.NET Architecture

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CLI - Common Language Infrastructure

- CLI defines the basic platform for the .NET architecture
- described by ECMA Standard 335
  http://www.ecma-international.org/publications/standards/ecma-335.htm
- Microsoft's .NET Framework
  - contains Common Language Runtime (CLR)
    = Microsoft's implementation of the CLI standard
  - completely fulfill the standard
  - and offers still more, e.g.
    - ASP.NET
    - ADO.NET
    - Web Services
    - extended class library
    - ...

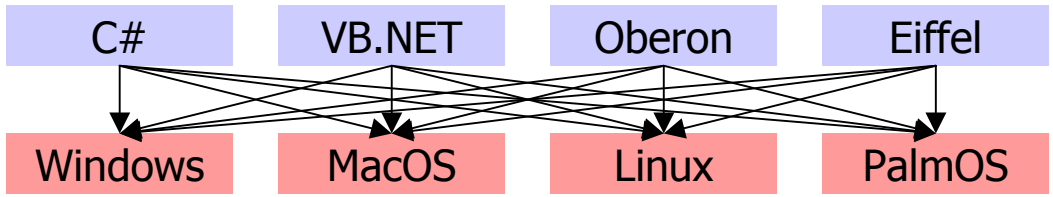
CLI Features

(buzzwords and acronyms ☺)

- common intermediate language ⇨ ***CIL***
- common type system ⇨ ***CTS***
- special deployment unit ⇨ ***Assembly***
- extensible type information ⇨ ***Metadaten***
- integration of many programming languages ⇨ ***CLS***
- code-based security model ⇨ ***CAS***
- automatic memory management ⇨ ***GC***
- just-in-time compilation (*NEVER* interpretation!) ⇨ ***JIT***
- dynamic type loading ⇨ ***VES***

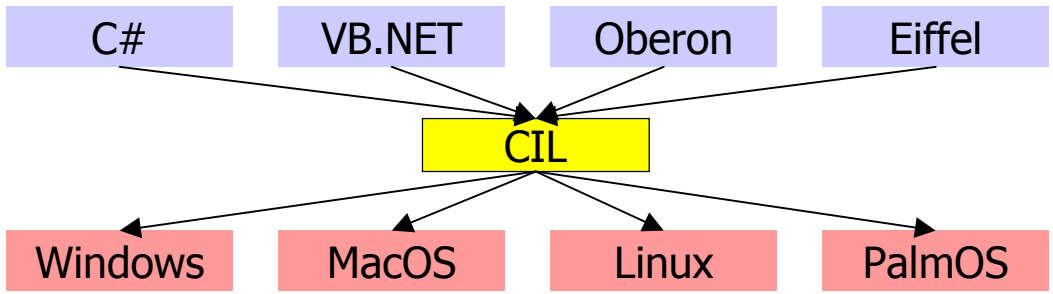
Advantages of a Virtual Machine

- portability (platform and language independence)
  - *w/o VM*: compilers for each language on each platform



e.g. 4 × 4 = **16**

  - *w/ VM*: translation into intermediate language (with .NET: CIL)
    one compiler per language and
    one CLR (JIT compiler) per platform



e.g. 4 + 4 = **8**

↓ ... compiler

- compactness of intermediate code
- better optimizations for native code at JIT compile time

Comparing VMs: CLR vs. JVM

- What's in the CLR that is *not* in the JVM?
  - objects on the stack (records, unions), custom value types
  - reference parameters (CALL-BY-REFERENCE)
  - varargs
  - function pointers
  - block matrices
  - overflow checking
  - tail calls
  - "native size" data types
  - boxing of value types
  - ...

⇨ CLR better suited for use with numerous different programming languages

The© Example: Hello, .NET-World!

HelloWorld.cs:

```
class HelloWorldApp {
    static void Main () {
        System.Console.WriteLine("Hello, .NET-World!");
    }
}
```

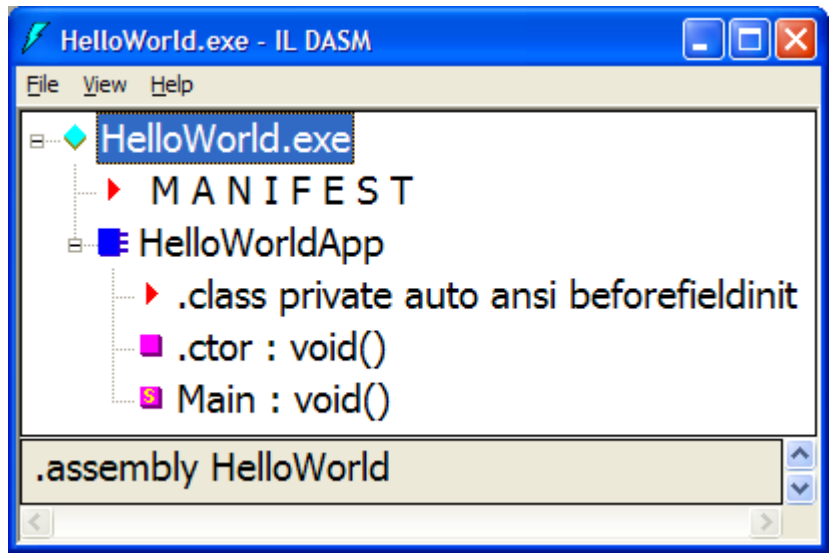
Compile and create assembly (w/ C# compiler):

```
> csc HelloWorld.cs
```

Assembly: HelloWorld.exe (3072 Byte!)

View metadata and CIL code (w/ IL disassembler):

```
> ildasm HelloWorld.exe
```

