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Independent Security Researcher

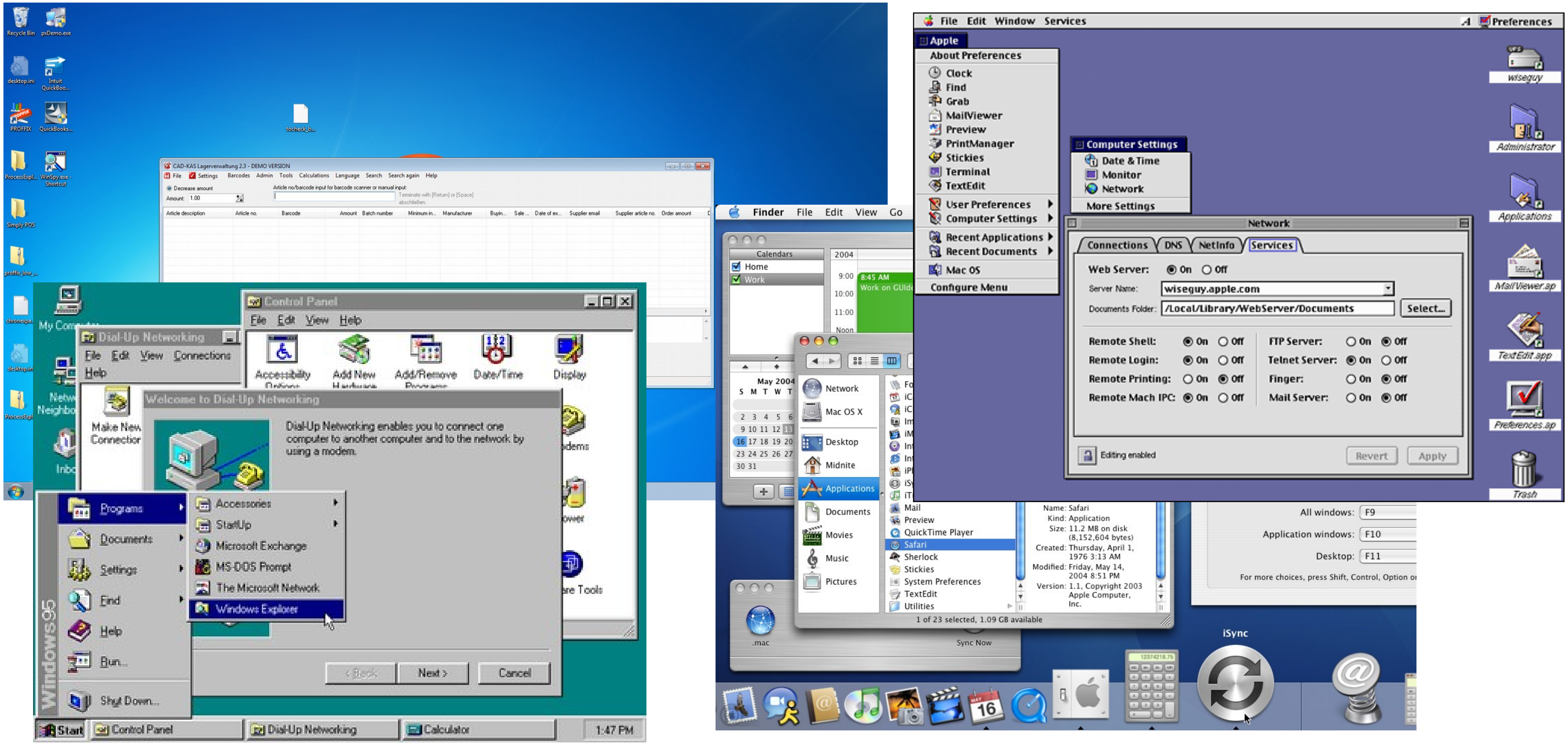
Finding and Exploiting Access Control Vulnerabilities in Graphical User Interfaces

KiwiCon 2016

Twitter: @collinrm

Graphical User Interfaces (GUIs)

- Because 'normal' people don't like shells



GUI Security History (Shatter Attacks)

- Shatter Attacks
  - C. Paget (2002), B. Moore (2003)
- Affected platform: Windows NT/2000/XP
- Remove limits of text edit fields
  - Paste input to cause memory corruption → code execution
- Target: progress with system privileges
  - Code execution → privilege escalation
- Now Windows has User Interface Privilege Isolation (UIPI)
  - Can't manipulate UI of process that have higher privileges

GUI Security History (Shatter Attacks)

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  - C. Paget (2002), B. Moore (2003)

- Affected platform: Windows NT/2000/XP

- <u>Remo</u>
  -

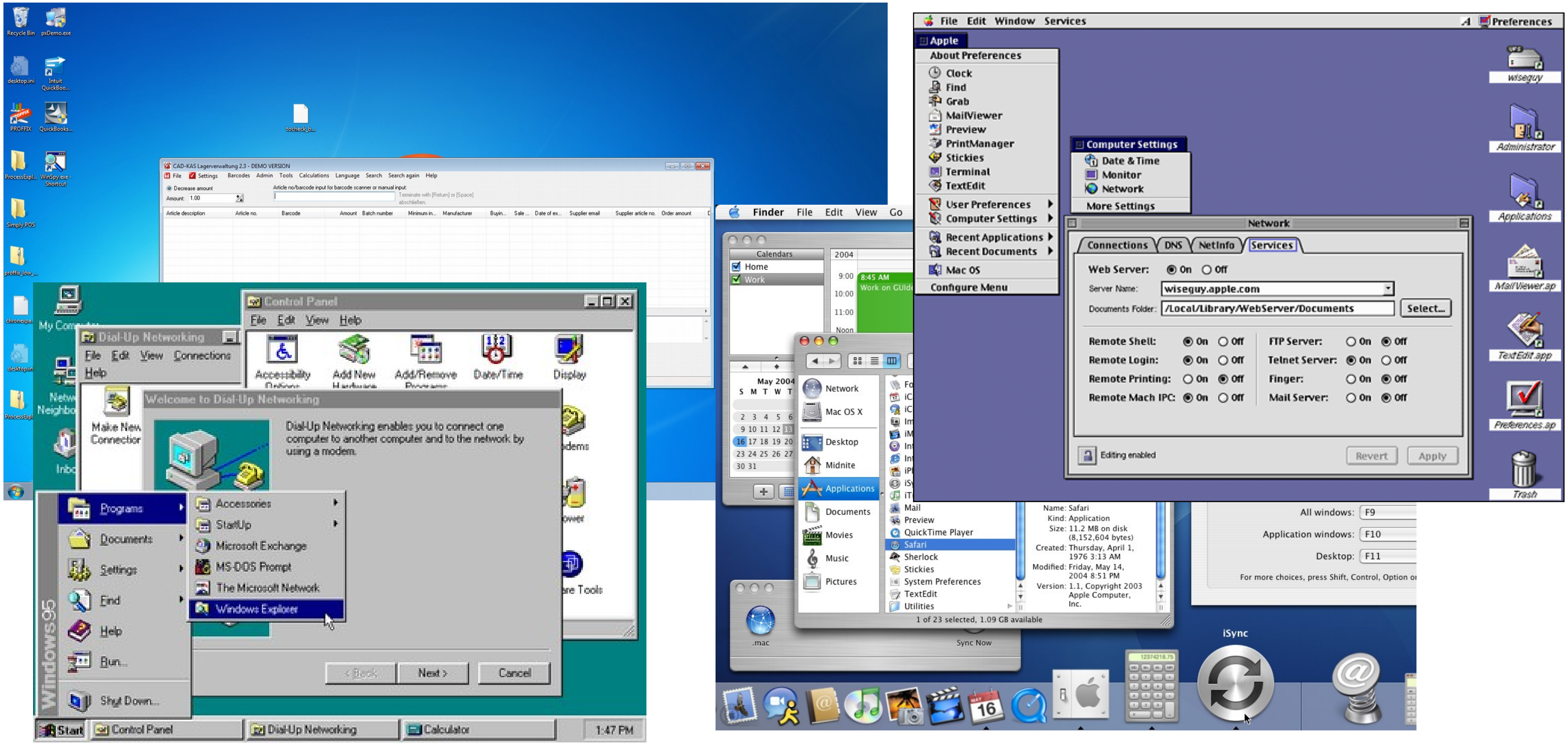
This talk is about Access Control issues in the UI

