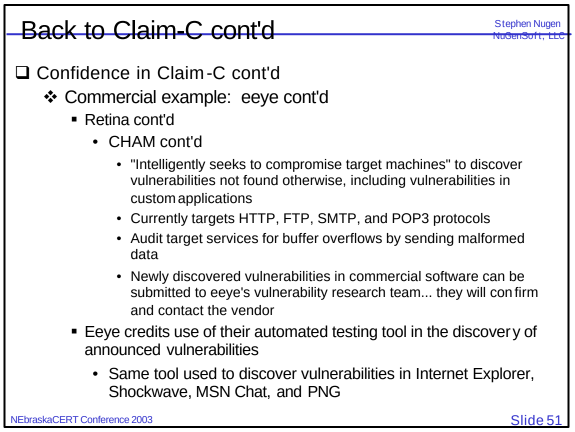
Test cont'd

- ❑ Generating Tests
  - ❖ Define test cases from iteration of mutation methods defined in Vuln Pattern
  - ❖ Add necessary scripts and wrappers to execute and measure the response to each test case
    - ▪ Specific to target platform (Target KB)
    - ▪ Specific to test tool(s)
  - ❖ Potentially boring, but not complex
- ❑ Feasible: Yes
  - ❖ Scripts and automated tools readily available
  - ❖ MI/AI techniques not required



Back to Claim-C

- ❑ Confidence in Claim-C
  - ❖ MI/AI techniques can and will be used to assist in the discovery of new vulnerabilities in commercial and custom software
  - ❖ Presenter's viewpoint: Claim-C shown feasible because all the required components shown feasible
  - ❖ Commercial example: eeye (based on public web pages)
    - ▪ Retina vulnerability scanner is two-part
      - Part-1: Signature-based vulnerability scanner
        - Fast
        - Relatively simple to use
      - Part-2: CHAM... operates like a "hackling-consultant" simulating the methods a hacker would likely use
        - Not fast
        - More difficult to use



Back to Claim-C cont'd

- ❑ Confidence in Claim-C cont'd
  - ❖ Commercial example: eeye cont'd
    - ▪ Retina cont'd
      - CHAM cont'd
        - "Intelligently seeks to compromise target machines" to discover vulnerabilities not found otherwise, including vulnerabilities in custom applications
        - Currently targets HTTP, FTP, SMTP, and POP3 protocols
        - Audit target services for buffer overflows by sending malformed data
        - Newly discovered vulnerabilities in commercial software can be submitted to eeye's vulnerability research team... they will confirm and contact the vendor
    - ▪ Eeye credits use of their automated testing tool in the discovery of announced vulnerabilities
      - Same tool used to discover vulnerabilities in Internet Explorer, Shockwave, MSN Chat, and PNG

Part-3: Summary Observations

❑ 1. MI/AI techniques can and will be used to discover new vulnerabilities faster

❑ 2. The results of #1 can and probably will be used maliciously, increasing the speed at which attacks evolve
- ❖ Widespread acceptance not required, just a few will do
- ❖ Commercial grade tools not required

❑ 3. The results of #1 can be used proactively by organizations to discover vulnerabilities in their software and remediate them before they are exploited
- ❖ Widespread acceptance unlikely
- ❖ Commercial tools required

Summary Observations cont'd

❑ 4. The results of #2 can be countered (mitigated) by
- ❖ Improving our administrative and technical countermeasures
  - ▪ Considering
    - Breadth
    - Depth
    - Agility
  - ▪ See other presentations
- ❖ Developing and purchasing software with less vulnerabilities
  - ▪ See other presentations
- ❖ Using MI/AI technologies to detect and protect ourselves from newly -discovered vulnerabilities
  - ▪ Fighting fire with fire... or more accurately: taking advantage of cheap, abundant machine cycles
  - ▪ The subject of most published research regarding MI/AI for InfoSec

Questions

Discussions

Rebuttal