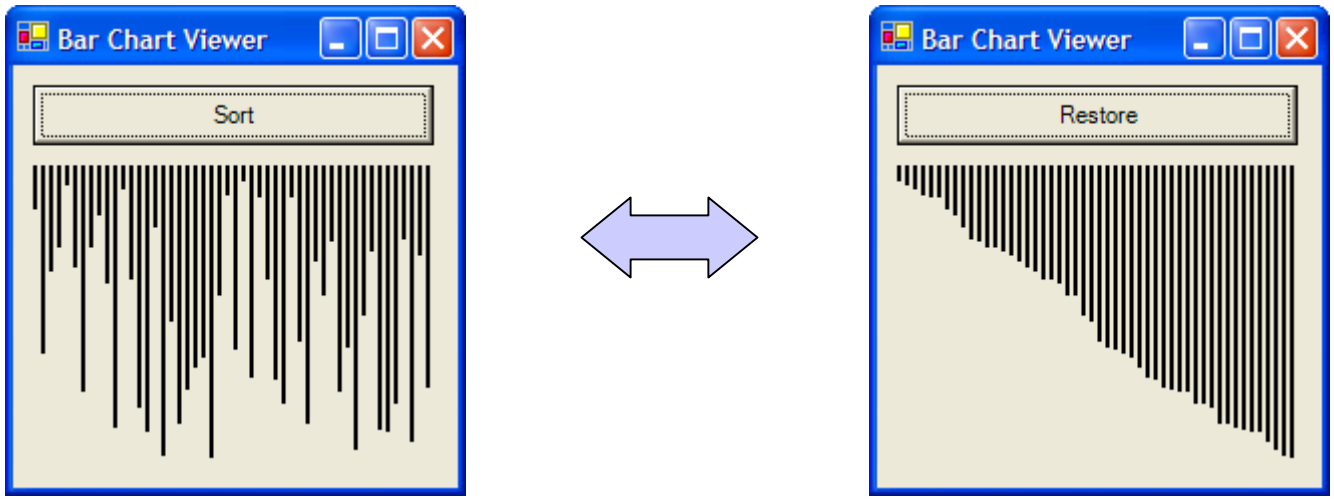


Assemblies and Modules

- Managed module =
  - physical unit: 1 .NET module = 1 .NET PE-file
  - contains type definitions with Metadata & CIL-code
  - is generated by a .NET compiler
- Assembly =
  - logical unit for:
    deployment, encapsulation, versioning, security
  - component (in terms of component-oriented software development)
  - combines modules and resource files (see ⇨ ***Manifest***)
  - is generated by a .NET compiler or the assembly linker (al.exe)
- Manifest
  - holds information about all the parts of an assembly
    e.g. which files it consists of, where to find these files, which types get exported outside the assembly, ...

Multi-Language Interoperability

- Demo: Visualization of a bar chart
  - button click toggles between unsorted and sorted view



- Implementation with different programming languages
  - C# ⇨ Windows Control (Chart)
  - Visual Basic .NET ⇨ Windows Form (connecting Chart ⇔ Button)
  - J# ⇨ Application (set window size, Main method)

Modules, Libraries, and Applications

- .NET compiler can produce each of the following:
  - modules (*.netmodule): not an assembly, not executable
  - dynamic link libraries (*.dll): not executable assembly
  - application (*.exe): executable assembly

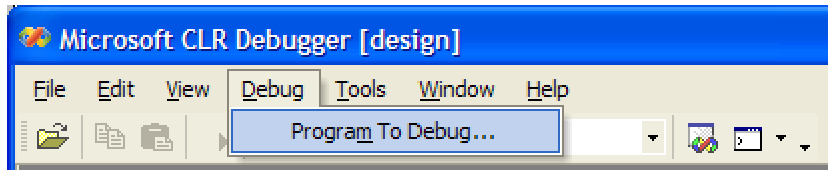
BarChartControl.cs *is compiled into a* ***.NET module****:*
csc /out:bar.mod **/target:module** /debug **BarChartControl.cs**

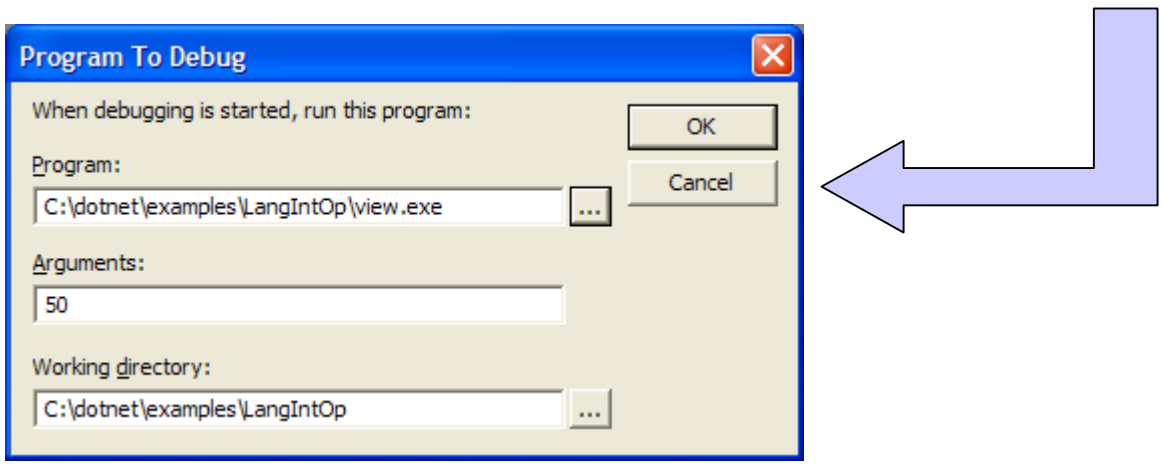
BarChartGUI.vb *is compiled into a* ***.NET library*** *and uses* bar.mod*:*
vbc /out:gui.dll **/target:library /addmodule:bar.mod**
/r:System.dll,System.Drawing.dll,System.Windows.Forms.dll /debug
BarChartGui.vb

BarChartApp.jsl *is compiled into a* ***.NET Windows application*** *and uses* gui.dll*:*
vjc /out:view.exe **/target:winexe /reference:gui.dll**
/r:System.Windows.Forms.dll /debug **BarChartApp.jsl**

GUI-Debugger (1)

- start GUI-Debugger
  - *.NET-SDK**\GuiDebug\DbgCLR.exe
- select program to debug





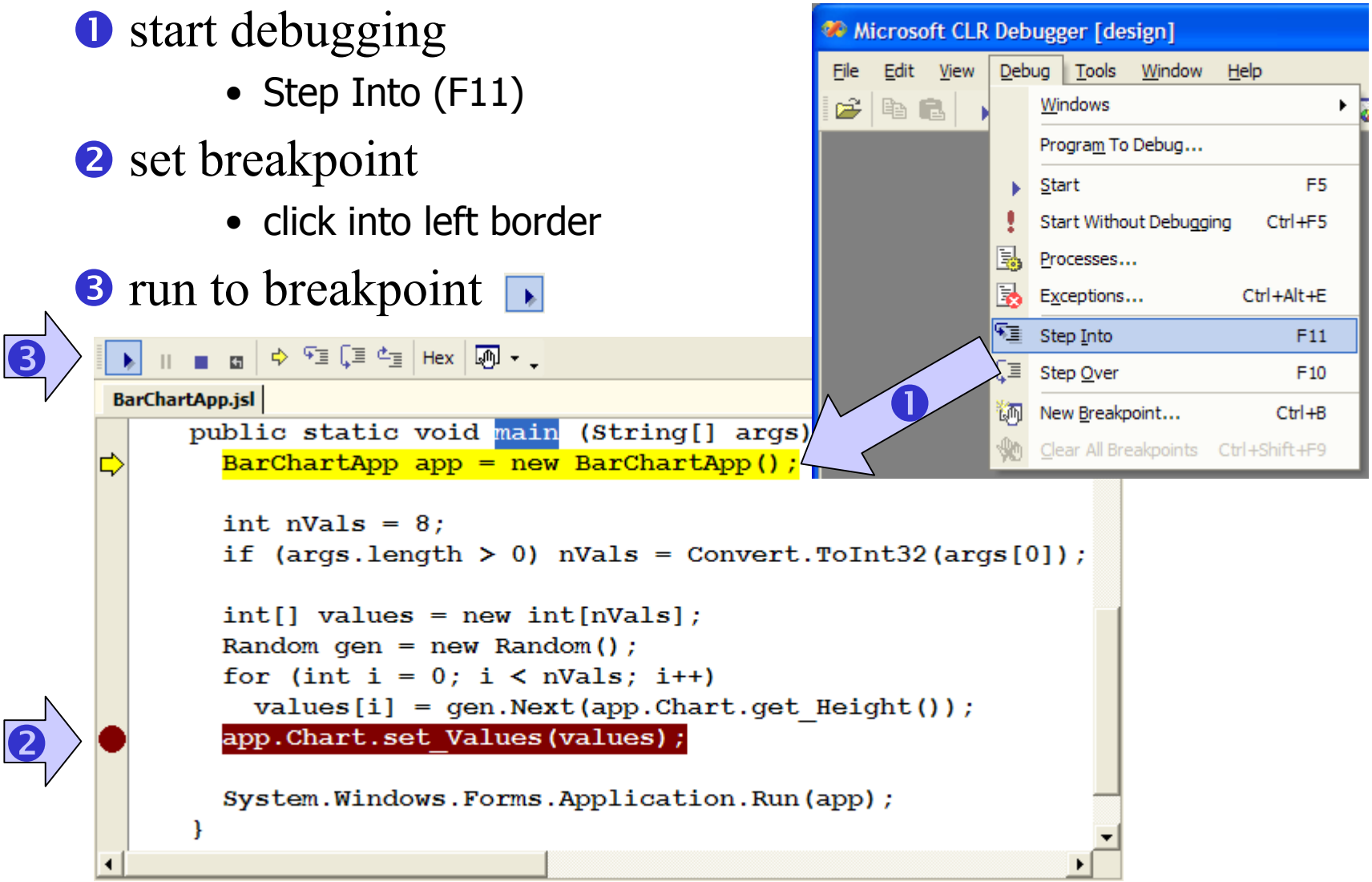
*) see Appendix A: Important Directories

