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  - The Common Language Specification (CLS) is an agreement between language designers and framework (that is, class library) designers. It specifies a subset of the CTS and a set of usage conventions.
  - The Virtual Execution System (VES) implements and enforces the CTS model. The VES is responsible for loading and running programs written for the CLI. It provides the services needed to execute managed code and data, using the metadata to connect separately generated modules together at runtime.

# The Common Language Runtime

- [Ref: Smith & Nair, *Virtual Machines: Versatile Platforms for Systems and Processes*, §5.5]
- [Ref: CLR Overview, https://docs.microsoft.com/en-us/dotnet/standard/clr]
- The Common Language Runtime (CLR) is an implementation of the CLI and is part of Miscrosoft's overall .NET framework.
  - Modules are of a standard format, containing metadata and code in the Microsoft intermediate language (MSIL).
  - Supports multiple languages, including C#, Java, Visual Basic .NET, and Managed C++.

# Validity and Verifiability

- Code modules can be verified for type safety similar to Java binary classes.
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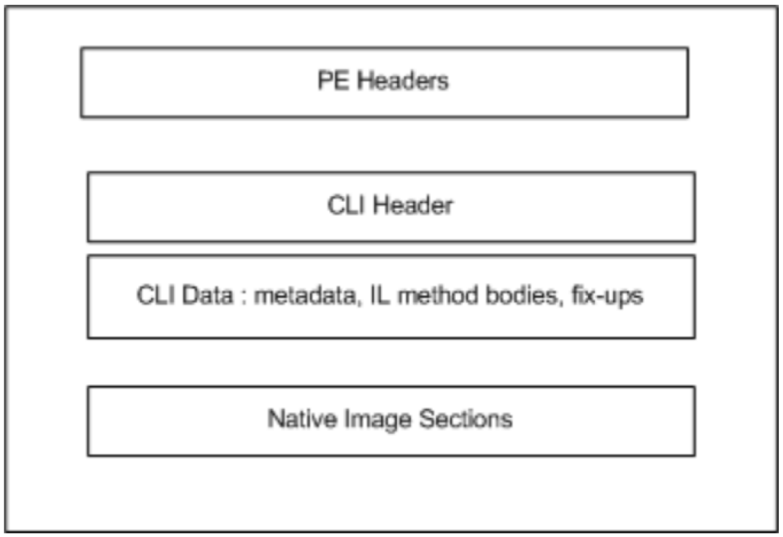
- Java only allows verifiable and unverifiable classes.

# Assemblies

- Assemblies form the fundamental units of deployment, version control, reuse, activation scoping, and security permissions for .NET-based applications.

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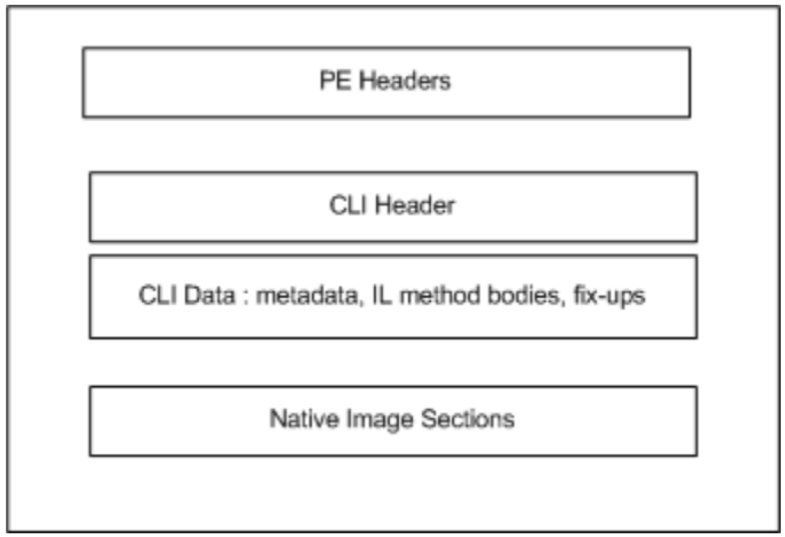