- Target: progress with system privileges
  - Code execution → privilege escalation

- Now Windows has User Interface Privilege Isolation (UIPI)
  - Can't manipulate UI of process that have higher privileges

Graphical User Interfaces (GUIs)

- Windows, Widgets, …



Dial-Up Networking enables you to connect one computer to another computer and to the network by using a modem.

Web Server: ● On ○ Off

Server Name: wiseguy.apple.com

Documents Folder: /Local/Library/WebServer/Documents

Remote Shell: ● On ○ Off		FTP Server: ○ On ● Off	
Remote Login: ● On ○ Off		Telnet Server: ● On ○ Off	
Remote Printing: ○ On ● Off		Finger: ○ On ● Off	
Remote Mach IPC: ● On ○ Off		Mail Server: ○ On ● Off	

Editing enabled

Name: Safari
Kind: Application
Size: 11.2 MB on disk (8,152,604 bytes)
Created: Thursday, April 1, 1976 3:13 AM
Modified: Friday, May 14, 2004 8:51 PM
Version: 1.1, Copyright 2003 Apple Computer, Inc.

1 of 23 selected, 1.09 GB available

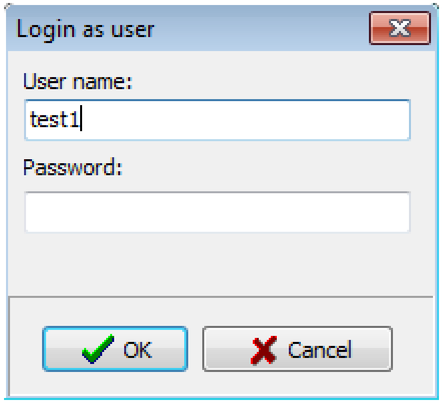
All windows: F9
Application windows: F10
Desktop: F11

For more choices, press Shift, Control, Option or

GUIs → Widgets and Windows

- Widget → base UI element
  - Smallest element in a UI framework
  - On MS Windows: widget = window

- Common widgets
  - Window
  - Frame
  - Button
  - Check-box
  - Text edit field
  - Drop down box
  - Slider

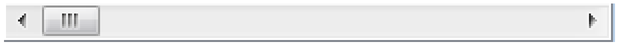


User name: test1

Password:

☑ Calculate date

● Decrease amount ○ Increase amount



Widget Attributes

- Attributes allow to change widget behavior at runtime
  - Allows user interface to be dynamic

- Common attributes

Enabled	→ enable / disable widget
Visibility	→ show / hide widget
Read/Write	→ allow / disallow changing data stored in widget

Widget Attributes

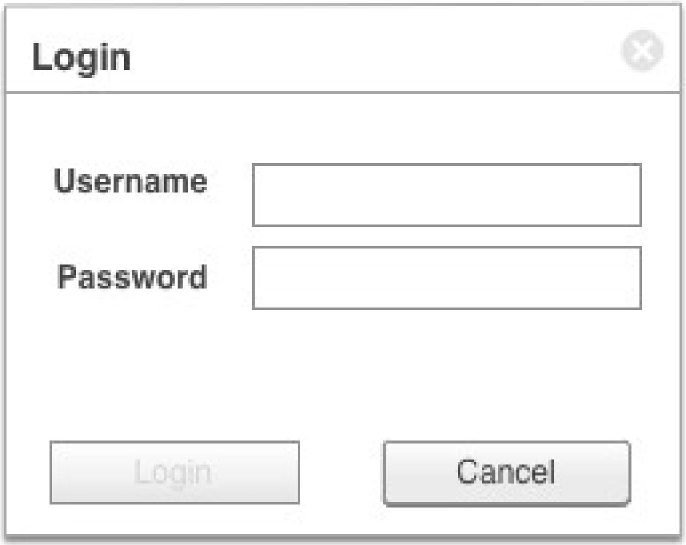
- Attributes allow to change widget behavior at runtime
  - Allows user interface to be dynamic

- Common attribut

  Enabled

  Visibility

  Read/Write



a stored in widget

Login button disabled → indicates username required

Access Control

- Fundamental security requirement

- Common in any kind of enterprise application
  - applications that handle sensitive data

- Different privilege levels
  - Create / Add data
  - View data
  - Modify data
  - Execute privileged functionality

Access Control

- Fundamental security requirement

- Common in any kind of enterprise application
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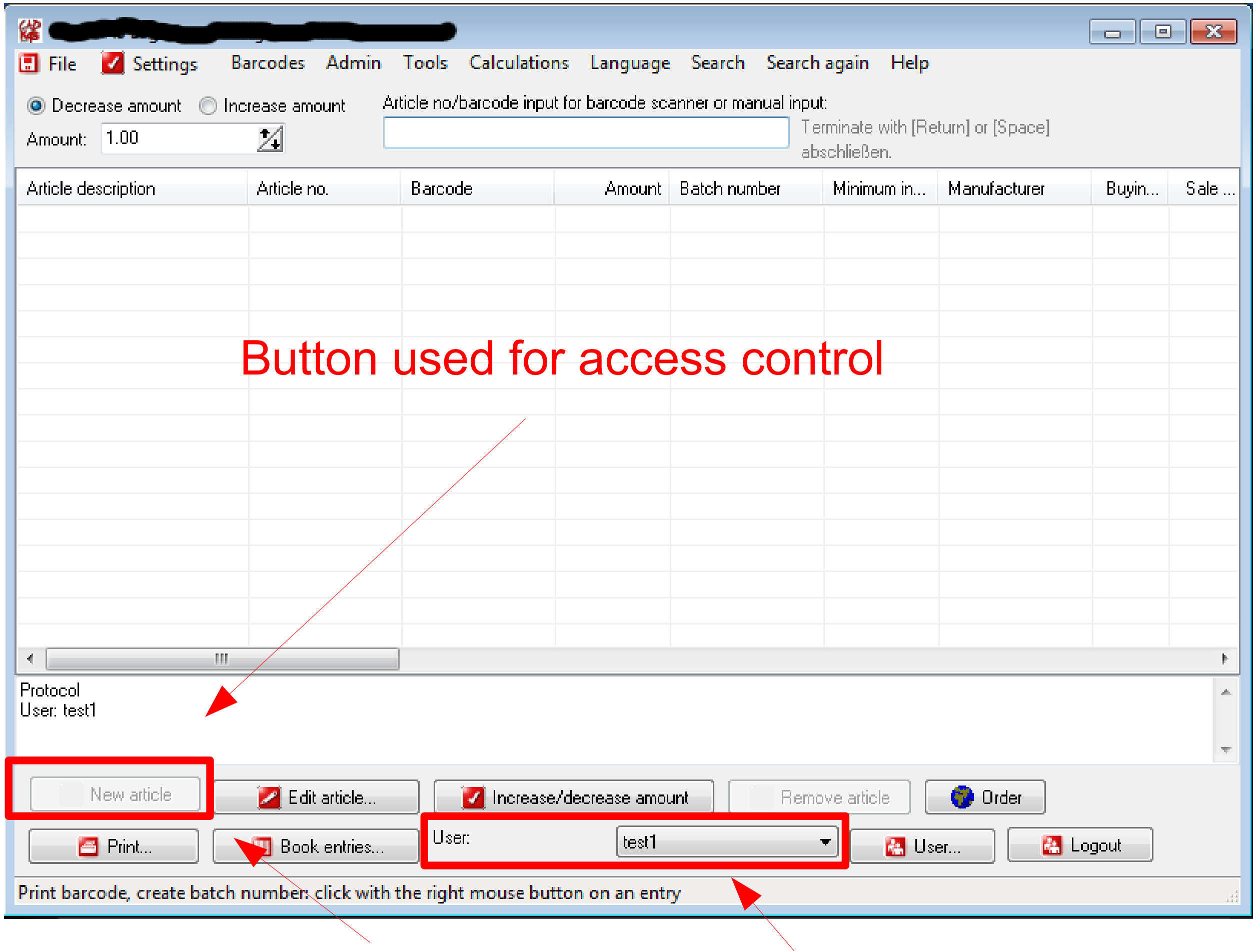
- Different privilege levels
  - Create / Add data
  - View data
  - Modify data
  - Execute privileged functionality