GUI-Debugger (2)

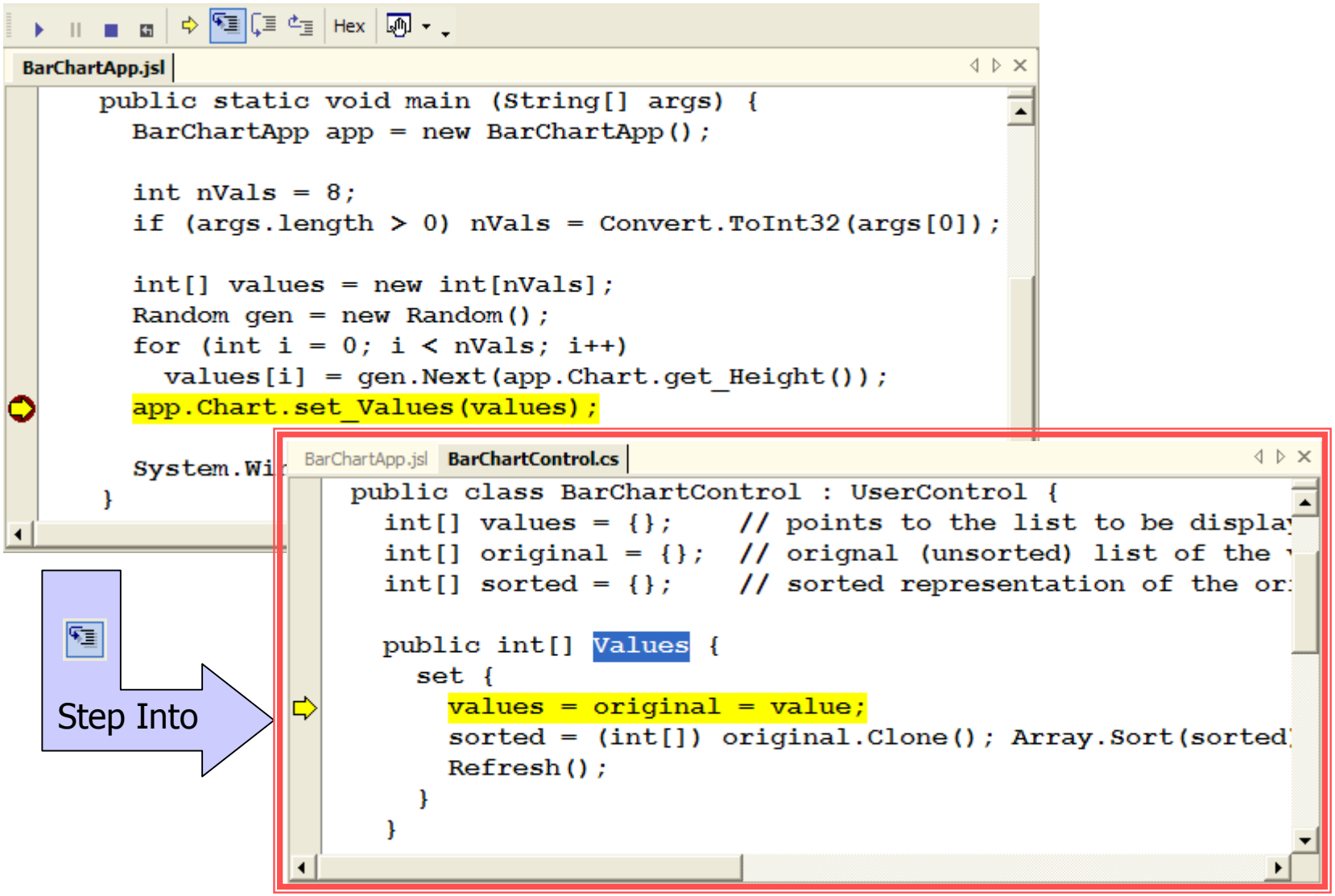
❶ start debugging
- Step Into (F11)

❷ set breakpoint
- click into left border

❸ run to breakpoint



Cross-Language Debugging



CIL and Metadata - Exported Types

IL-Assembler-Code of main *method of* view.exe*:*

```
.method public hidebysig static void main (string[] args) cil managed {
    .entrypoint
    .locals init ( class BarChartApp app, int32 nVals, int32[] values, . . . )
    . . .
    ldloc.0
    ldfld class [gui]BarChartControl [gui]BarChartGui::Chart
    ldloc.2
    callvirt instance void [gui]BarChartControl::set_Values(int32[])
    . . .
}
```

