Project Zonnon:
The Language, The Compiler, The Environment

Eugene Zouev

Bergen Language Design Laboratory
Bergen University

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Outline

- Project History
- Zonnon Language
- Zonnon Compiler
- CCI & Zonnon Compilation Model
- Integration into Visual Studio
- Zonnon Builder
- Link, Conclusion, Acknowledgements

Project History

1999, Oberon.NET

Projects 7 & 7+ launched by Microsoft Research

2001, Active Oberon

ETH Zürich; the notion of active object

2004, Active C#

ETH Zürich; communication mechanism based on syntax-oriented protocols

2004-2006, Zonnon

Zonnon Highlights

A member of the family of Pascal,Modula-2, Oberon: compact, easy to learn and use

Supports modularity (with importing units and exporting unit members)

Supports object-oriented approach based on definition/implementation paradigm and refinement of definitions

Supports concurrency based on the notion of active objects and syntax-based communication protocols

Zonnon Program Architecture 1

Module

Definition

Object

Implementation

Zonnon Program Architecture 1

Module

System managed object:
- encapsulates resources
- implements definitions
- aggregates implementations

Definition

Unified unit of abstraction:
- represents abstract interface
- refines another definition

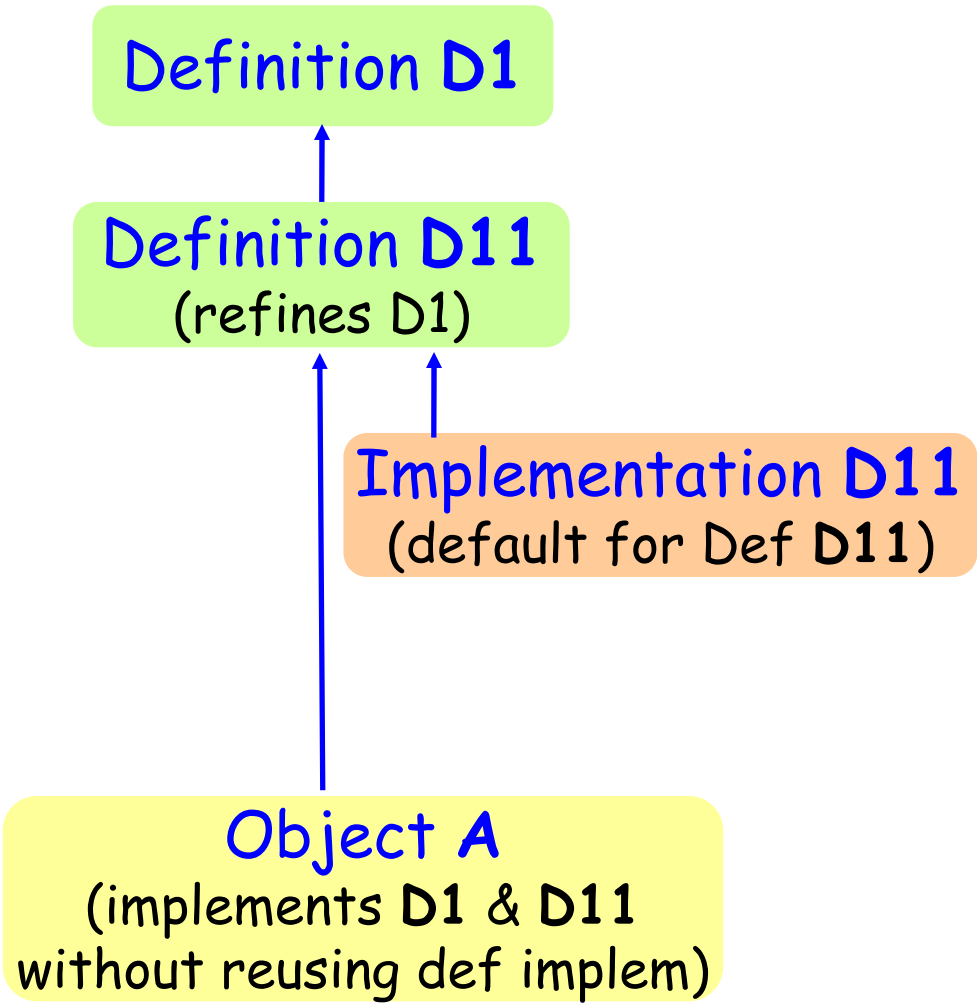
Object

Program managed actor/resource:
- implements definitions
- aggregates implementations
- specifies concurrent behaviour

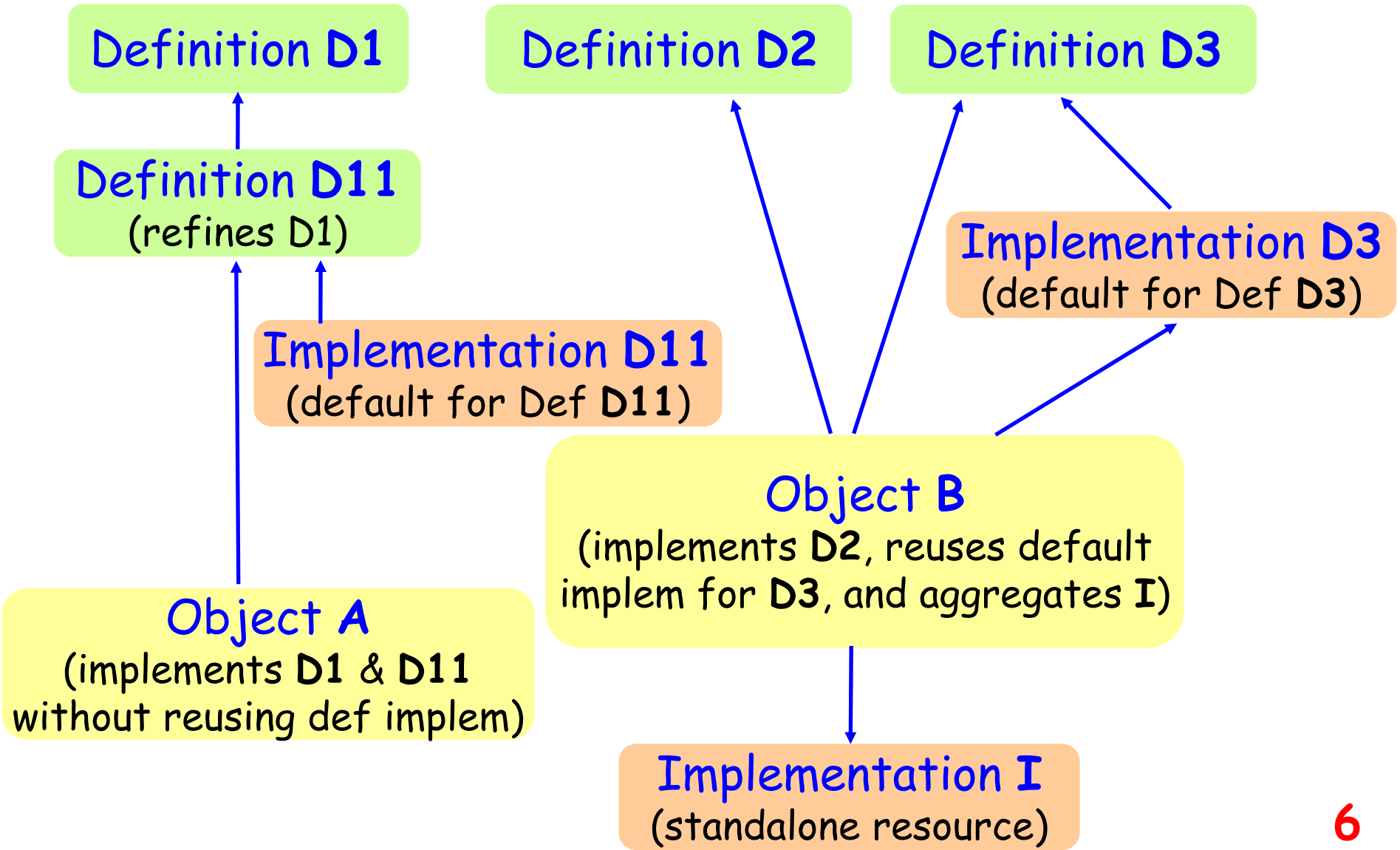
Implementation

- def.implementation of a definition
- standalone aggregation unit

Zonnon Program Architecture 2



Zonnon Program Architecture 2



Definitions

```
(* Common interface for all kind of vehicles *)
definition Vehicle;
    var { get } Speed : integer;  (* read-only *)
    procedure SpeedUp ( d:integer );
    procedure SlowDown ( d:integer );
end Vehicle.
```

```
definition Truck refines Vehicle;
    (* Inherits interface from Vehicle *)
    const SpeedLimit = 90;
end Truck.
```

