Tamara Dahlgren, Tom Epperly, Scott Kohn, & Gary Kumfert

Center for Applied Scientific Computing

Audience Calibration

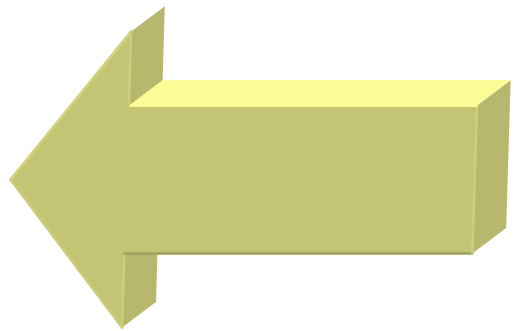
- What is a component?
- Who writes code?
- Who uses code?
- What languages used?
- What platforms used?
- # 3rd party libraries your code uses?
- # apps uses your libraries?

Outline

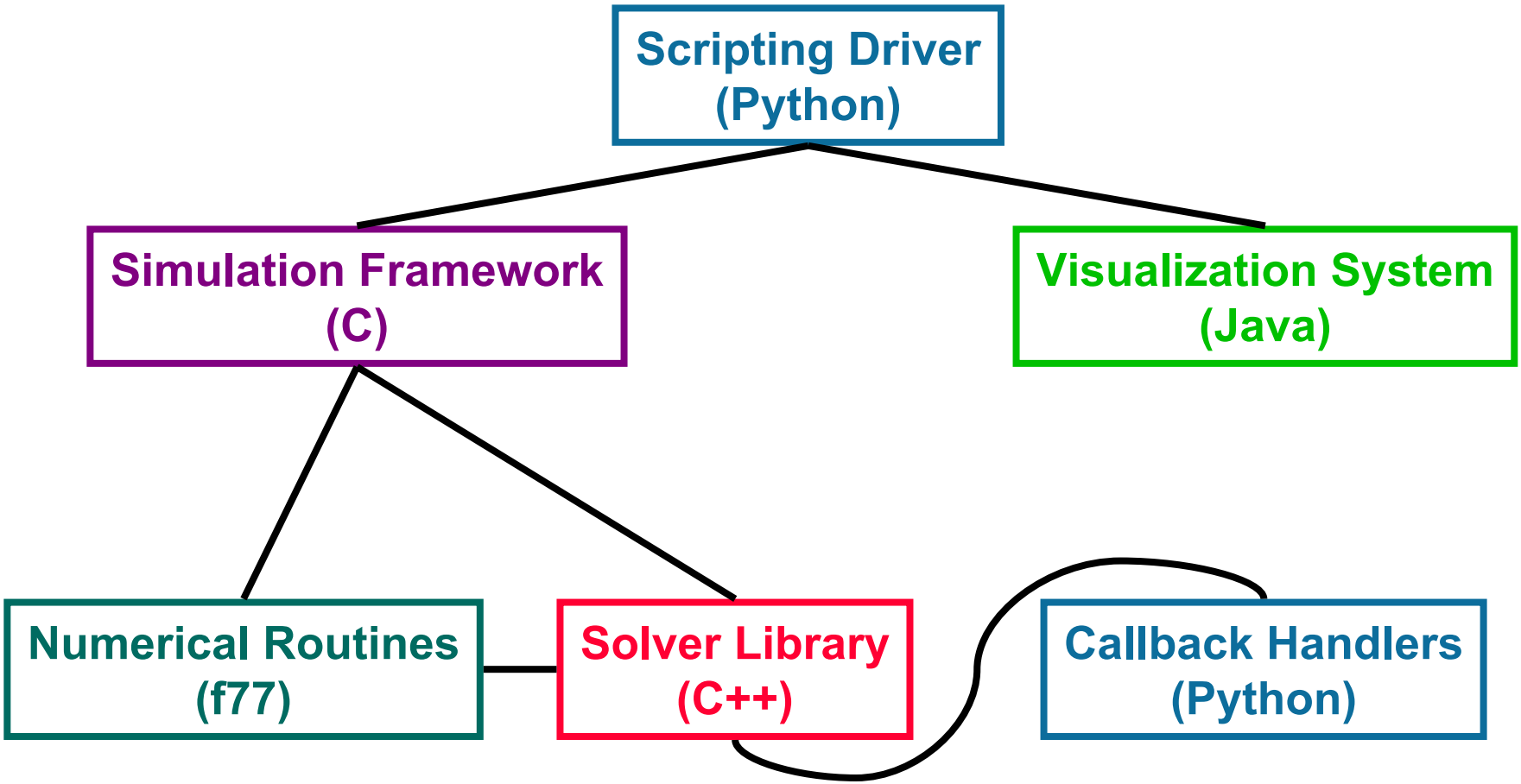
- Problem Motivation
- Babel Solution Strategy
- SIDL
- Using Babel
- Outstanding Problems
- Future R&D