local variable 0

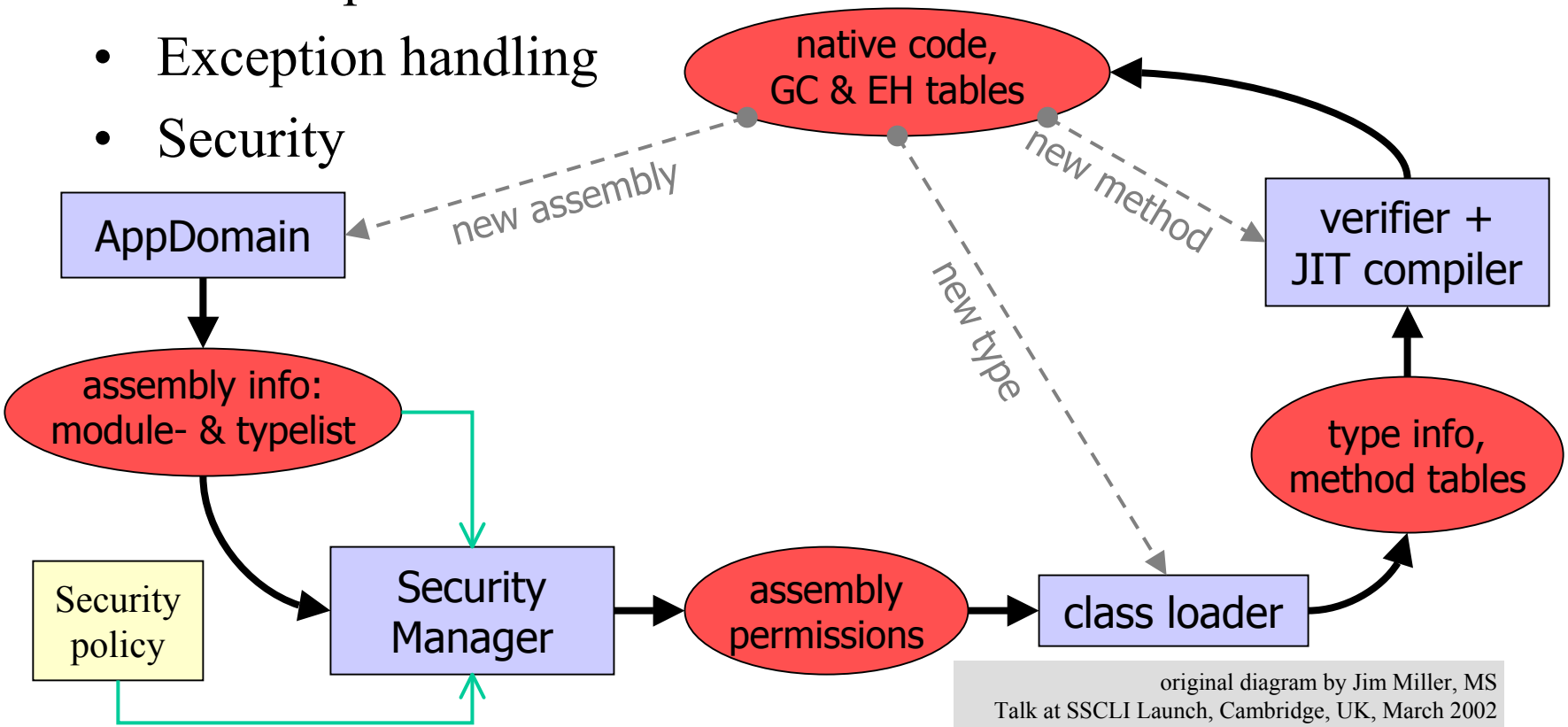
local variable 2

Manifest of gui.dll*:*

```
    .assembly gui { . . . }
    .module gui.dll
    .module extern bar.mod
    .file bar.mod
        .hash = ...
    .class extern public BarChartControl { .file bar.mod
                                           .class 0x02000002 }
```

Virtual Execution System (VES)

- Type safety
- Memory management (memory layout of objects, GC, …)
- JIT compilation
- Exception handling
- Security



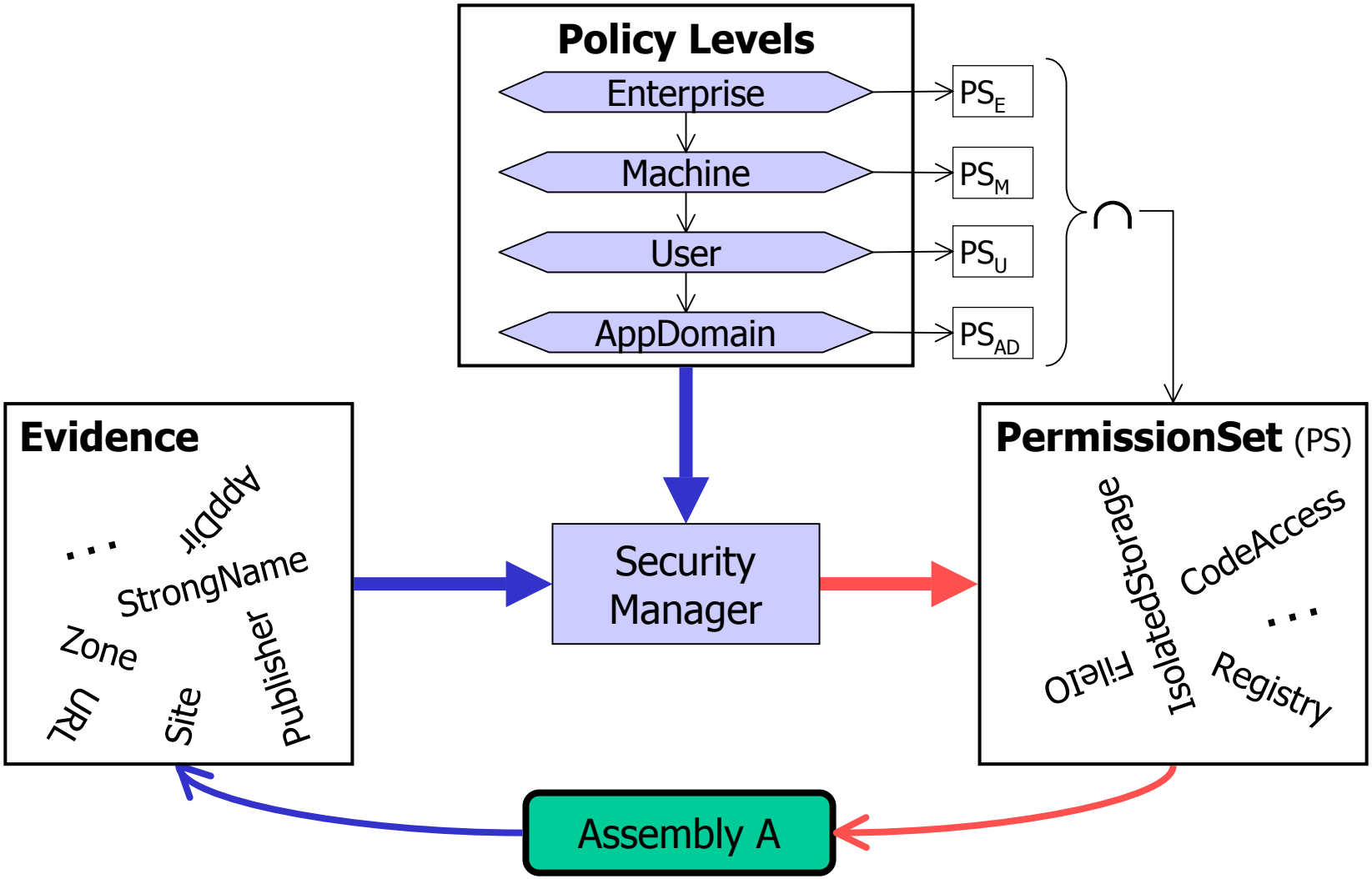
original diagram by Jim Miller, MS
Talk at SSCLI Launch, Cambridge, UK, March 2002