Definition & Implementation

```
(* Common interface for random numbers generators *)
definition Random;
    var { get } Next : integer;  (* read-only *)
    procedure Flush; (* reset *)
end Random.
```

```
(* A default implementation of the generator *)
implementation Random;
    var { private } z : real;
    procedure { public, get } Next : integer;
        const a = 16807; m = 2147483647; q = m div a; r = m mod a;
        var g : integer;
    begin g := a*(z mod q) - r*(z div q);
        if g>0 then z := g else z := g+m end;
        return z*(1.0/m)
    end Next;
    procedure Flush;  begin  z := 3.1459 end Flush;
begin Flush
end Random.
```

Definitions & Objects

```
(* Common interface for the random numbers generator *)
definition Random;
    var { get } Next : integer;  (* read-only *)
    procedure Flush; (* reset *)
end Random.
```

```
(* A custom implementation of the generator *)
object myRandom implements Random;
  (* Procedure Next is reused from default implementation *)

  (* Procedure Flush is customized *)
  procedure Flush implements Random.Flush;
  begin
      z := 2.7189
  end Flush;
begin
   Flush
end myRandom.
```

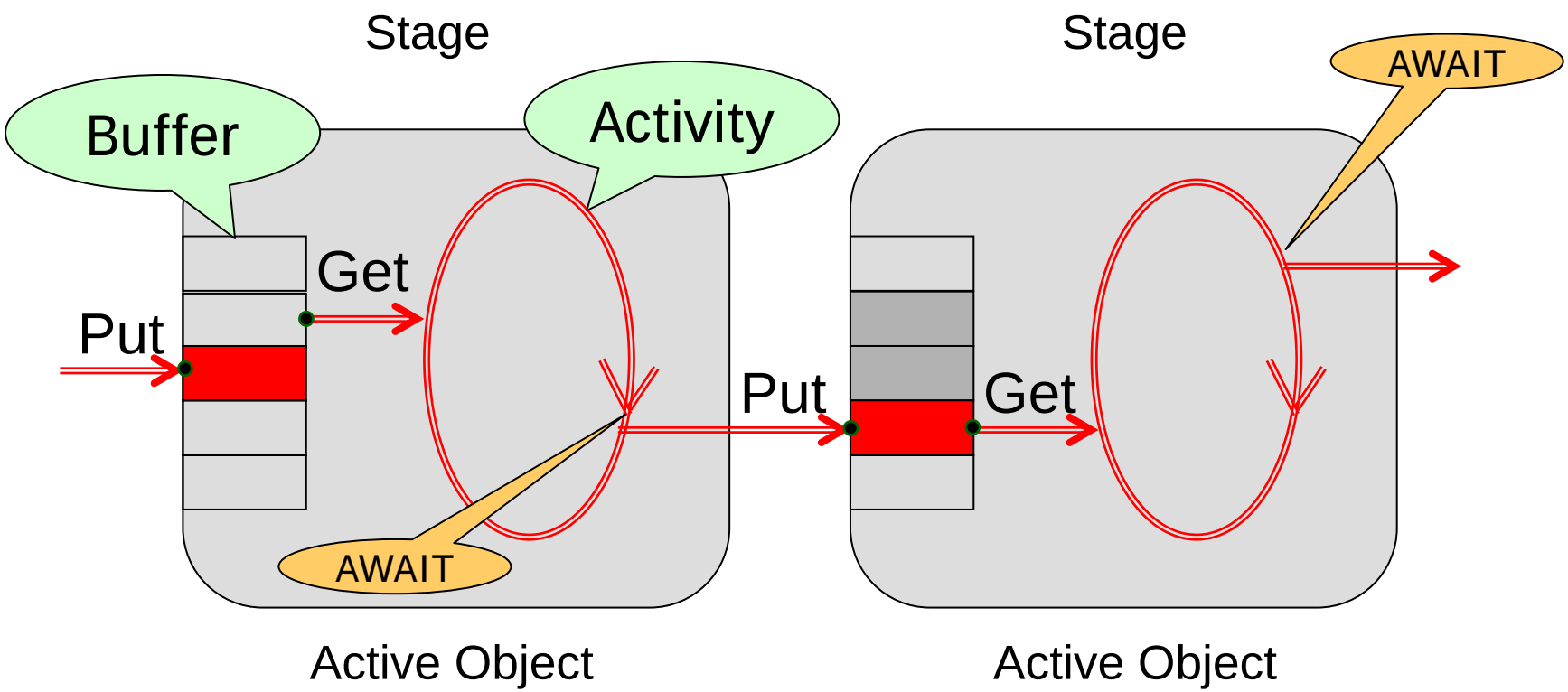
Modules & Objects

```
module Test;
   import Random, (* both definition and implem are imported *)
          myRandom;
   var x : object { Random };
            (* x's actual type is either Random or any type
               implementing Random *)

   object R2 implements Random;
            (* Another implementation of Random definition *)
     . . .
   end R2;
begin
   x := new Random;
    . . .
   x := new myRandom;
    . . .
   x := new R2;
end Test.
```

Activity Example: A Pipeline with Active Objects 1

Taken from a talk of JG, BK, and DL



System-wide activity is scheduled by evaluating the set of all AWAIT preconditions

Activity Example: A Pipeline with Active Objects 2

Taken from a talk of JG, BK, and DL

```
object Stage (next: Stage);
        var { private } n, in, out: integer;
            buf: array N of object; (*used as a circular buffer*)
        procedure  { private }  Get (var x: object);
        begin { locked } (*mutual exclusion*)
          await (n # 0);  (* precondition to continue*)
          dec(n); x := buf[out]; out := (out+1) mod N
        end Get;
        procedure { public } Put (x: object);
        begin { locked } await (n # N); (*mutual exclusion*)
          inc(n); buf[in] := x; in := (in+1) mod N
        end Put;
        activity Processing; var x: OBJECT;
        begin loop Get(x); (*process x;*) next.Put(x) end
        end Processing;
begin (*initialise this new object instance*)
    n := 0; in := 0; out := 0; new Processing;
end Stage;
```

Wait whilst the buffer is empty

Wait whilst the buffer is full

each activity has a separate thread

Activities & Protocols

```
definition D;
   protocol P = (a, b, c); (* declaration of a protocol *)
end D.
```

```
object O; import D;
   activity A implements D.P; (* declaration of an activity *)
      begin ... return u, v, w;   (* activity returns tokens *) ...
            x, y := await;    (* activity receives tokens *)
   end A;
   var p: P; (* declaration of an activity variable *)
begin
   p := new A;   (* create an activity *)
      (* Continued dialog between caller and callee *)
   p(x, y);                  (* caller sends tokens x, y to activity p*)
   u, v, w := await p;       (* caller receives tokens from p *)
   if u = P.a then ... end;  (* using the token received from p *)
   r := p(s, t);             (* same as a(s, t); r := await p *)
   await p;                  (* wait for activity to terminate *)
end O.
```