- **Implementing access control using the GUI is tempting**

Access Control in the GUI



[redacted]

Amount: 1.00

Protocol
User: test1

User: test1

Print barcode, create batch number: click with the right mouse button on an entry

Button used for access control

Disabled Button

Application Specific User

Access Control in the GUI

- Widgets can be manipulated
  - Feature of UI frameworks
  - No need to modify application binary

- Manipulate widget → bypass GUI-based access control

A Real World Attack **DEMO**

Access Control in the GUI

- Widgets can be manipulated
  - Feature of UI frameworks
  - No need to modify application binary
- Manipulate widget → bypass GUI-based access control
- Attacks using the UI are folklore
- **First to systemantically investigate GUI security**

Threat Model

- **Applications with internal user management**
  - Multiple users or user and administrator
  - Accounts are NOT backed by the OS
- **Accounts have different privileges**
  - Reading vs. writing data
  - Executing privileged functionality
- Application domain
  - Enterprise applications → users with different privileges
  - Applications that manage data → require access control

GUI Element Misuse (GEM)

- Misusing GUI elements to implement access control
- GEM vulnerability → access control bypass vulnerability
- GEM classes
  - **Unauthorized Callback Execution**
  - **Unauthorized Information Disclosure**
  - **Unauthorized Information Manipulation**

Unauthorized Callback Execution

- Activation of UI element results in callback execution
  - Click button → execute callback → perform operation

- Assumption
  - Disabled UI element cannot be interacted with

- Attack
  - Enable UI element
  - Interact with UI element
    - Execute callback → perform operation

Unauthorized Information Disclosure

- UI element is used to store sensitive information
  - UI element is shown only to privileged user

- Assumption
  - Hidden UI element cannot be made visible

- Attack
  - Set UI element visible
    - UI element is drawn by the UI framework
      - Data stored in UI element can be accessed
  - Access data stored in UI element programmatically

Unauthorized Information Disclosure **DEMO**

- gemtools_unhide.exe
  - Make all widgets of an application visible
  - Take screenshots of app windows
  - Tool available:
    - http://www.mulliner.org/security/guisec/feed/

Unauthorized Data Modification

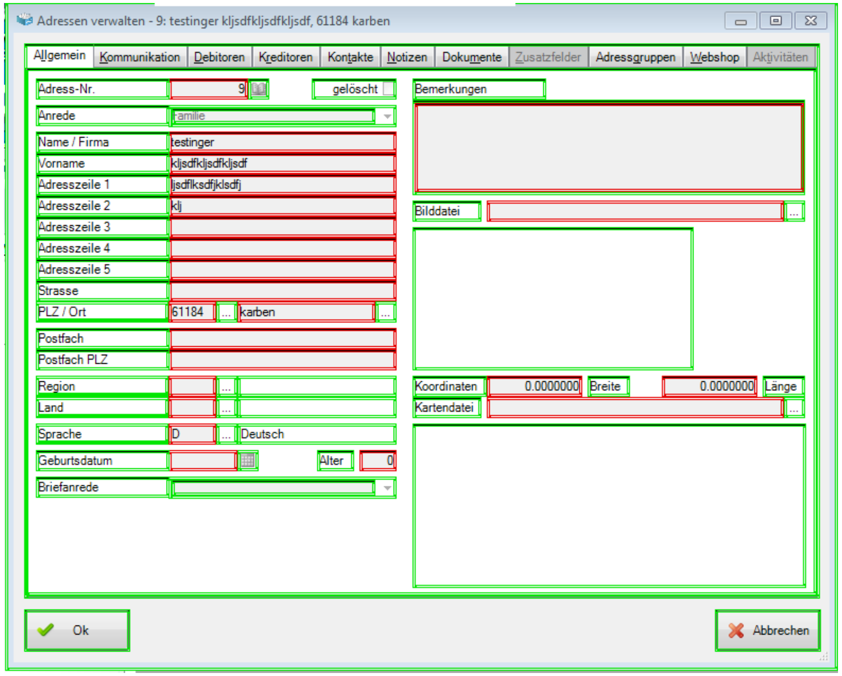
- UI element is used to display and edit data
  - Privileged user can edit data
  - Unprivileged user can view data
- Assumptions
  - Read-Only UI element does prevent data modification
  - Data modified only if element was writable → save data
- Attack
  - Set UI element Read-Write
    - Set/Change data
      - Click “save”

Unauthorized Data Modification **DEMO**

- WinSpy++ gemcolors edition!
  - Identify R/W settings of widgets

Widget Configuration

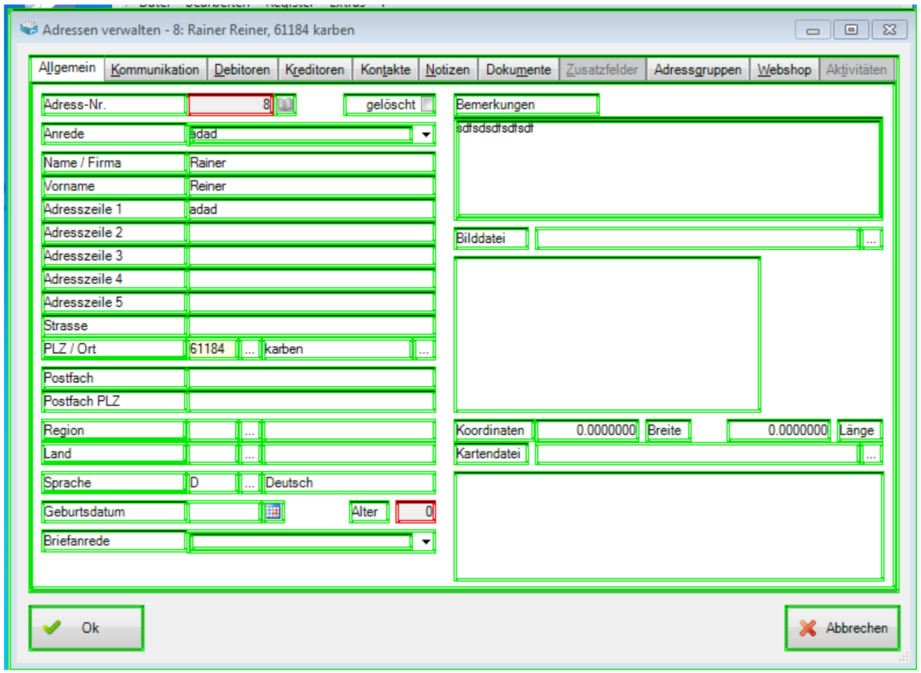
User1 (Low Privileges)