Problem Motivation

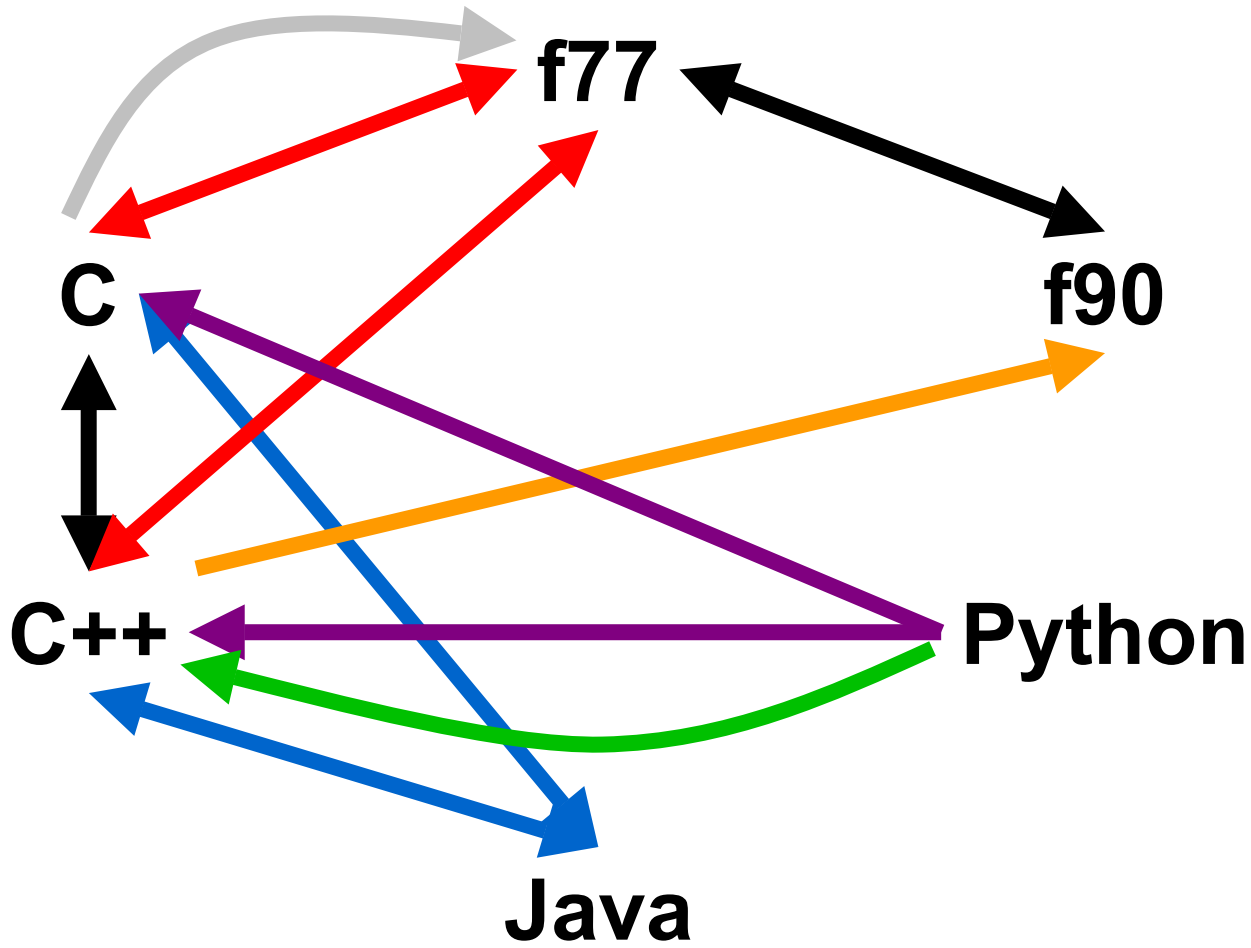
- Code Reuse is Hard.
- Scientific Code Reuse is Harder!
- Barriers to Reuse...
  - Language Interoperability
  - Semantics
  - Software Portability
  - Lack of Standards
  - More...