Syntax-Based Protocols

```
definition Fighter;
   (* See full example in the Zonnon Language Report *)
   (* The protocol is used to create Fighter.Karate activities *)
   protocol (* syntax of the dialog*)
     { fight = { attack ( { defense  attack } |
                          RUNAWAY [ ?CHASE] |
                          KO | fight ) }.
       attack = ATTACK strike.
       defense = DEFENSE strike.
       strike = bodypart [ strength ].
       bodypart = LEG | NECK | HEAD.
       strength = integer. }
     (*enumeration of the dialog elements to be exchanged*)
     Karate = ( RUNAWAY, CHASE, KO, ATTACK, DEFENSE,
                LEG, NECK, HEAD );
end Fighter.
```

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Zonnon Compiler

Compiler front-end is written in C# using conventional compilation techniques (recursive descent parser with full semantic control)

Compiler uses CCI framework as a code generation utility and integration platform

Three versions of the compiler are implemented (all share the single core):

- command-line compiler
- compiler integrated into Visual Studio
- compiler integrated into Zonnon Builder

Zonnon Compiler in Visual Studio

Just Demo:
Binary Search

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Common Compiler Infrastructure

Universal framework for developing compilers for .NET and integrating them into Visual Studio

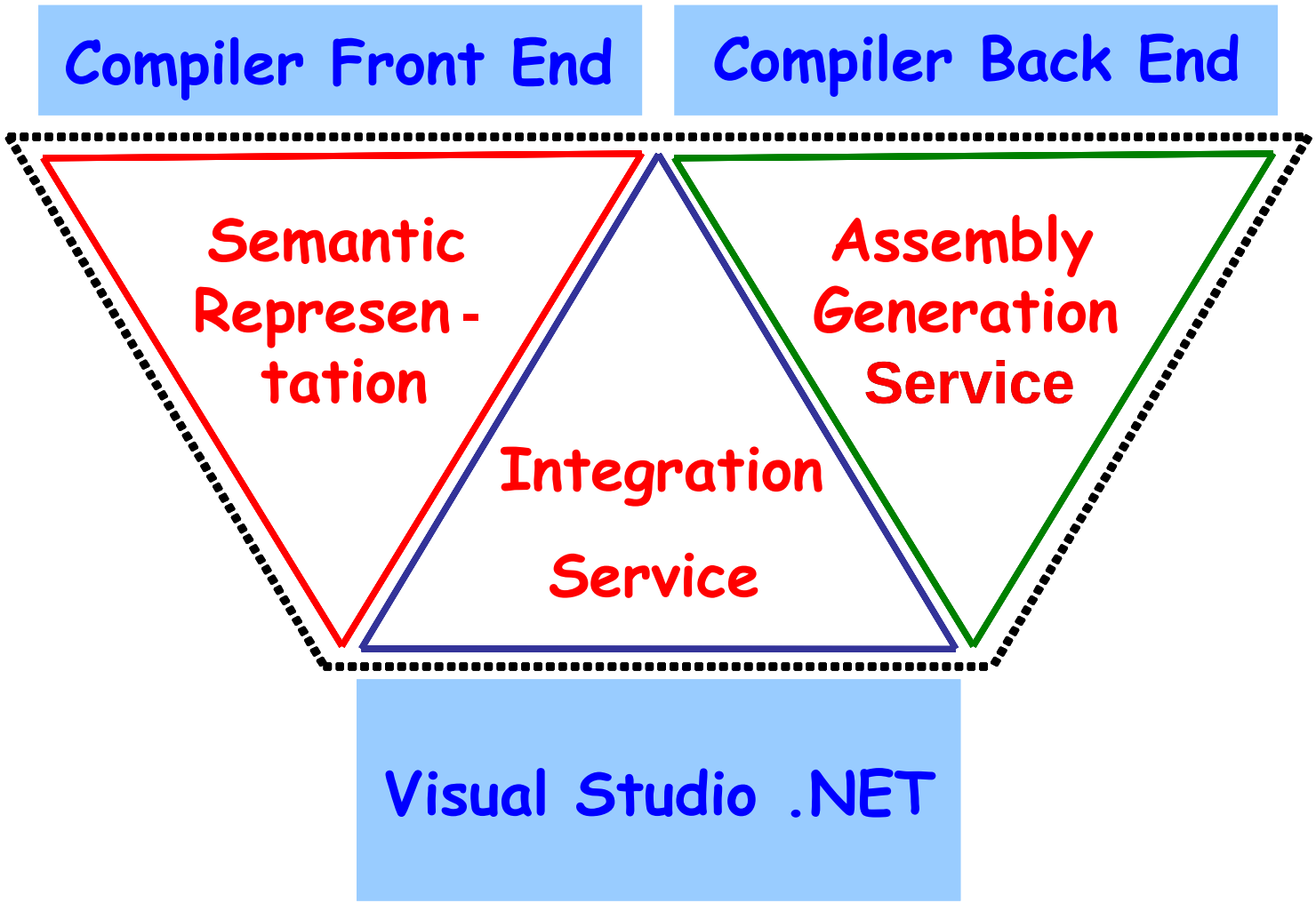
Supports CLR-oriented semantic analysis, program tree building and transformation, name resolution, error processing and IL+MD generation; doesn't support lexical & syntax analyses

Can also be used as a faster alternative to System.Reflection library

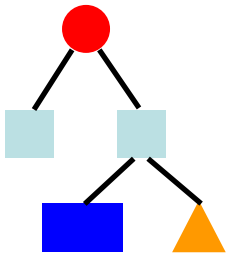
Doesn't require COM programming: C# only

Implemented in Microsoft; is used in Cw & Spec# compilers (as well as in their predecessors)

CCI Architecture



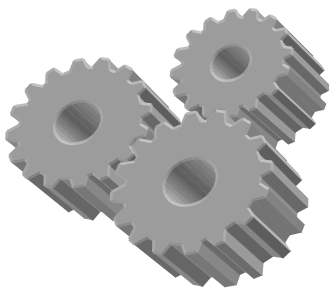
CCI Major Parts



Intermediate Representation (IR) –

A rich hierarchy of C# classes representing most common and typical notions of modern programming languages.

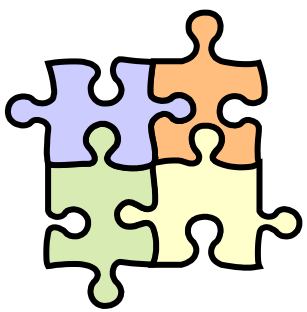
`System.Compiler.dll`



Transformers ("Visitors") –

A set of classes performing consecutive transformations IR ⇒ MSIL

`System.Compiler.Framework.dll`



Integration Service –

Variety of classes and methods providing integration to Visual Studio environment (additional functionality required for editing, debugging, background compilation, project management etc.)

CCI Way of Use: Common Principles

All CCI services are represented as **classes**.
In order to make use of them the compiler writer should define classes derived from CCI ones.
(The same approach is taken for Scanner, Parser, IR, Transformers, and for Integration Service)

Derived classes should implement some abstract or virtual methods declared in the base classes (they compose a "unified interface" with the environment)

Derived classes may (and typically do) implement some **language-specific functionality**.