.NET Security

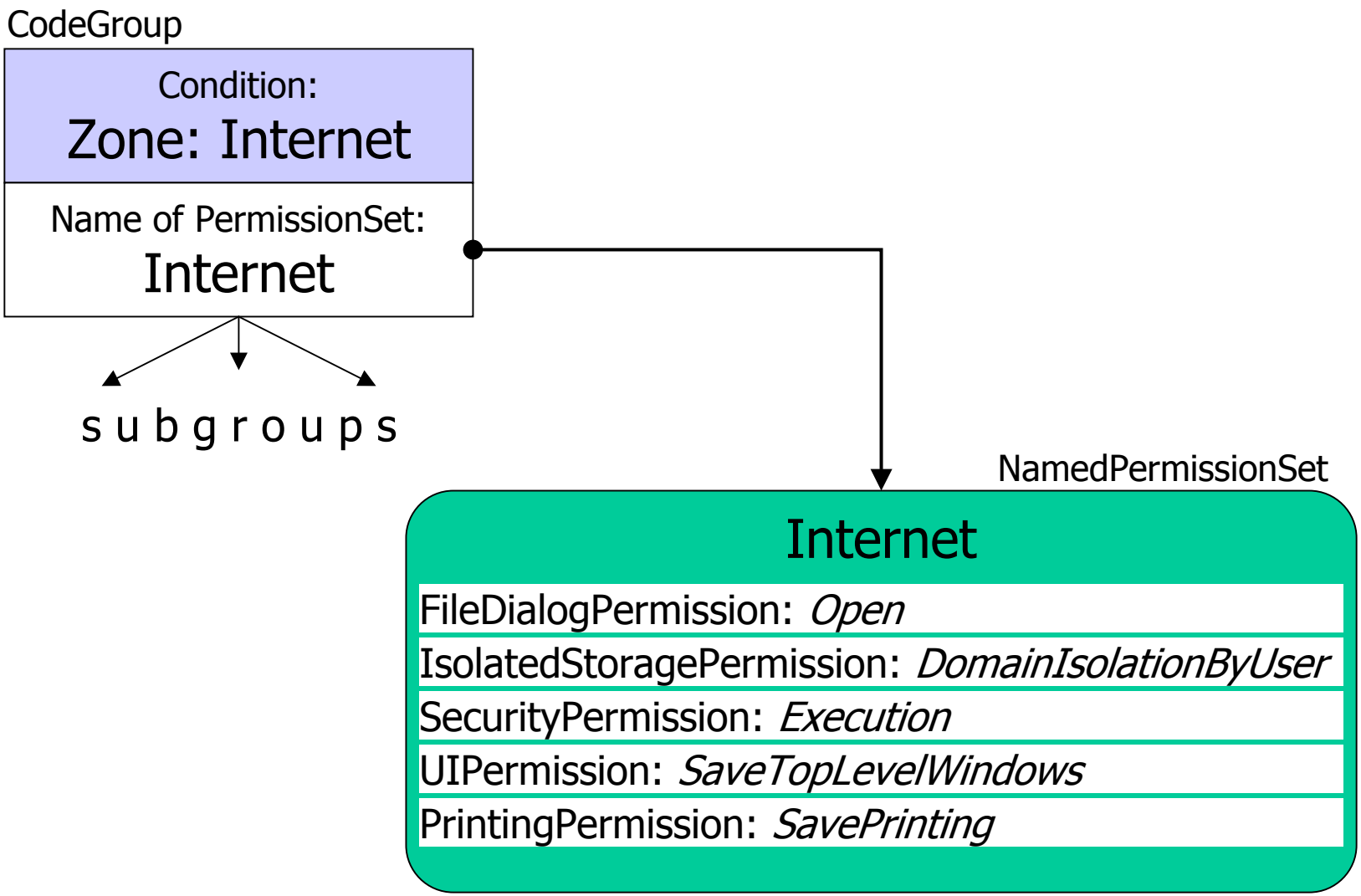
- role-based security
  - exists on most operation systems
  - permissions are assigned to a ***user***
  - based on ***group affiliation***
  - namespace System.Security.Principal has supporting interfaces
    - System.Security.Principal.IPrincipal → role, group
    - System.Security.Principal.IIdentity → user

- code-based security (*Code Access Security (CAS)*)
  - permissions are assigned to ***assemblies***
  - based on ***assembly information*** (*evidence*) and ***security policy***

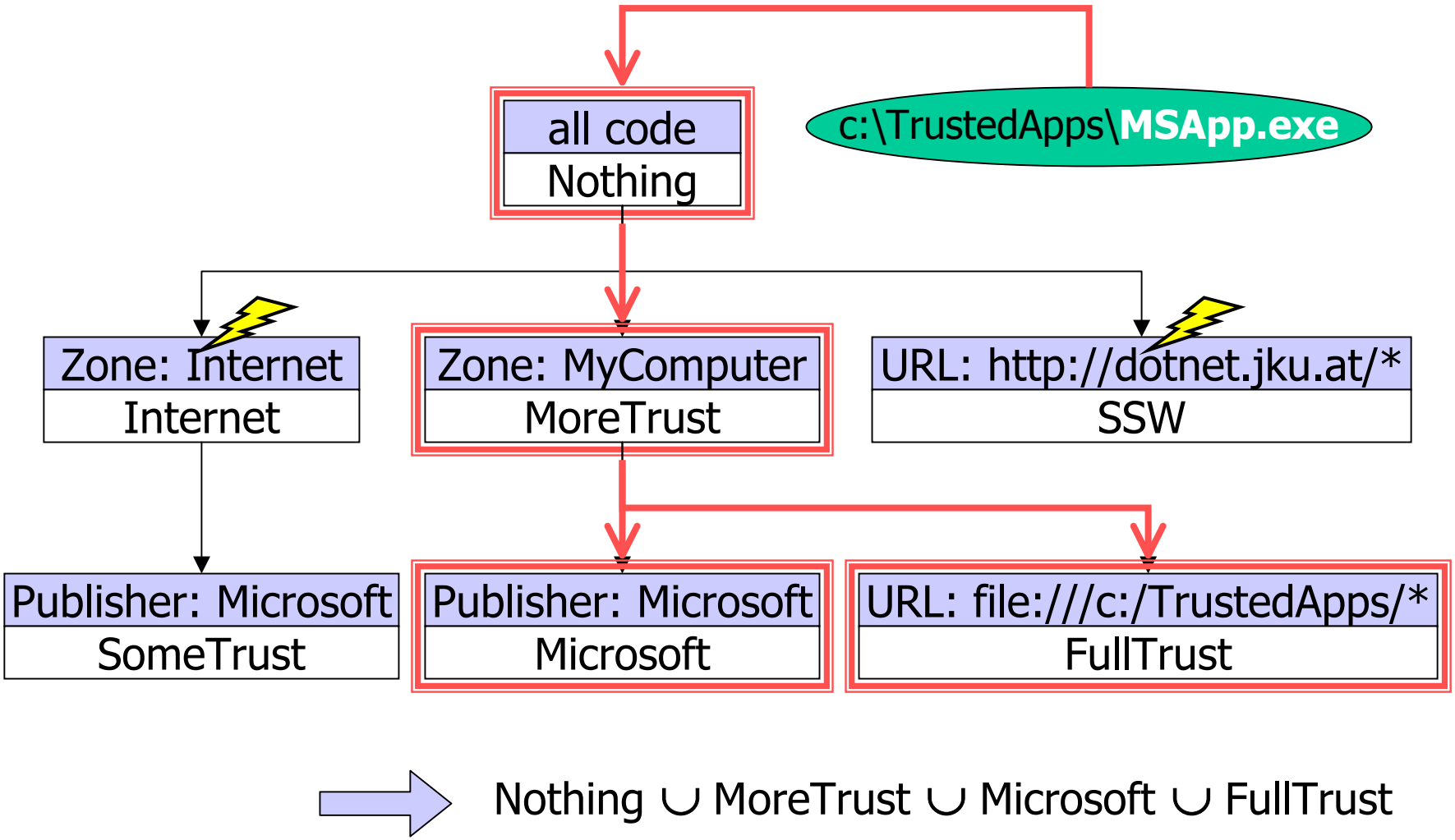
Code Access Security (CAS)