What I mean by "Language Interoperability"



Current Language Interoperability



Native

cfortran.h

SWIG

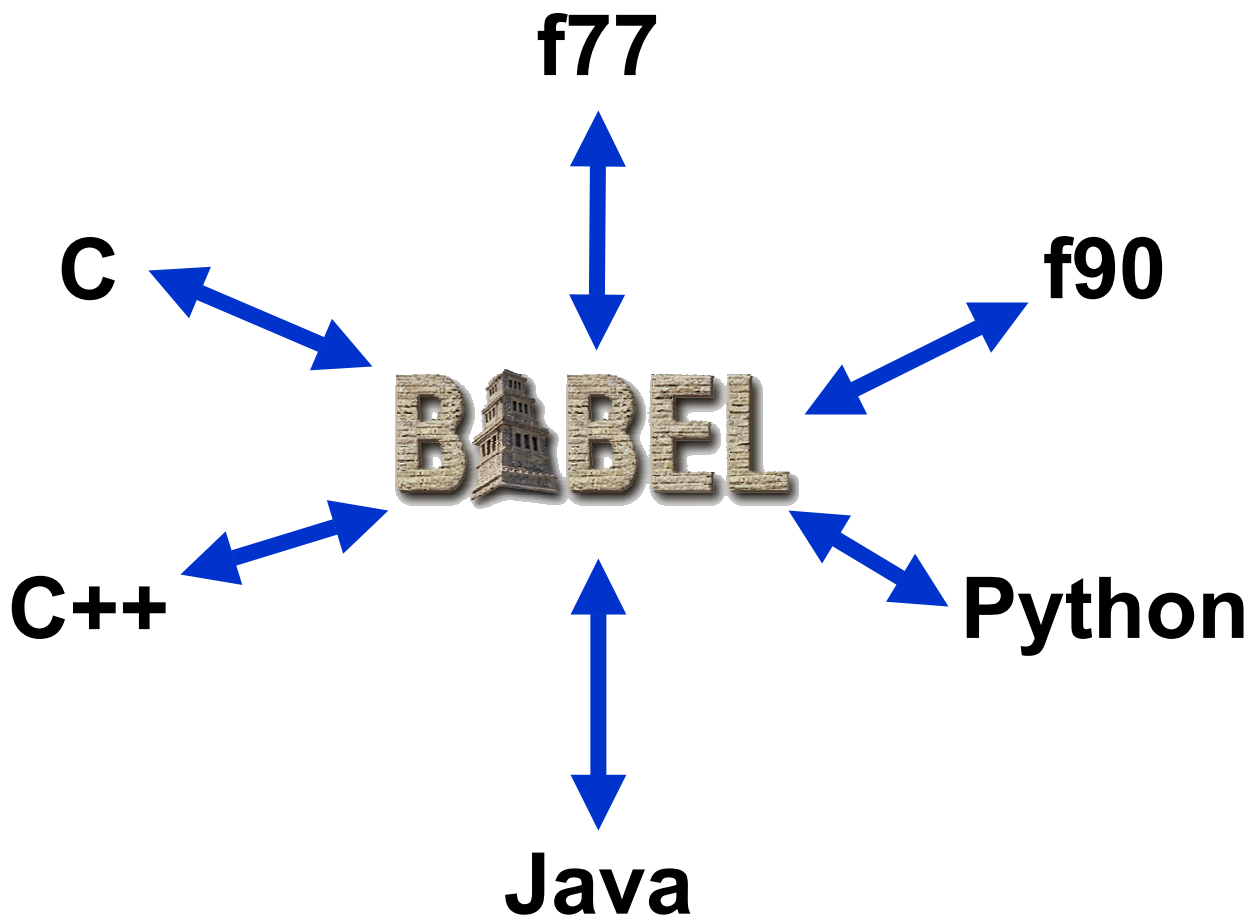
JNI

Siloon

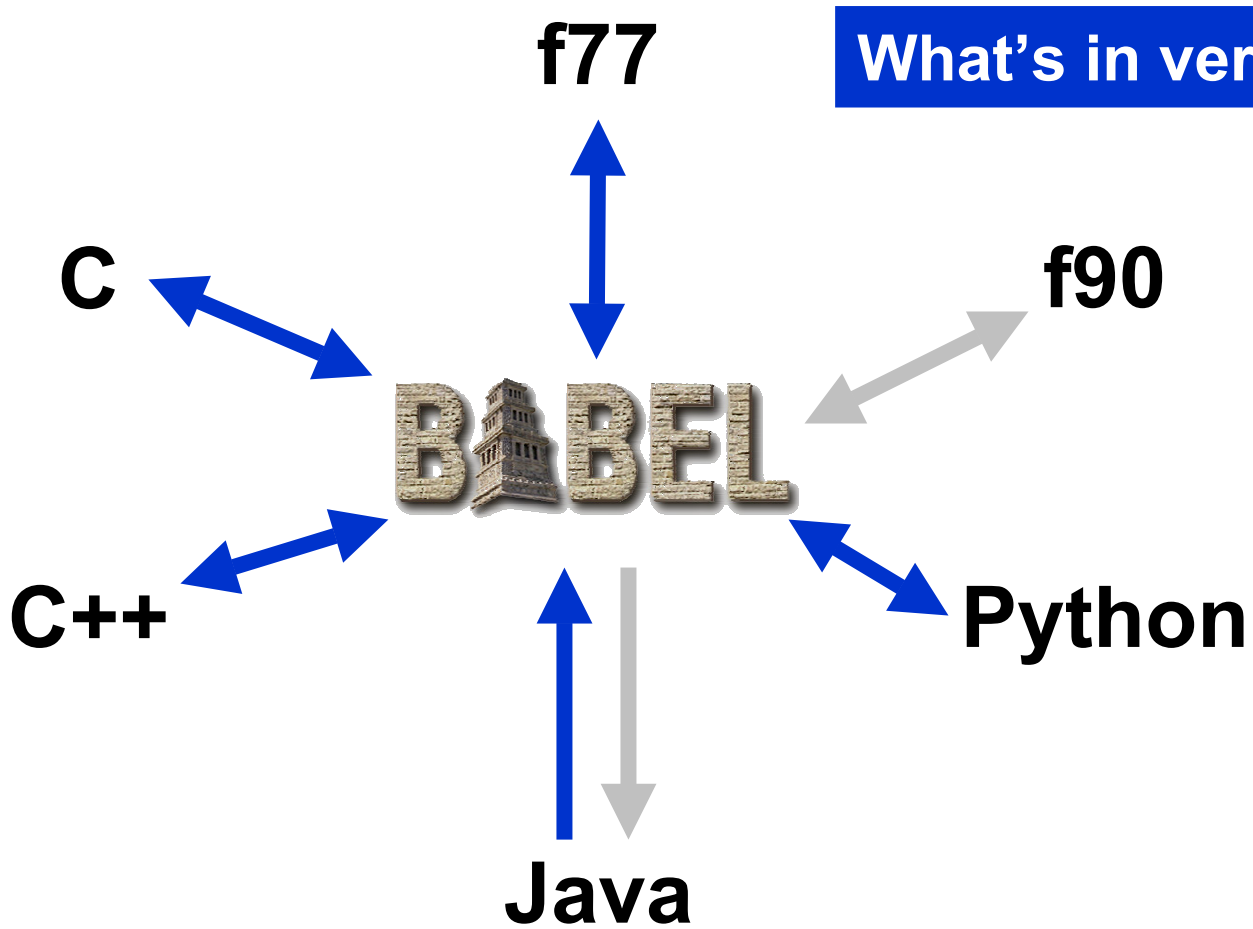
Chasm

Platform Dependent