CCI Way of Use: Parser Example

```
using System.Compiler;

namespace ZLanguageCompiler
{
    public sealed class ZParser : System.Compiler.Parser
    {
        public override ... ParseCompilationUnit(...)
        {
            . . .
        }

        private ... ParseZModule(...)
        {
            . . .
        }
    }
}
```

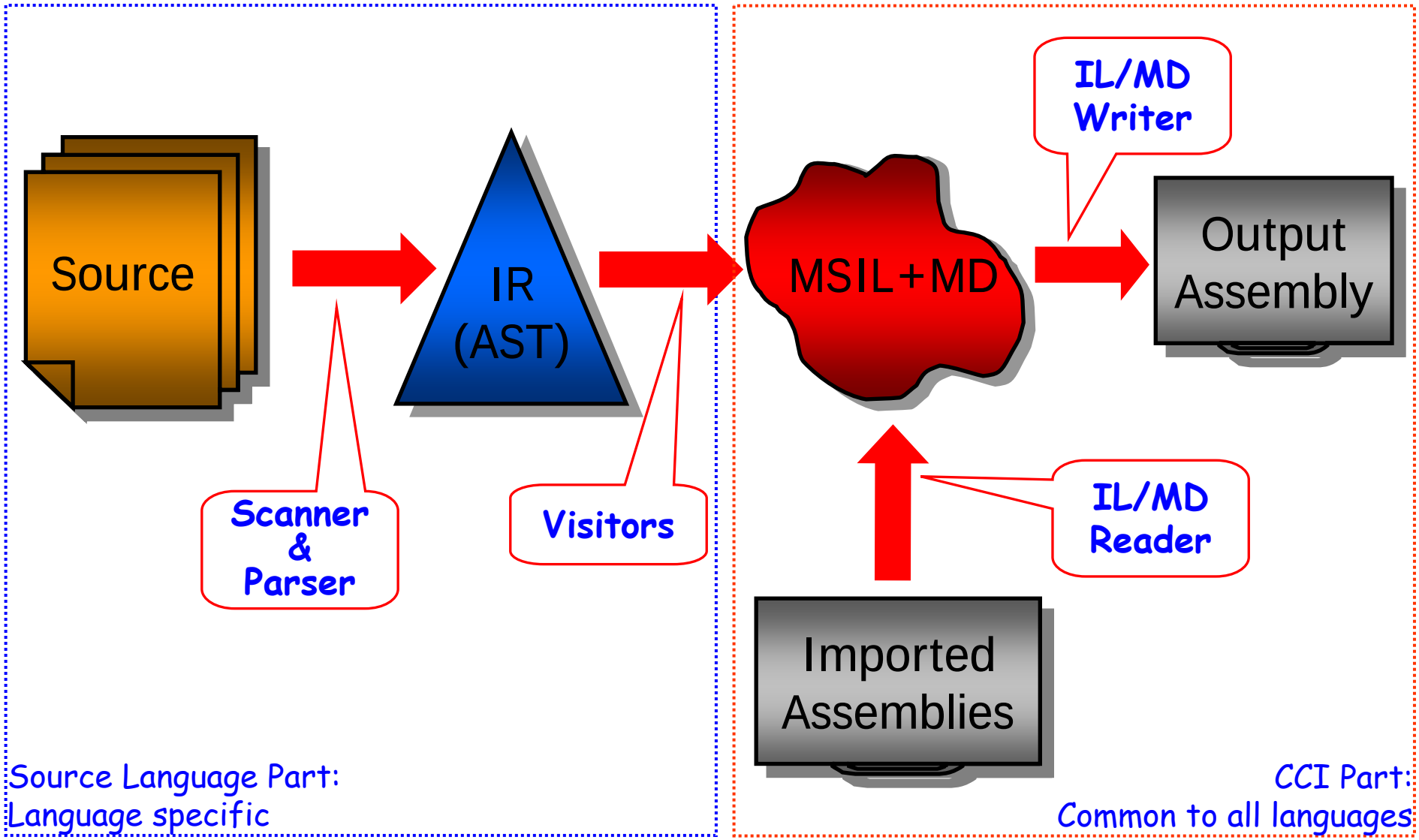
Call

Prototype parser: abstract class from CCI

Parser's "unified interface": implementation of the interface between Z compiler and environment

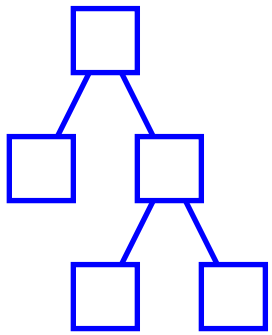
Z parser's own logic

CCI Compilation Model 1

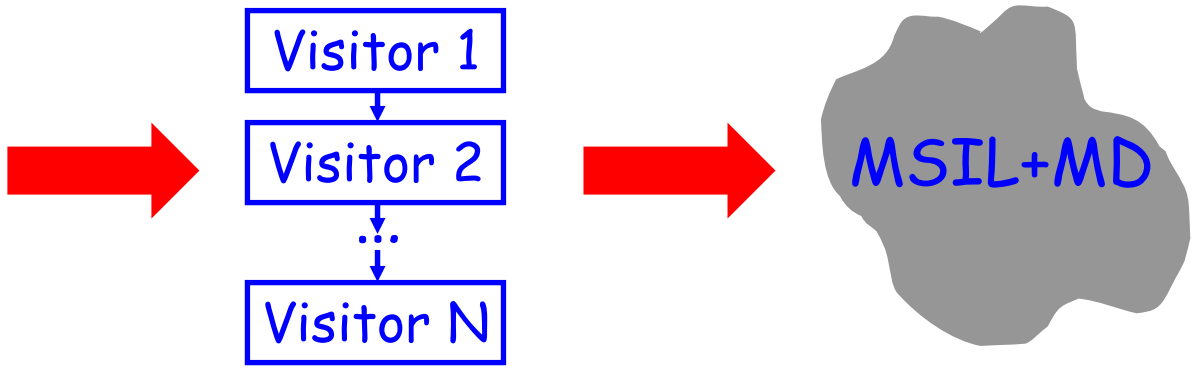


CCI Compilation Model 2

CCI IR Hierarchy

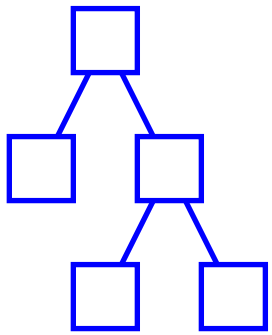


CCI Base Transformers

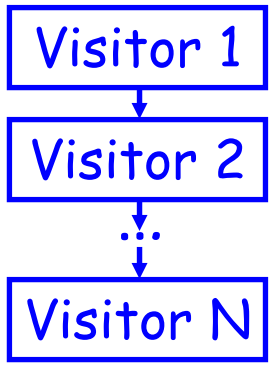


CCI Compilation Model 2

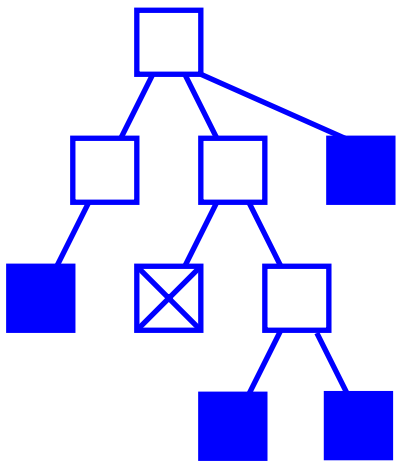
CCI IR Hierarchy



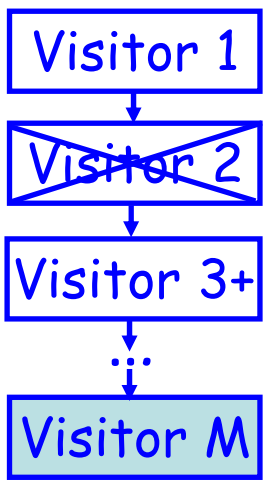
CCI Base Transformers



X Language IR Hierarchy



X Language Transformers



CCI Compilation Model 3: Example

Extending the IR Hierarchy

Ada `exit` statement: `exit when <Condition>;`

CCI Compilation Model 3: Example

Extending the IR Hierarchy

Ada `exit` statement: `exit when <Condition>;`

1. Extend existing `Exit` node

```
public class AdaExit : Exit {
    Expression condition;
}
```

2. Add new statement to the hierarchy

```
public class AdaExit : Statement {
    Expression condition;
}
```

```
public class If : Statement
{
    Expression condition;
    Block      falseBlock;
    Block      trueBlock;
}
```

3. Use semantic equivalent from the existing hierarchy

Represent `Exit` as an instance of class `If` with
`condition` == *<Condition>*,
`falseBlock` == `null`, and
`trueBlock` == `Block` with one element of type `Exit`.