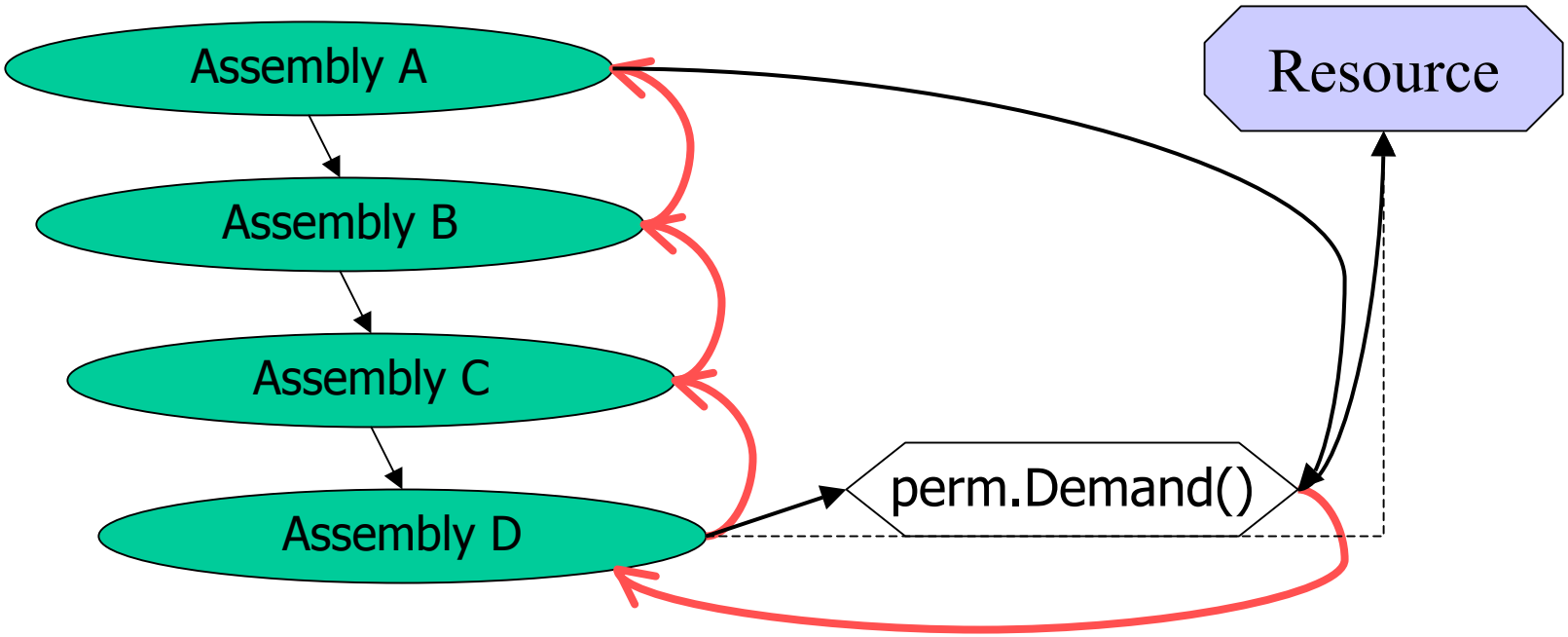
Code Groups & Permission Sets



Levels of Security Policy



Security Stack Walk



- CLR checks permissions of all callers
- only if all callers have the required permissions perm, the resource may be accessed

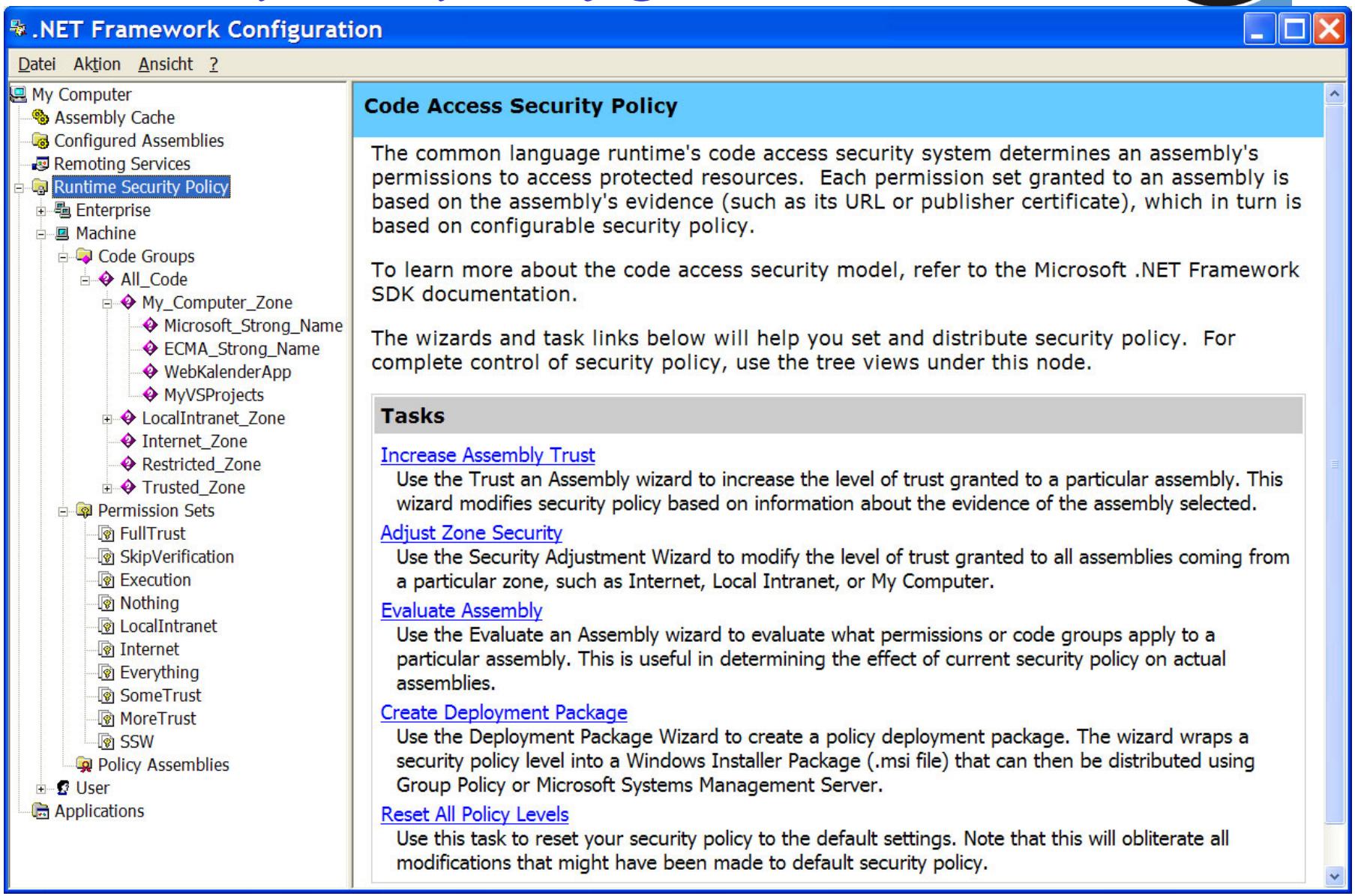
Security Policy Configuration (1)