Adressen verwalten - 9: testinger kljsdfkljsdfkljsdf, 61184 karben

Adress-Nr.	9
gelöscht	□
Anrede	Familie
Name / Firma	testinger
Vorname	kljsdfkljsdfkljsdf
Adresszeile 1	ljsdflksdfjklsdfj
Adresszeile 2	klj
Adresszeile 3	
Adresszeile 4	
Adresszeile 5	
Strasse	
PLZ / Ort	61184 ... karben ...
Postfach	
Postfach PLZ	
Region	...
Land	...
Sprache	D ... Deutsch
Geburtsdatum	
Alter	0
Briefanrede	
Bemerkungen	
Bilddatei	...
Koordinaten	0.0000000 Breite 0.0000000 Länge
Kartendatei	...

User2 (High Privileges)



Adressen verwalten - 8: Rainer Reiner, 61184 karben

Adress-Nr.	8
gelöscht	□
Anrede	adad
Name / Firma	Rainer
Vorname	Reiner
Adresszeile 1	adad
Adresszeile 2	
Adresszeile 3	
Adresszeile 4	
Adresszeile 5	
Strasse	
PLZ / Ort	61184 ... karben ...
Postfach	
Postfach PLZ	
Region	...
Land	...
Sprache	D ... Deutsch
Geburtsdatum	
Alter	0
Briefanrede	
Bemerkungen	sdfsdsdfsdfsdf
Bilddatei	...
Koordinaten	0.0000000 Breite 0.0000000 Länge
Kartendatei	...

Technical Requirements 1/2

- Applications must be executed by the same OS user
  - Interaction between applications via IPC
- Attack steps:
  - Discover UI elements (widgets)
  - Obtain window HANDLE for widget
  - Manipulate widget

Technical Requirements 2/2

- All this is done through very basic Win32 APIs
  - `SendMessage..()` family of functions
  - `EnableWindow()`
  - `SendInput()`
  - `EnumChildWindows()` → get all windows
  - `SetWindowPos()` → visible/hide window
  - `GetWindowLong()`
  - `IsWindowEnabled()`
  - `IsWindowVisible()`
  - `GetClassName()`

- This stuff is very well documented

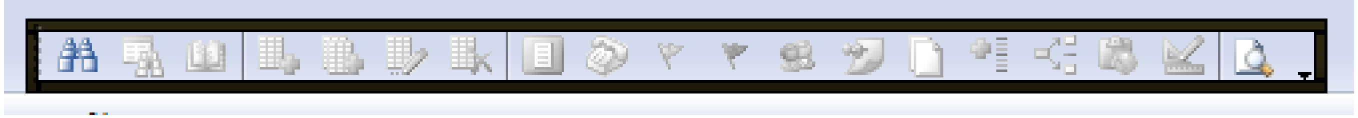
UI Frameworks

- On MS Windows a window is the basic UI element
  - Everything is a window
- Win32 API provides basic functionality
  - 'actual' window
  - Button
  - Text field
- Other UI frameworks are build on top of the Win32 UI API
  - Provide their own widget types
  - Implement drawing and receiving user input

Win32 vs. .NET

- .NET
  - Win32 windows + custom widgets
  - Implement drawing and receiving user input
  - Win32 API can see widget but not always manipulate it

- Attacker
  - Can use Win32 API to interact .NET widgets
    - Enough for most attacks
  - Using .NET API provides access to actual .NET widgets
    - e.g., see individual buttons inside a 'button bar'



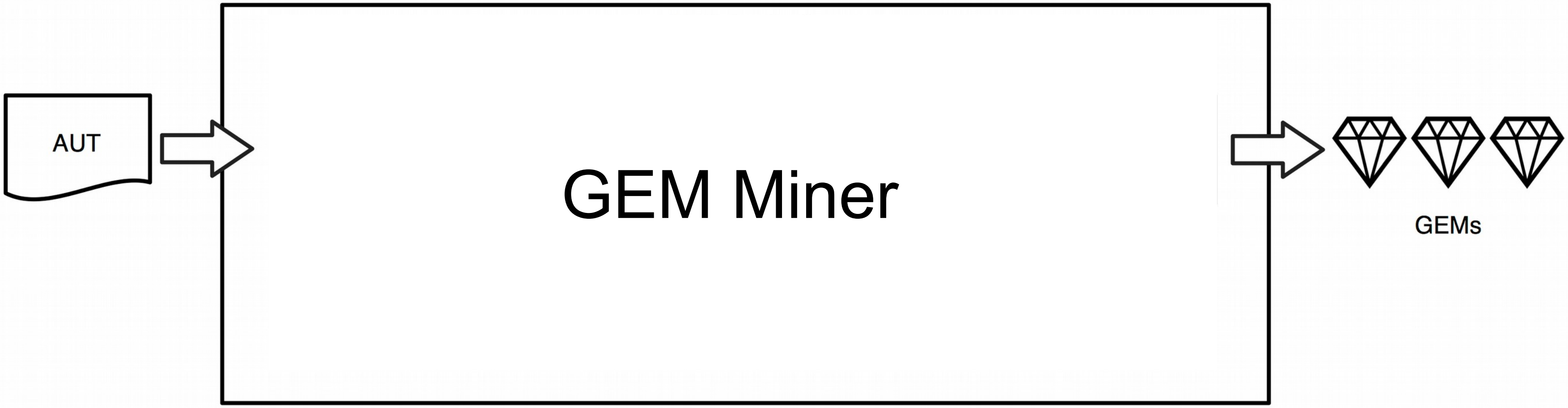
.NET 'button bar' for Win32 this is one button, for .NET it is 19

Two Corner Stones of GEM Vulnerabilities

- **False assumptions by developers**
  - GUI cannot be changed externally
    - Widget attributes are protected

- **Non sophisticated attacker**
  - Only point-and-click
  - Black box attack → change value in field or click button
    - No reverse engineering or program understanding
    - Don't need to manually tamper with files or database
    - No network protocol knowledge