CCI Compilation Model 4: Example

Extending a Visitor

```
using System.Compiler;

namespace AdaLanguageCompiler
{
  public sealed class Looker : System.Compiler.Looker
  {
    public override Node Visit ( Node node )
    {
      switch ( node.NodeType ) {
        case NodeType.AdaExit:
          return this.VisitAdaExit(node);
        default:
          return base.Visit(node);
      }
    }
    private If VisitAdaExit ( AdaExit node )
    {  /* Transform AdaExit node to If node */  }
  }
}
```

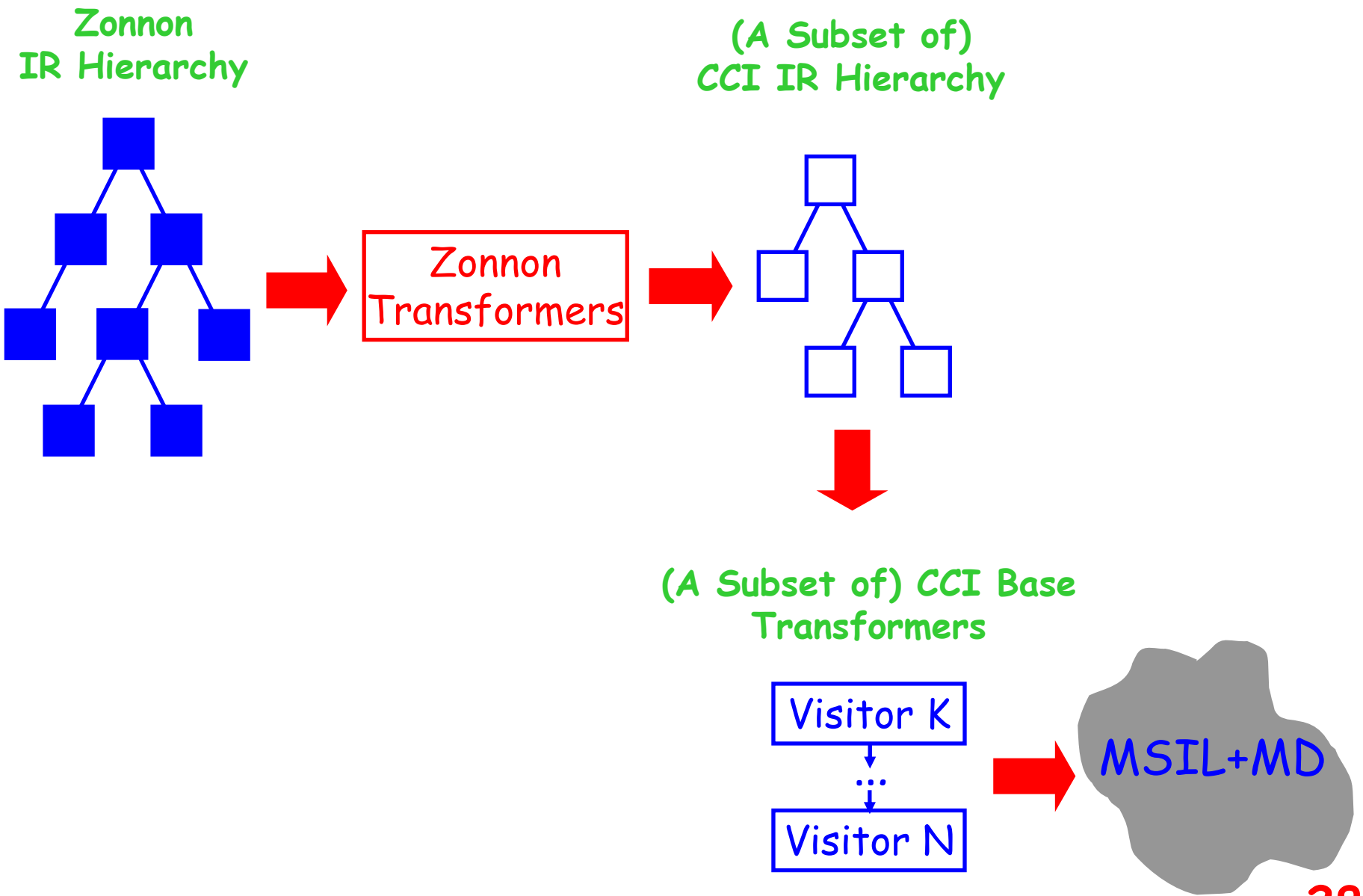
Prototype visitor: base CCI class

"Dispatcher" method

Call to prototype visitor

Additional semantic functionality

Zonnon Compilation Model 1



Zonnon Compilation Model 2

Example: Zonnon Tree & Transformers

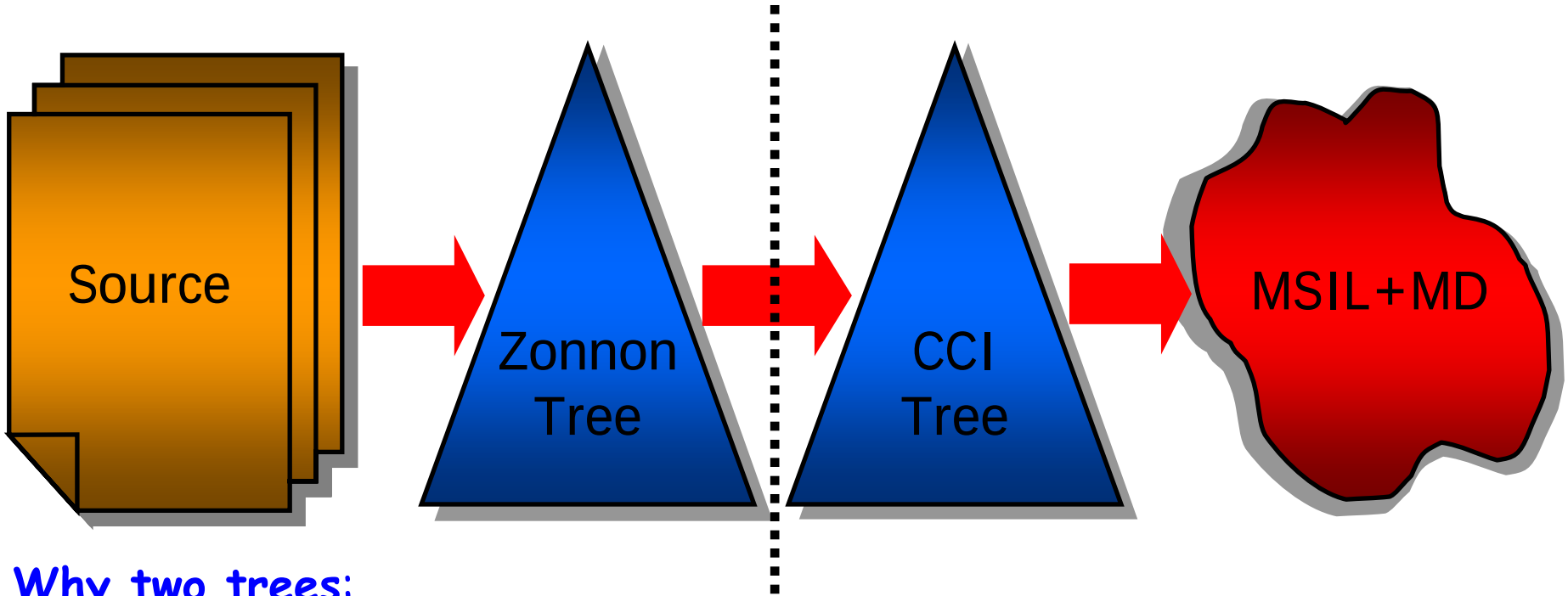
```
public sealed class DEFINITION_DECL : UNIT_DECL
{
   // Constructor
   public DEFINITION_DECL ( Identifier name ) : base(name) { }
   // Structure
   public DECLARATION_LIST  locals; // members, procedure headings
   public UNIT_DECL         base_definition;
   public UNIT_DECL         default_implementation;

   // Fills the structure after parsing the source
   public static DEFINITION_DECL create
                  ( IDENT_LIST name, MODIFIERS modifiers ) {  }
   // Resolves forward declarations
   public override NODE resolve ( ) { ... }
   // Checks semantic correctness
   public override bool validate ( ) { ... }
   // Generates CCI node(s)
   public override Node convert ( ) { ... }
}
```