- Microsoft .NET Framework Configuration Tool
  - MMC (Microsoft Management Console) Snap-In
  - Start with
    - Start | Control Panel | Administrative Tools | Microsoft .NET Framework Configuration or
    - mscorcfg.msc at the command line
  - supports (with wizards)
    - creating/editing of code groups
    - creating/editing of of permission sets
    - determines permissions/code groups of an assemblies

- Code Access Security Policy Tool (caspol.exe)
  - command line tool
    - e.g. activate/deactivate security checks

      caspol **-security** (on | off)

Security Policy Configuration (2)



Appendix A: Important Directories

- Windows-specific directories
  - *Windows*: e.g. c:\WINDOWS\ , c:\WINNT\
  - *Programs*: e.g. c:\Program Files\
  - *User*: e.g. c:\Documents and Settings*UserName*\
- .NET-specific directories
  - *.NET-Runtime*:
    e.g. *Windows*\Microsoft.NET\Framework\v1.0.3705
  - *.NET-SDK*:
    e.g. *Programs*\Microsoft.NET\FrameworkSDK or
    Programs\Microsoft Visual Studio .NET\FrameworkSDK
  - *GAC* (Global Assembly Cache): e.g. *Windows*\assembly\

Appendix B: Configuration Files

- Machine configuration
  - *.NET-Runtime*\CONFIG\machine.config
- Application configuration
  - in the application directory
  - filename = application filename + .config
    e.g. MyApp.exe → MyApp.exe.config
- Security policy
  - level ENTERPRISE: *.NET-Runtime*\CONFIG\enterprisesec.config
  - level MACHINE: *.NET-Runtime*\CONFIG\security.config
  - level USER: e.g.
    User\Application Data\Microsoft\CLR Security Config\v1.0.03705\security.config
  - level APPDOMAIN:
    in program code with AppDomain.SetAppDomainPolicy (...)

C#: BarChartControl (1)

BarChartControl.cs:

```
using System; using System.Drawing; using System.Windows.Forms;

public class BarChartControl : UserControl {
   int[] values = {};          // points to currently displayed list (original or sorted)
   int[] original = {};        // original (unsorted) list of the values
   int[] sorted= {};           // sorted representation of the original list

   public int[] Values {
      set {
         values = original = value;
         sorted = (int[]) original.Clone(); Array.Sort(sorted);
         Refresh();
      }
   }

   public bool Sorted { get { return values == sorted; } }
   . . .
```

C#: BarChartControl (2)

BarChartControl.cs (Forts.):

```
    . . .

    public void ToggleSorted ()  {
        if (values == sorted) values = original;
        else values = sorted;
        Refresh();
    }

    protected override void OnPaint (PaintEventArgs e)  {
        Brush b = new SolidBrush(ForeColor);                    // fill color for bars
        int w = DisplayRectangle.Width / (values.Length*2-1); // width of bars
        int x = 0;                                              // starting position
        foreach (int i in values) {
            e.Graphics.FillRectangle(b, x, 0, w, i);
            x += w * 2;
        }
    }
}
```

Visual Basic .NET: BarChartGUI (1)

BarChartGUI.vb:

```
Imports System
Imports System.Drawing
Imports System.Windows.Forms

Public Class BarChartGui
Inherits Form

    Private    Dim WithEvents ToggleButton As New Button()
    Protected Dim Chart As New BarChartControl()

    Public Sub New ()
        ToggleButton.Location = New Point(10, 10)
        ToggleButton.Size = New Size(200, 30)
        ToggleButton.Text = "Sort"
        Controls.Add(ToggleButton)

        Chart.Location = New Point(10, 50)
        Chart.Size = New Size(200, 150)
        Controls.Add(Chart)
    End Sub
    . . .
```

inherits from a class library type (unknown source language)

type of field is implemented in C#

writing to a Property (unknown source language)

writing to a Property (source language C#)

Visual Basic .NET: BarChartGUI (2)

BarChartGUI.vb (Forts.):

```
. . .

Private Sub Toggle_Click (ByVal sender As Object, ByVal e As EventArgs) _
        Handles ToggleButton.Click

    Chart.ToggleSorted()

    If Chart.Sorted Then
        ToggleButton.Text = "Restore"
    Else
        ToggleButton.Text = "Sort"
    End If
End Sub

End Class
```

invocation of method (source language C#)

reading of a Property (source language C#)