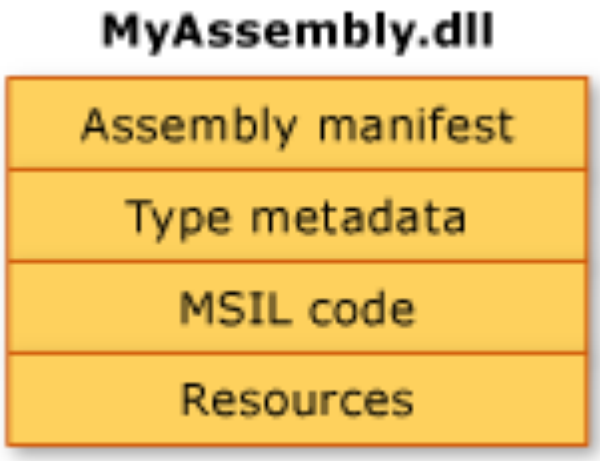

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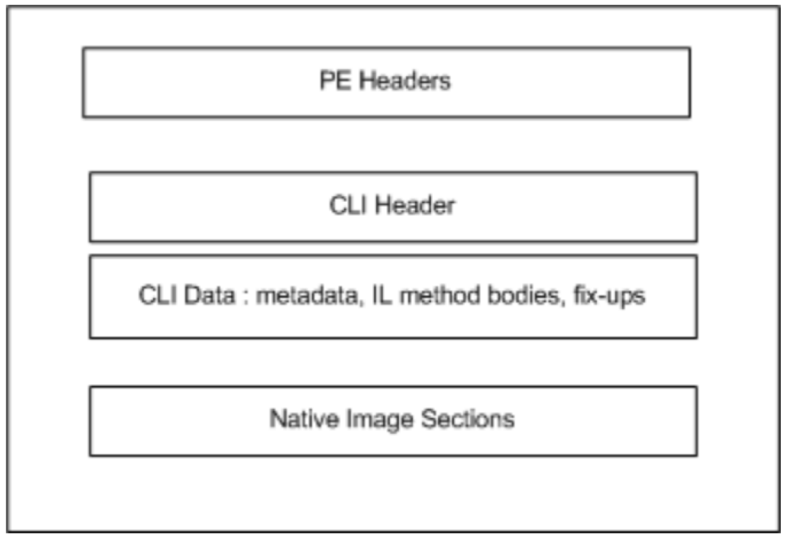


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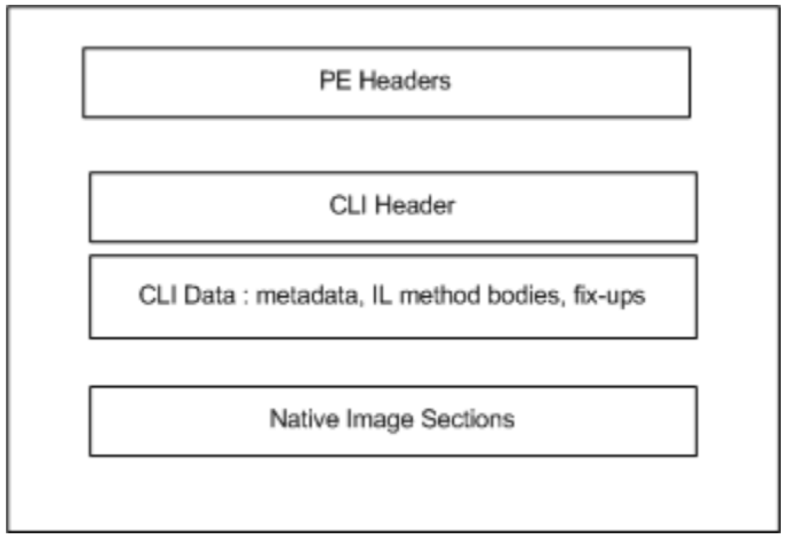


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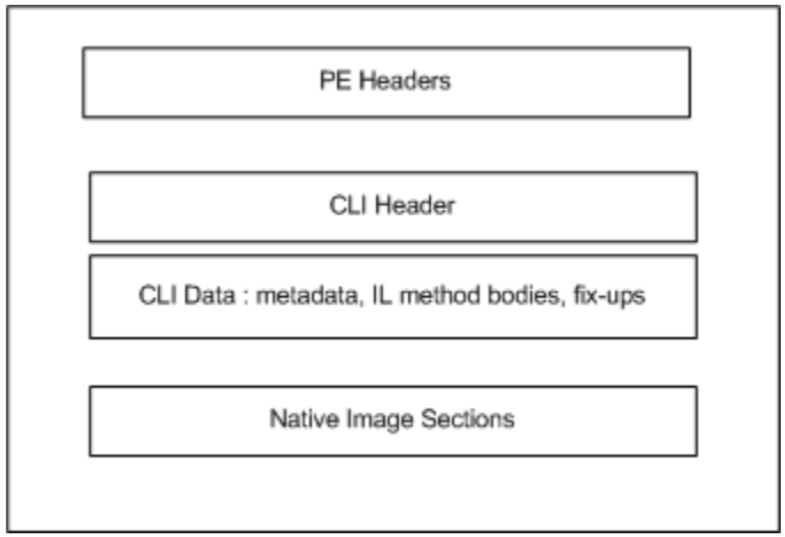
  - Assemblies are only loaded into memory if they are required.

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  - Typically JIT-compiled into native code.
- Differences from Java bytecode.
  - The local data area and argument area for an MSIL method are not defined to be part of a stack frame (although they might be implemented as such).
  - Rather than a single constant pool, MSIL supports a number of metadata tables called streams.
    - These tables are accessed by tokens identifying the stream and the entry within it.
  - MSIL instructions are type-generic (only one `add` instruction, with the type being inferred from the operand types).
  - Certain MSIL instructions are unverifiable, in order to support C-like memory operations and control flow.

# Cross-Language Interoperability

- Interoperability is supported in a more integrated way than in Java, extending to data.
  - A type defined in one language can be used across other languages.
    - Made possible by common metadata.
    - Hidden cost: may require significant changes to existing language implementations.
  - The CLS component of the CLI contains a set of standard rules intended to ensure interoperability.