Zonnon Transformers

convert transformer encapsulates mappings Zonnon->CLR

Zonnon Compilation Model 3



Why two trees:

- Reflect the conceptual gap between Zonnon and the CLR
- Zonnon semantic representation is kept independent from the CCI and the target platform
- Conversion Zonnnon tree -> CCI tree explicitly implements and encapsulates mappings from the Zonnon language model to the CLR

Zonnon Compilation Model 4

Some Mappings Zonnon->CLR

```
definition D;
   var x : T;
   const k = 10;
   type e = (a,b,c);
   procedure p ( y : T );
end d.
```

```
interface D {
   T x { get; set; }
    // Nothing
    // Nothing
   void p ( T y );
}
```

```
implementation D;
   var x, y : T;
   procedure p ( y : T ) implements D.p;
   begin
       ...x...
      ...k...
      ...e...
    end p;
end d.
```

```
public class D_implem : D {
    enum e { a, b, c };
    T x, y;   // x hides D's x
    void p ( T y )
    {
        ...x...   // "native" x
        ...k...   // D_default.k
        ...e...   // D_default.e
   }
}
```

Zonnon Compilation Model 5

Some Mappings Zonnon->CLR

```
object O implements d;
  procedure p ( y : T ) implements d.p;
  begin
     ...x...
  end p;
end O.
```

```
public sealed class O : D, D_implem          // Option 1
{
    public override void p ( T y ) { // hides D_implem's p()
      ...x...
    }
}
```

```
public sealed class O : D {                  // Option 2
    private D_implem mixed;
    public override void p ( T y ) {
      ...mixed.x...
    }
}
```

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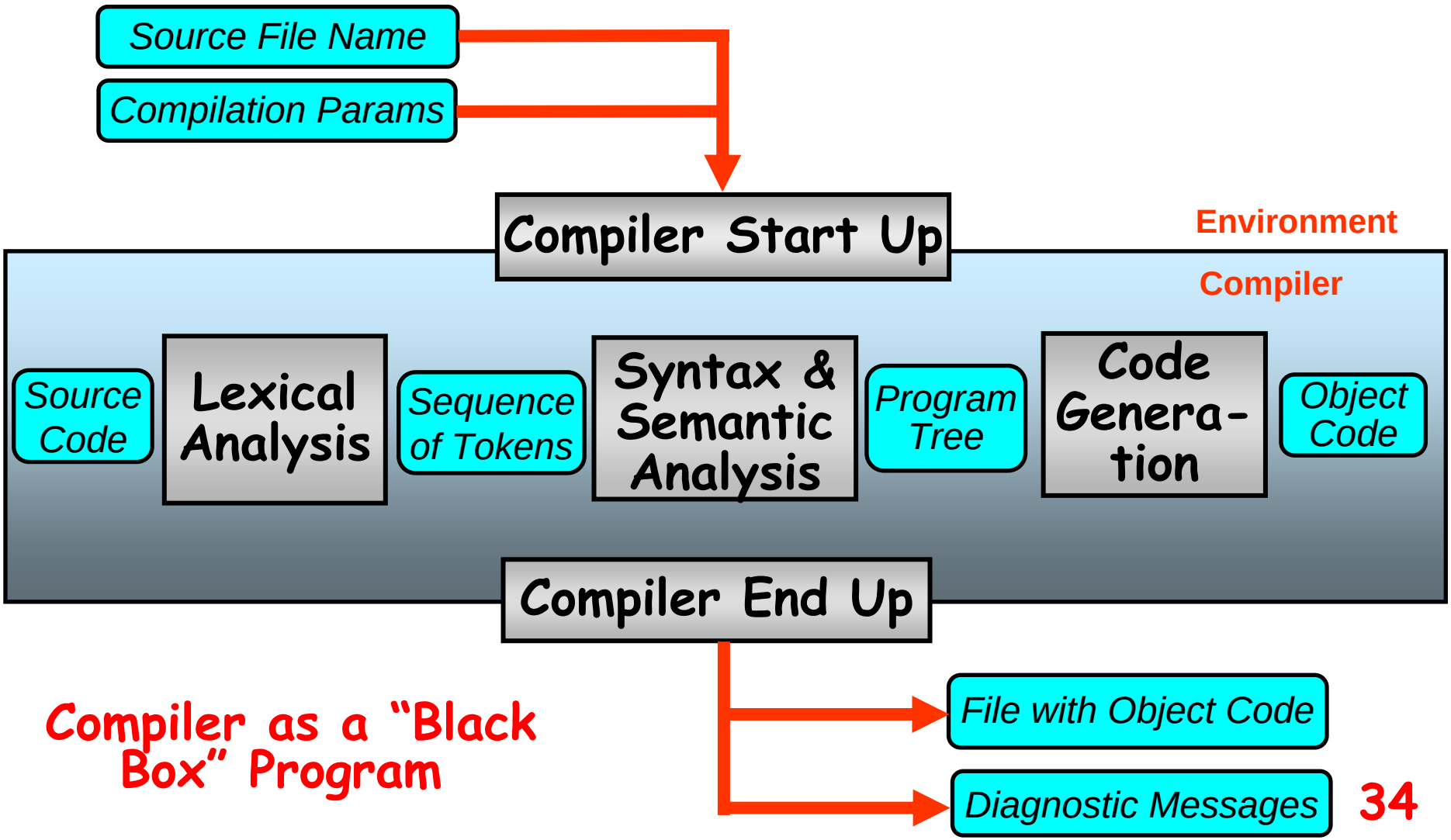
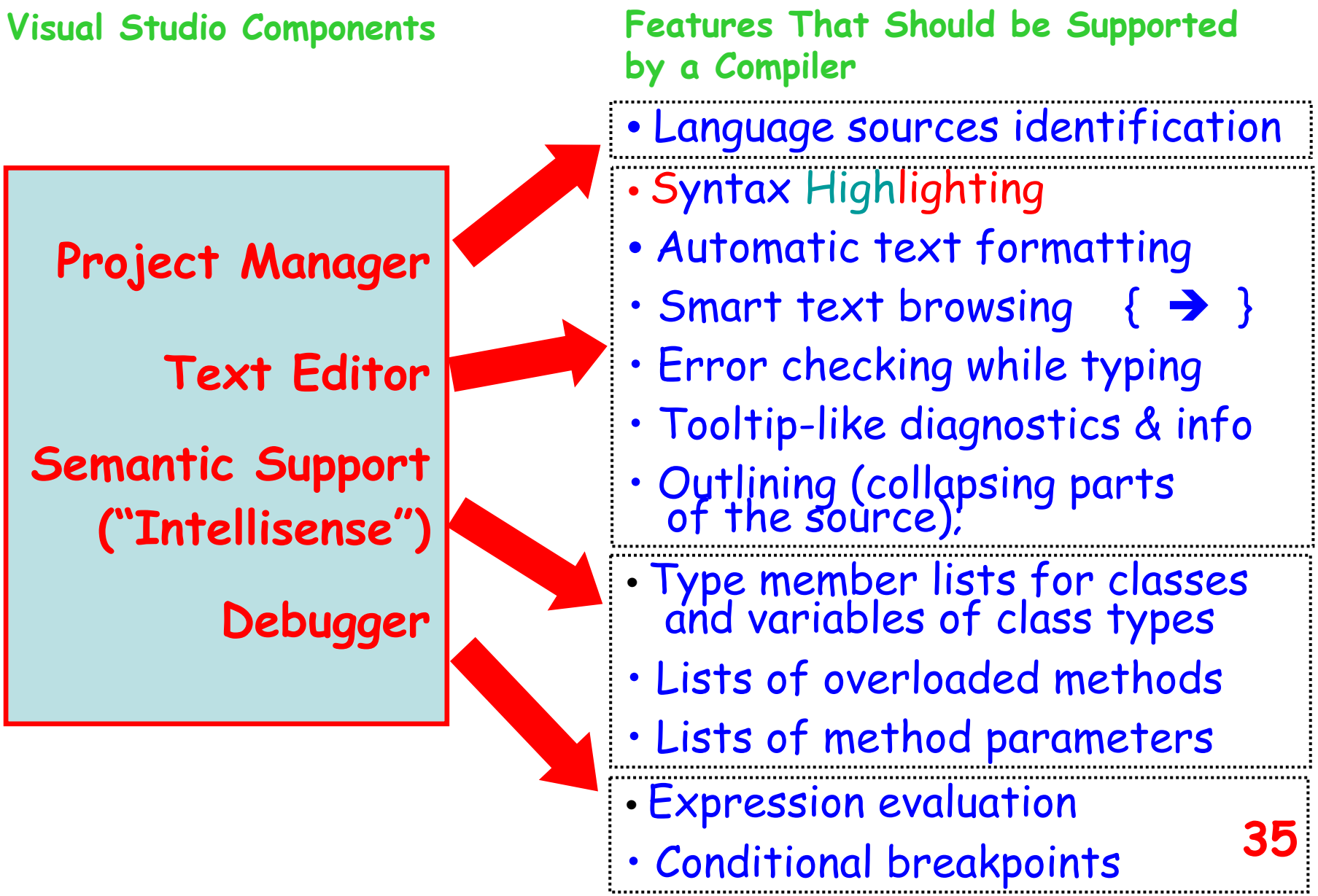
Compiler Integration: Traditional Approach