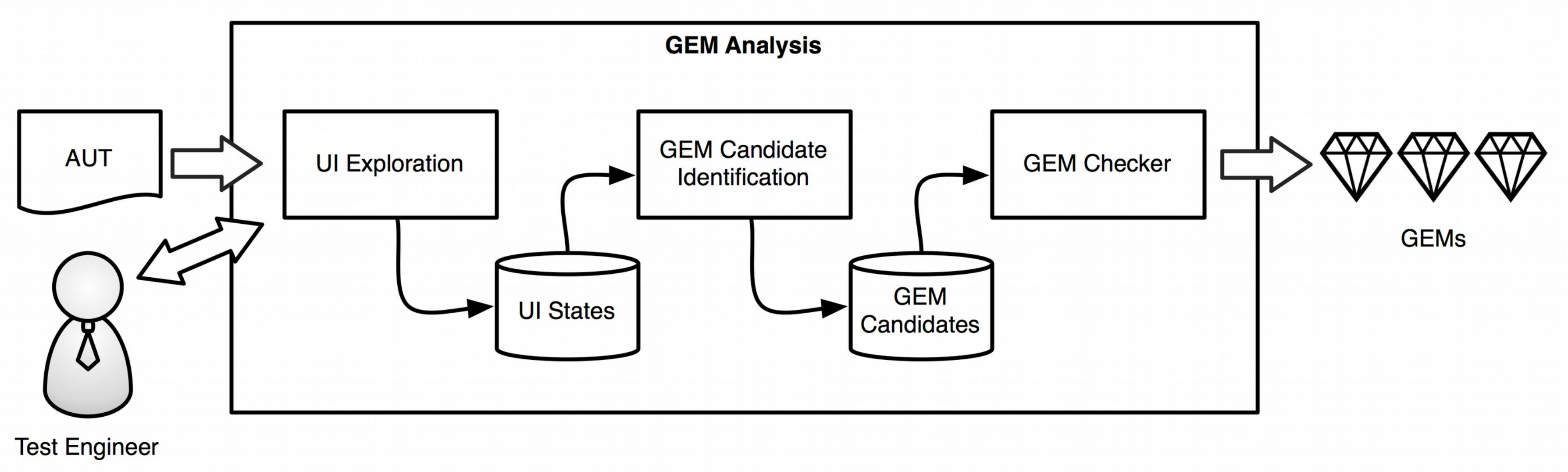
The GEM Miner Analysis



- Systematically test applications for GEM vulnerabilities
  - Automated analysis
  - **Complex applications cannot be tested manually**

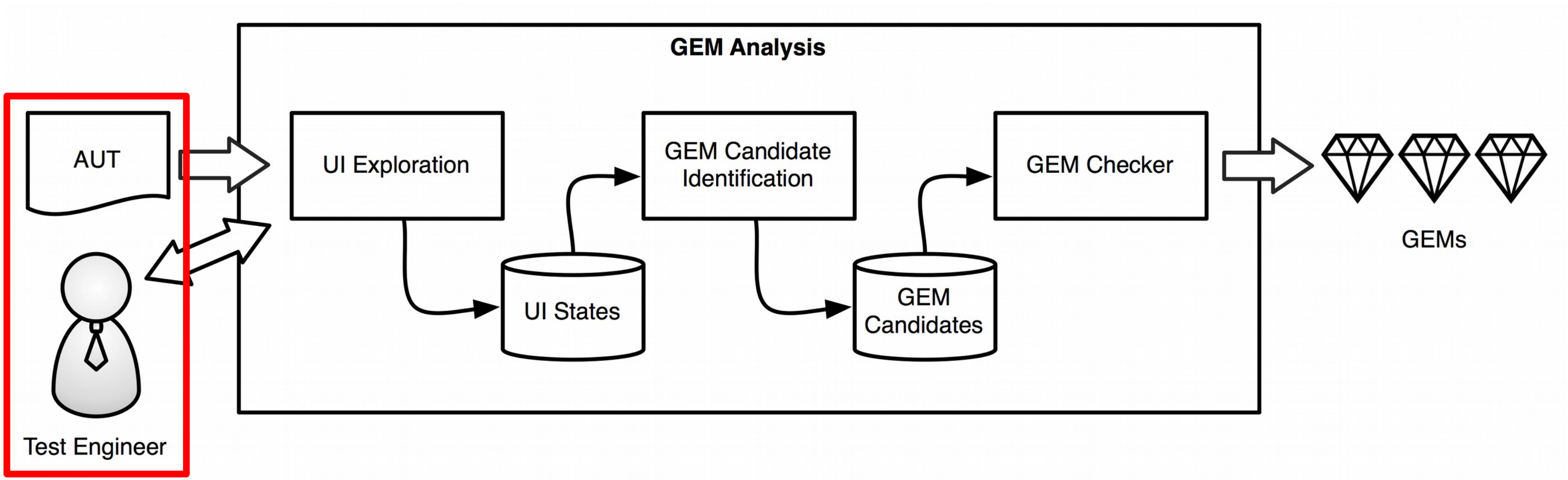
- Black box analysis
  - We do **NOT** require: source code, reverse engineering, etc.

The GEM Miner System



- Explore application UI and record widgets and attributes
- Identify GEM candidate widgets
- Check the GEM candidates

Application Seeding

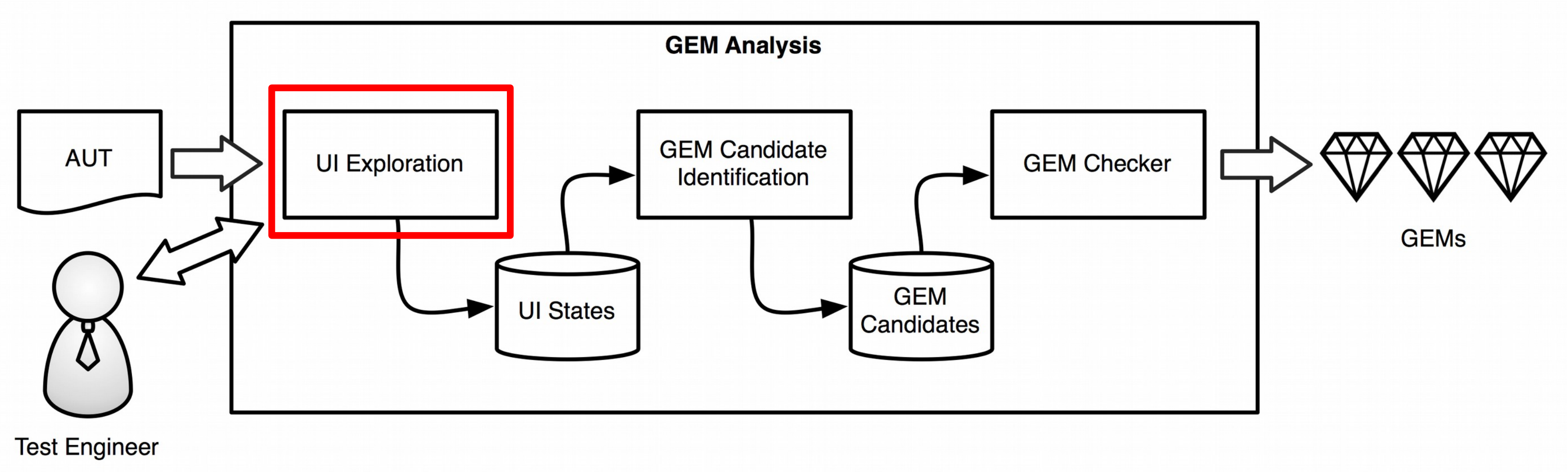


- Create application specific users
  - Users + administrator

- Create data
  - e.g., items of an inventory management system

- Configure access control (restrict privileges of one account)