J#: BarChartApp

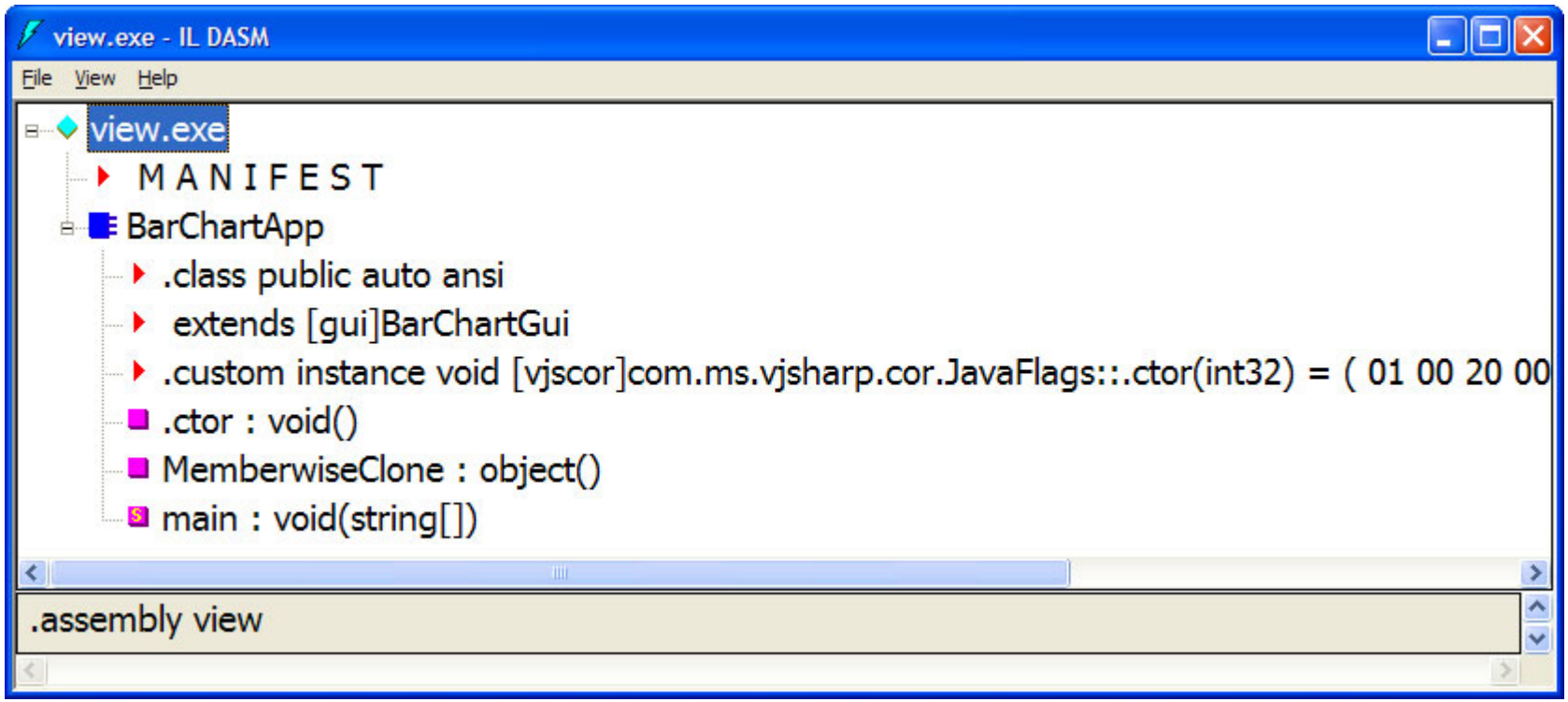
BarChartApp.jsl:

```
import System.*;

class BarChartApp extends BarChartGui {
    BarChartApp () {
        set_Text("Bar Chart Viewer");
        set_Width(230);
        set_Height(245);
    }

    public static void main (String[] args) {
        BarChartApp app = new BarChartApp();
        int nVals = 8;
        if (args.length > 0) nVals = Convert.ToInt32(args[0]);
        int[] values = new int[nVals];
        Random gen = new Random();
        for (int i = 0; i < nVals; i++) values[i] = gen.Next(app.Chart.get_Height());
        app.Chart.set_Values(values);
        System.Windows.Forms.Application.Run(app);
    }
}
```

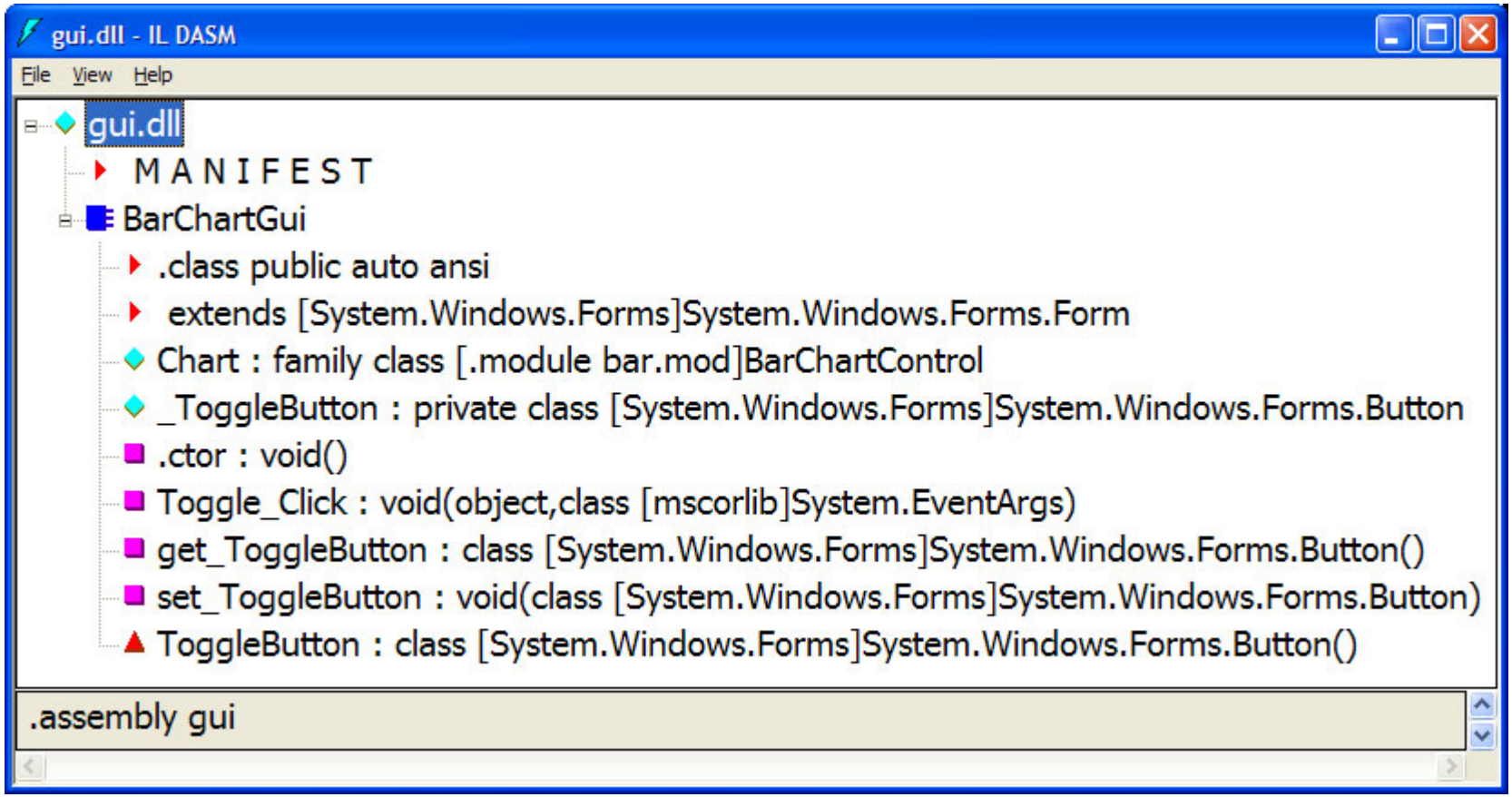
inherits from type implemented in C#

J# does not support C#-like Properties → use compiler-generated methods instead

IL-Disassembler: view.exe



IL-Disassembler: gui.dll



IL-Disassembler: bar.mod