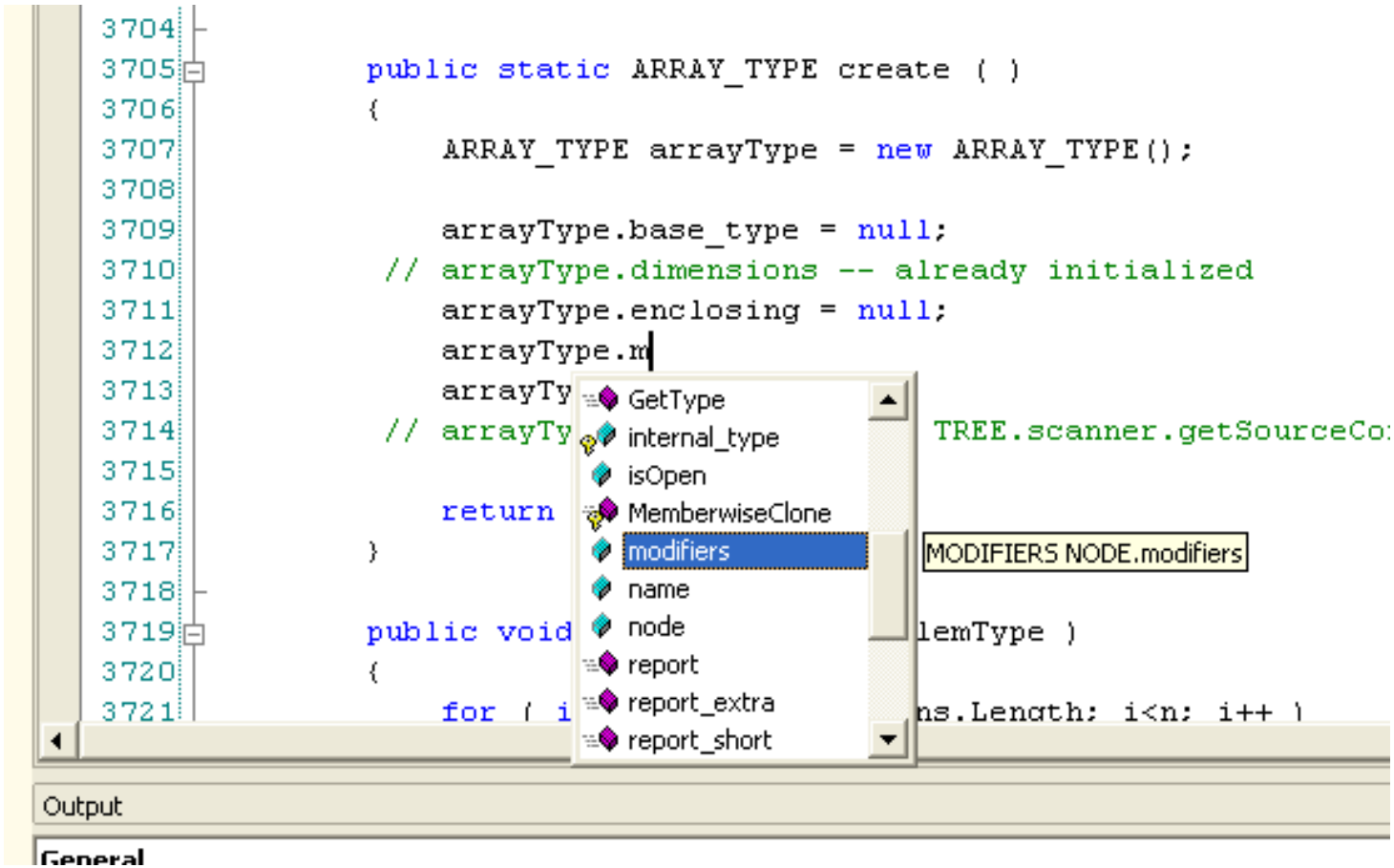
Compiler as a "Black Box" Program

What Does Integration Assume? 1

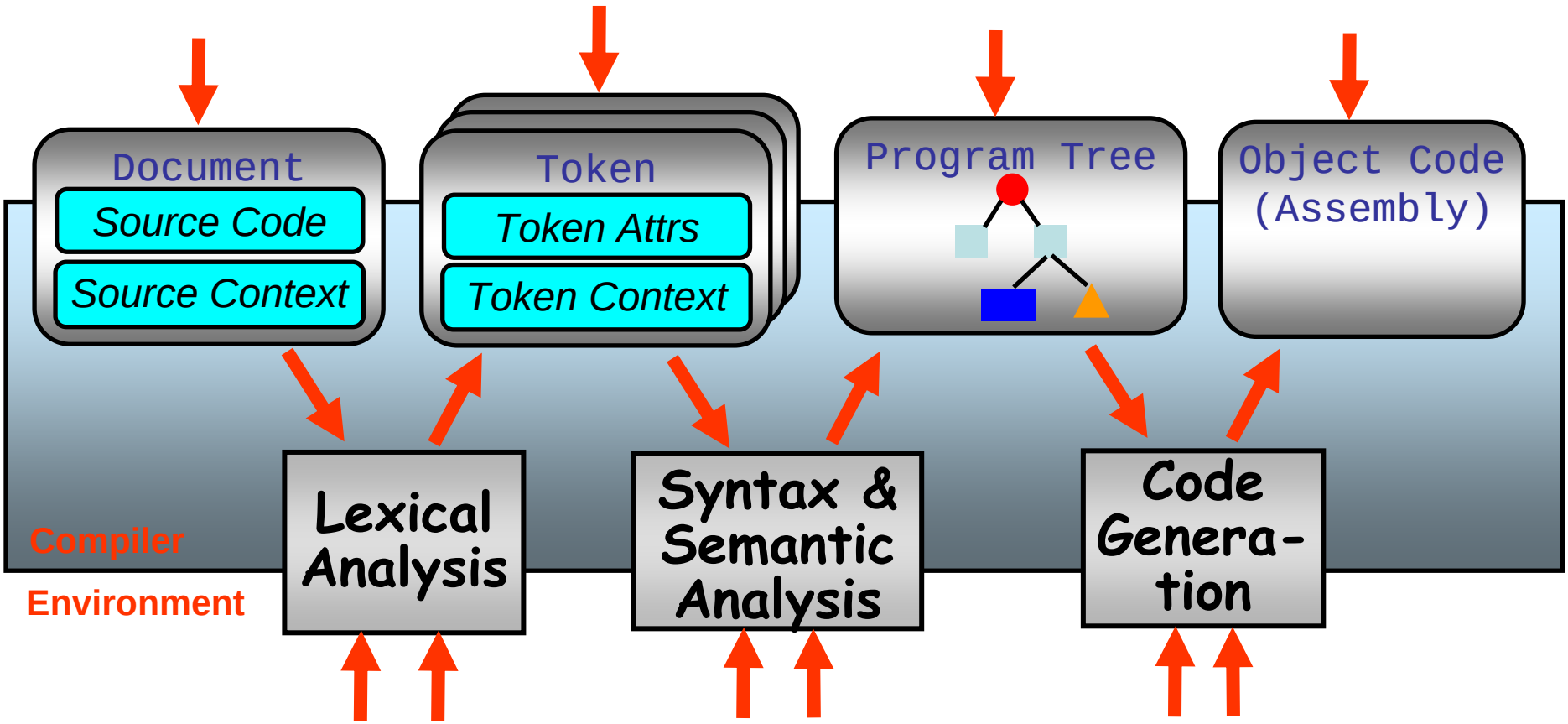


What Does Integration Assume? 2

Example of "Intellisense" Feature

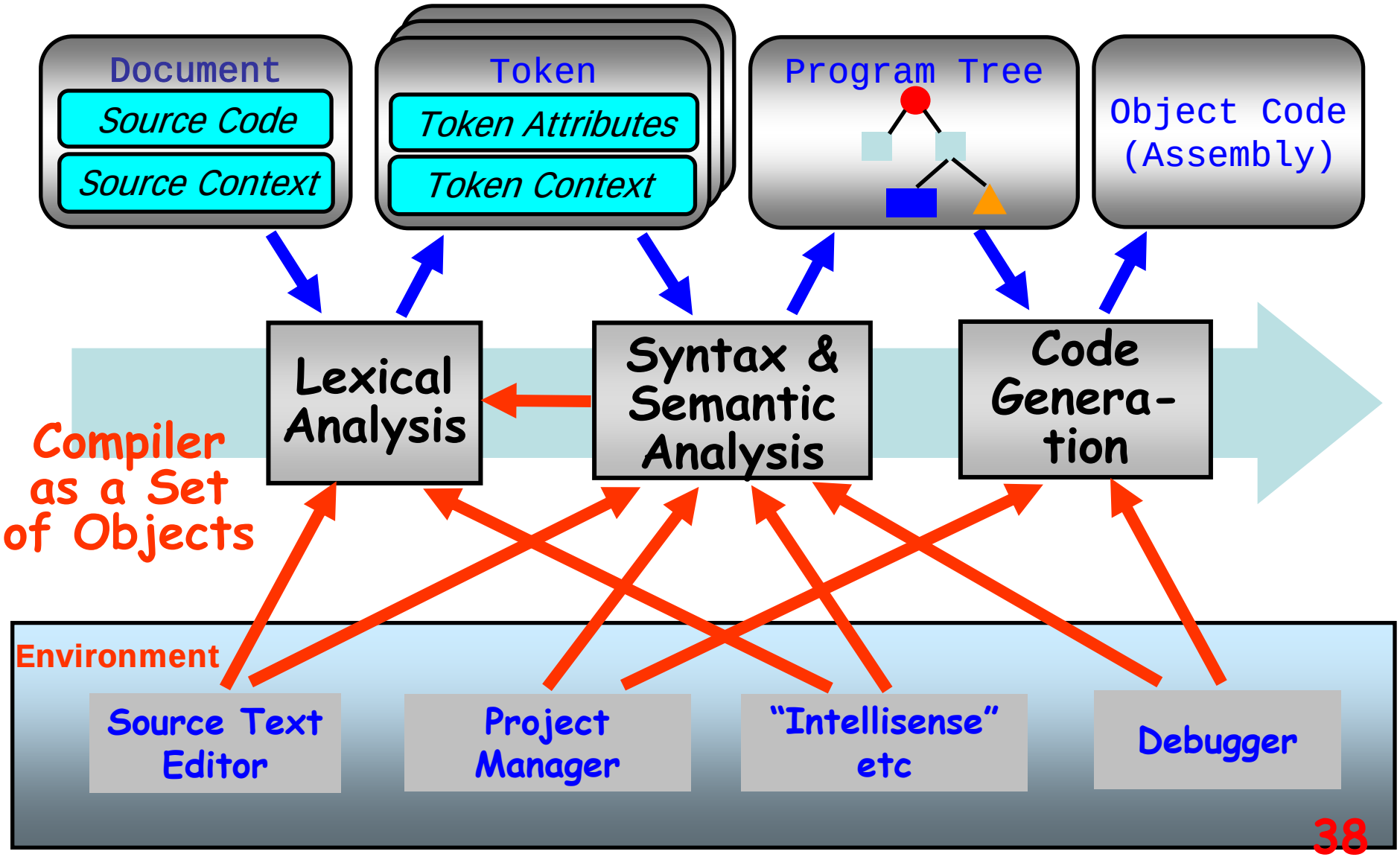


Compiler Integration: CCI Approach



Compiler as a Collection of Resources

Compiler Integration: CCI Approach



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Zonnon Builder

A standalone, easy-to-use integrated development environment: convenient for beginners and looks familiar to Pascal programmers

A simple and light-weight alternative to Visual Studio

Supports a typical development cycle comprising source code editing, compiling, execution, testing, debugging, project management, file versioning

Supports a simplified development cycle where a single program file is being developed, compiled, debugged and run

Just Demo:
Chess Notebook Program

Zonnon Web Page

www.zonnon.ethz.ch

Zonnon program samples
(including Chess Notebook),
Zonnon Test Suite (1000+ test cases),
Zonnon Language Report,
Related Papers and Talk Slides,
Zonnon Compiler Distribution
(updated almost every Monday)

Conclusion

Zonnon is a new programming language which combines conventional notation and classic modularity with modern and powerful paradigms like object orientation and language-level concurrency

Zonnon can be used together with other .NET languages within the same environment (Visual Studio)

To the best of our knowledge, the Zonnon compiler is the first compiler developed outside of Microsoft that is fully integrated into Visual Studio

Zonnon is used for teaching minor students programming (as the first language) in Nizhny Novgorod university, Russia

People Involved

J.Gutknecht, ETH Zürich
Primary Language Author

B.Kirk, Robinson Associates

D.Lightfoot, Oxford Brookes University
Zonnon Language Report

H.Venter, Microsoft
Common Compiler Infrastructure

E.Zouev, ETH Zürich
Zonnon Compiler, Integration into VS

V.Romanov, Moscow State University
Zonnon Test Suite, Zonnon Builder, Chess NB

A.Freed, NASA
First "Industrial" Zonnon User

V.Gergel, R.Mitin, NN State University, Russia
An Introductory Course in Programming
based on Zonnon; Zonnon Program Samples

Questions?
Suggestions?
Critique?