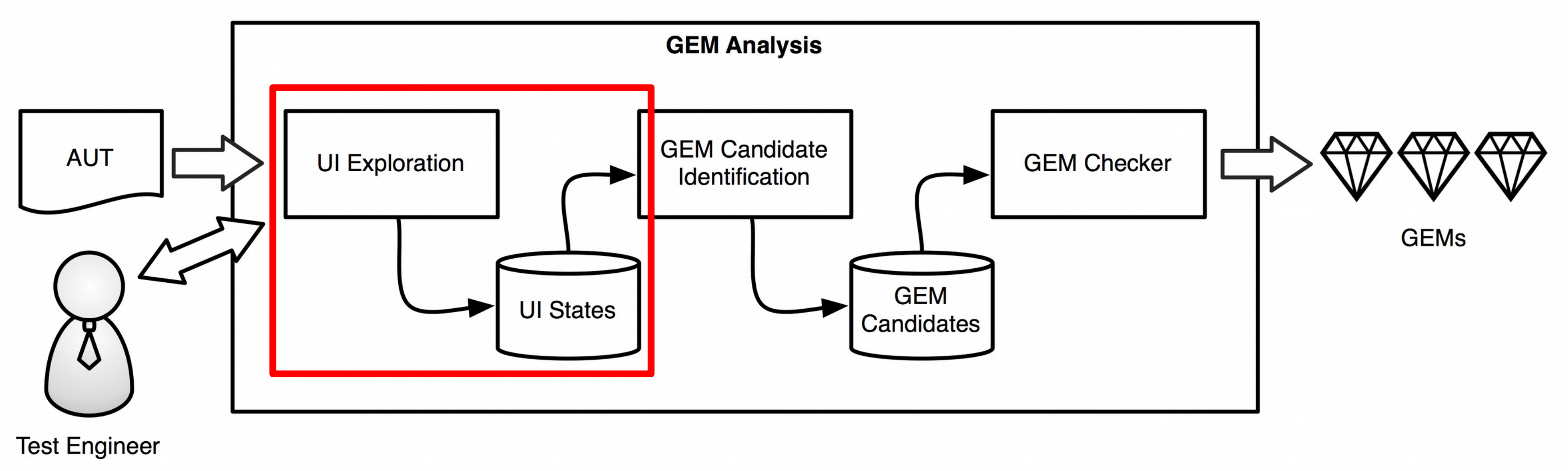
UI Exploration



- Explore the application's UI
  - Interact with widgets
    - click button, set check box, select drop down, ...

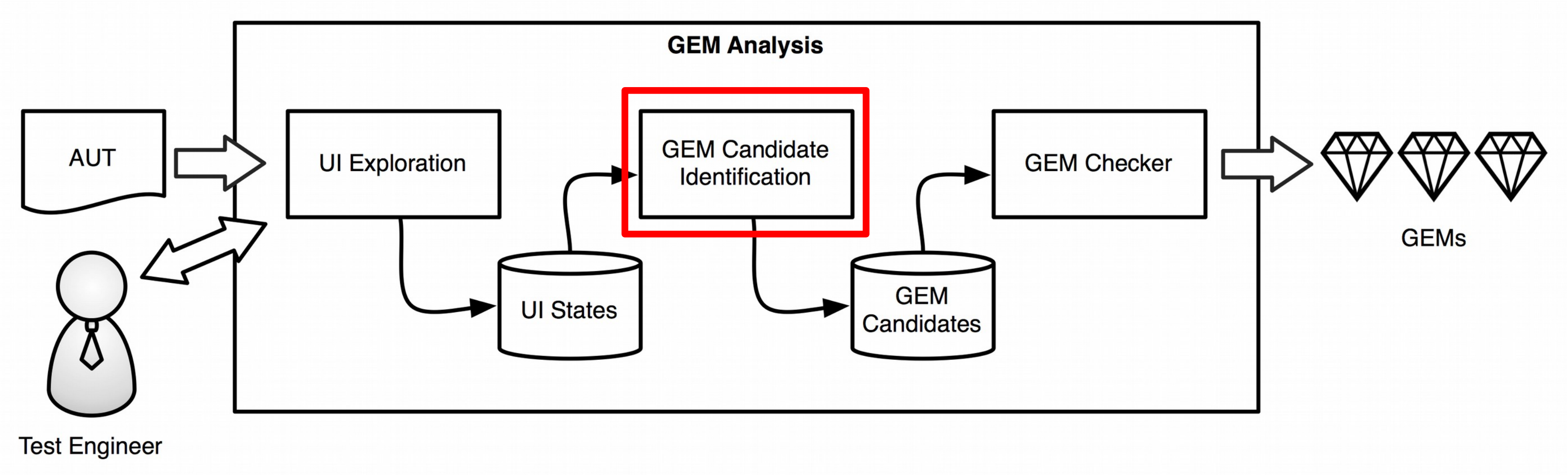
- Record
  - Widgets and attributes
  - Interactions

UI Exploration – for all privilege levels



- UI Exploration is executed once for each distinct privilege level
- Result: UI State for each privilege level
- UI State
  - Windows, contained widgets, and their attributes

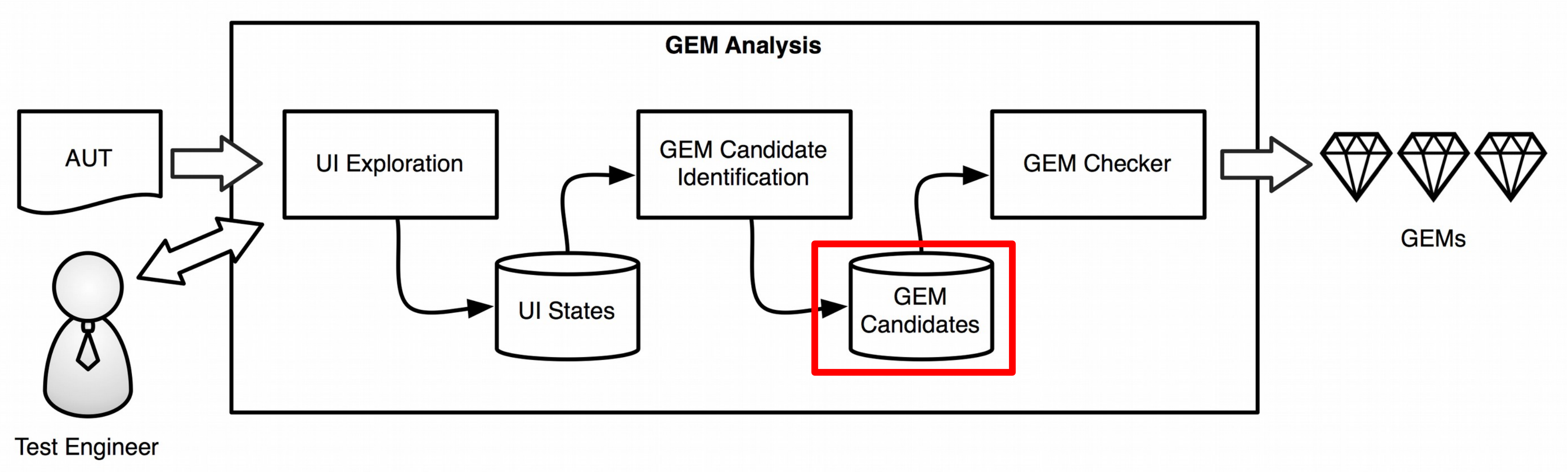
GEM Candidate Identification



- Compare UI States of different privilege levels
  - Widget with different attributes → GEM candidate

Level	Attributes	UI Element	Label
Low	Visible Disabled	TbitBtn	“New Article”
High	Visible Enabled	TbitBtn	“New Article”
Low	Visible Enabled	TbitBtn	“Help”
High	Visible Enabled	TbitBtn	“Help”
Low	Visible Enabled Read	EDIT	“”
High	Visible Enabled Write	EDIT	“”

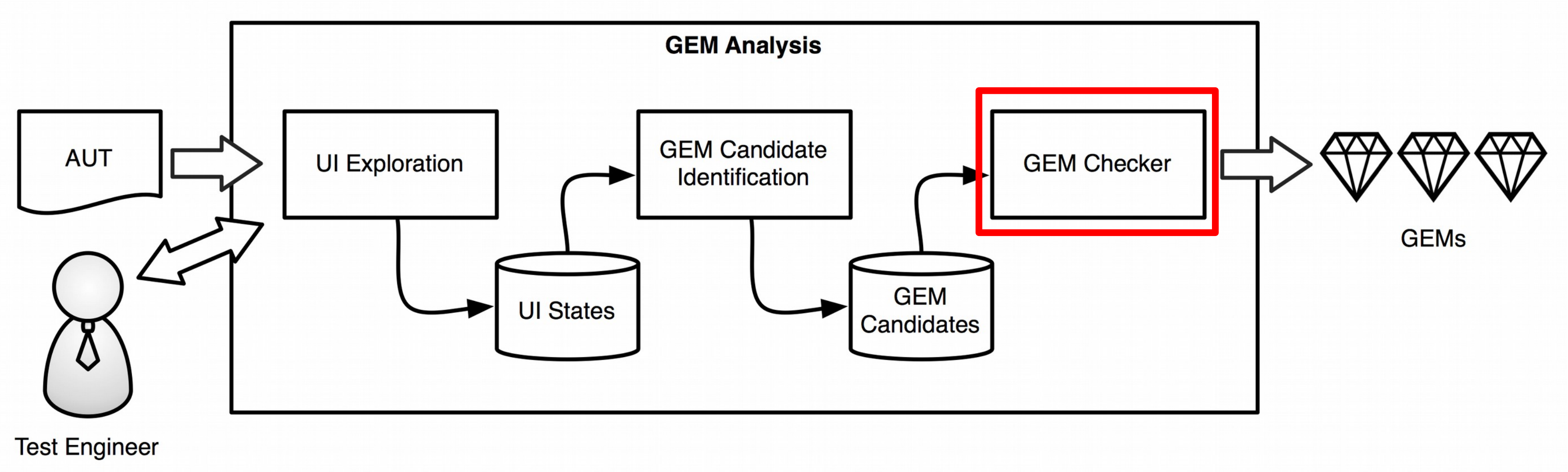
GEM Candidates



- GEM Candidate
  - Widget that likely can be used to bypass access control

- Candidate information
  - Widget type and ID
  - Path to candidate widget
  - “successor” (e.g. if widget creates a new window)

GEM Checking



- Execute AUT
- Drive application to GEM candidate
- Test GEM candidate
  - Manipulate and activate widget
  - Inspect result

GEM Candidate Testing

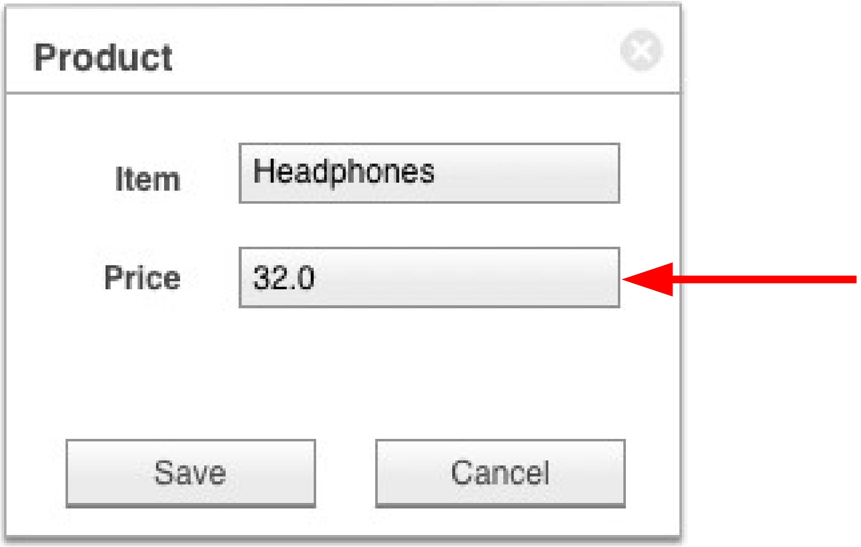
- Different strategy for each widget and GEM type
  - Callback execution: active widget → callback executed?
  - Information disclosure: can widget contain data?
  - Information modification: modified data accepted by app?

- Black box testing
  - Manipulate the UI for testing
  - Check results by only inspecting the UI

- Tests are independent from the application
  - No application specific knowledge needed

Testing Data Modification GEMs 1/4

- Drive application to window containing GEM candidate



Product

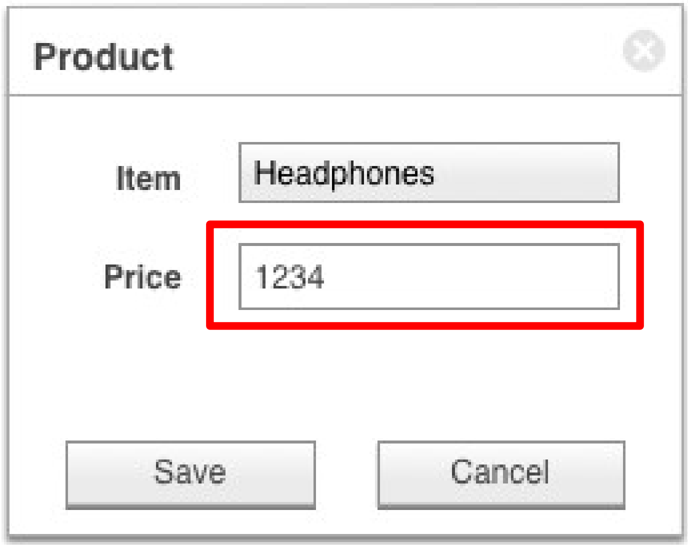
Item: Headphones

Price: 32.0

Candidate

Testing Data Modification GEMs 2/4

- Set text edit field writable
- Change/Set test value
- Close window



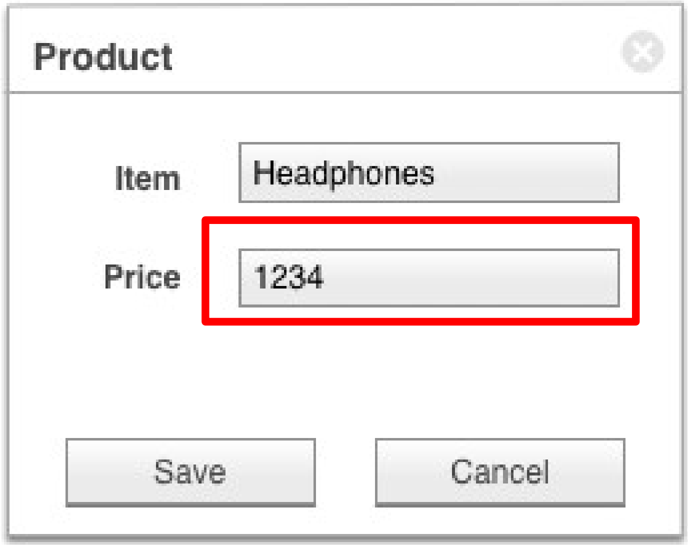
Product

Item: Headphones

Price: 1234

Testing Data Modification GEMs 3/4

- Drive application to window containing GEM candidate
- Check if test value present

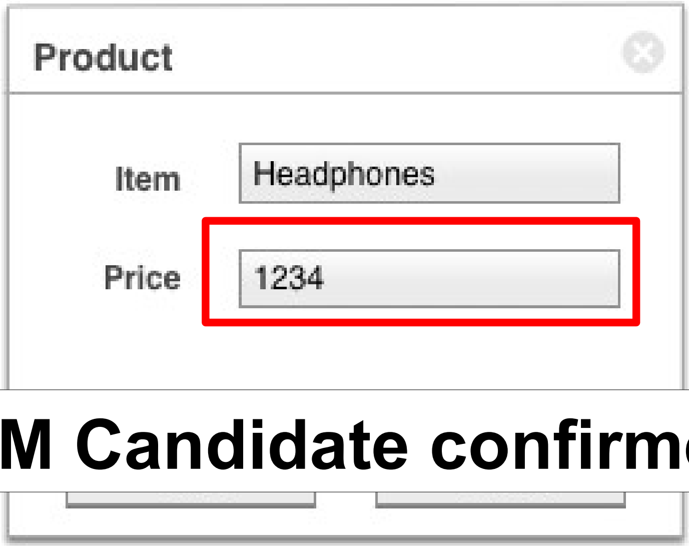

Product

Item: Headphones

Price: 1234

Testing Data Modification GEMs 4/4

- Drive application to window containing GEM candidate
- Check if test value present



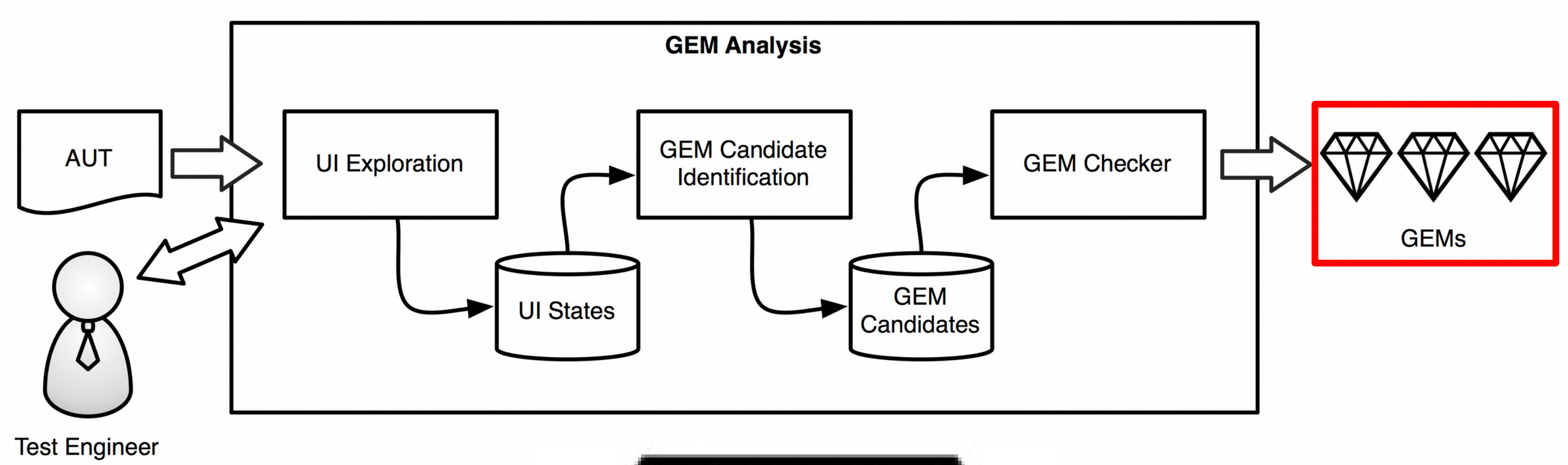
Product

Item: Headphones

Price: 1234

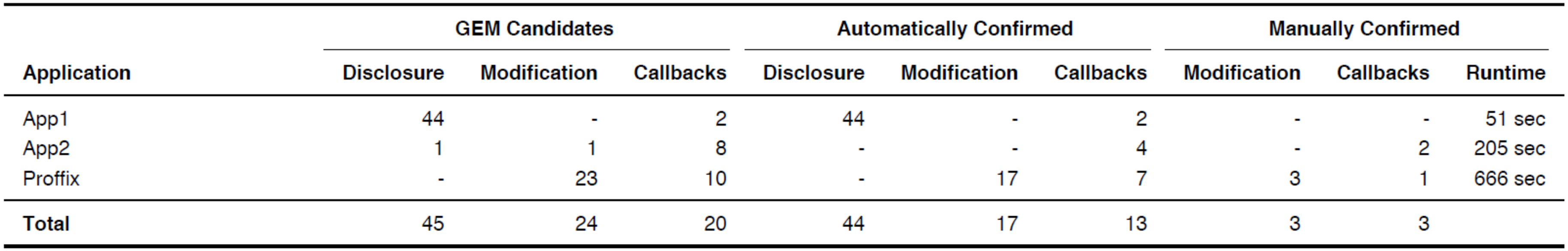
GEM Candidate confirmed!

Result → GEMs no longer hidden!



Widget + Type
Window
Path to Widget

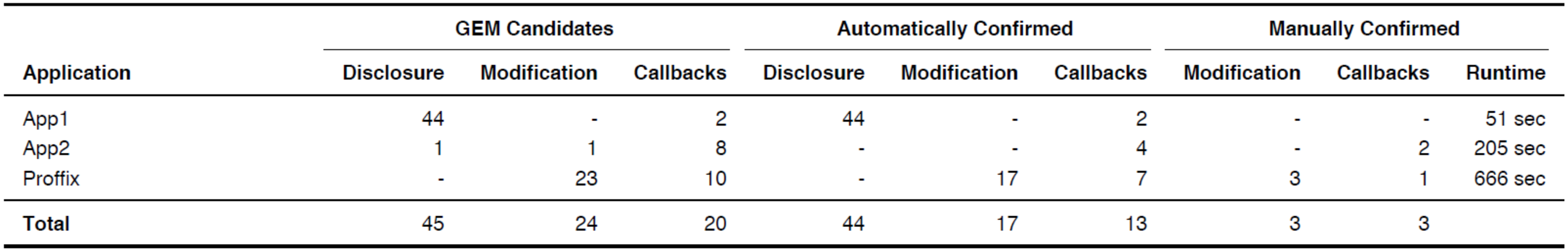
Analyzing Real World Applications



	GEM Candidates			Automatically Confirmed			Manually Confirmed		
Application	**Disclosure**	**Modification**	**Callbacks**	**Disclosure**	**Modification**	**Callbacks**	**Modification**	**Callbacks**	**Runtime**
App1	44	-	2	44	-	2	-	-	51 sec
App2	1	1	8	-	-	4	-	2	205 sec
Proffix	-	23	10	-	17	7	3	1	666 sec
Total	45	24	20	44	17	13	3	3	

- App1 : inventory management
  - Multiple users + admin mode
- App2 : employee and project management
  - Multiple users + admin
- Proffix : customer relationship management
  - Multiple users + admin, fine-grained access control

Analyzing Real World Applications



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Proffix	-	23	10	-	17	7	3	1	666 sec
Total	45	24	20	44	17	13	3	3	

- App1 : Win32 management
  - Multiple users + admin mode
- App2 : Win32 and project management
  - Multiple users + admin
- Proffix : .NET r relationship management
  - Multiple users + admin, fine-grained access control

Summary

- GEM Vulnerabilities
  - Exist in commercial software
  - Can be exploited by non sophisticated attackers

- GEM Miner Analysis
  - Systematic method to find GEM vulnerabilities
  - Independent of UI framework and application

- The GEM Miner System
  - Can automatically find and verify GEM bugs
  - Implemented for Windows but can be ported to other OSes

Conclusions

- We introduced GUI Element Misuse (GEMs)
  - New class of security vulnerabilities
  - Misuse of the UI to implement access control
- We defined three classes of GEMs
  - Information Disclosure and Modification, Callback Execution
- We build GEM Miner to analyze Windows applications for GEMs
  - We discovered a number of previously-unknown bugs
- First step towards including the UI in security testing
  - We specifically address access control vulnerabilities

EOF

Thank you!

Any Questions?

http://mulliner.org/security/guisec/