Babel Enabled Language Interoperability



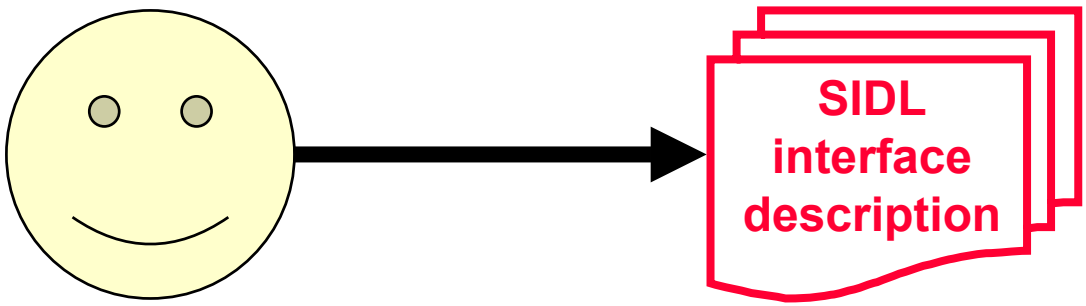
Babel Enabled Language Interoperability



Outline

- Problem Motivation
- **Babel Solution Strategy**
- SIDL
- Using Babel
- Outstanding Problems
- Future R&D

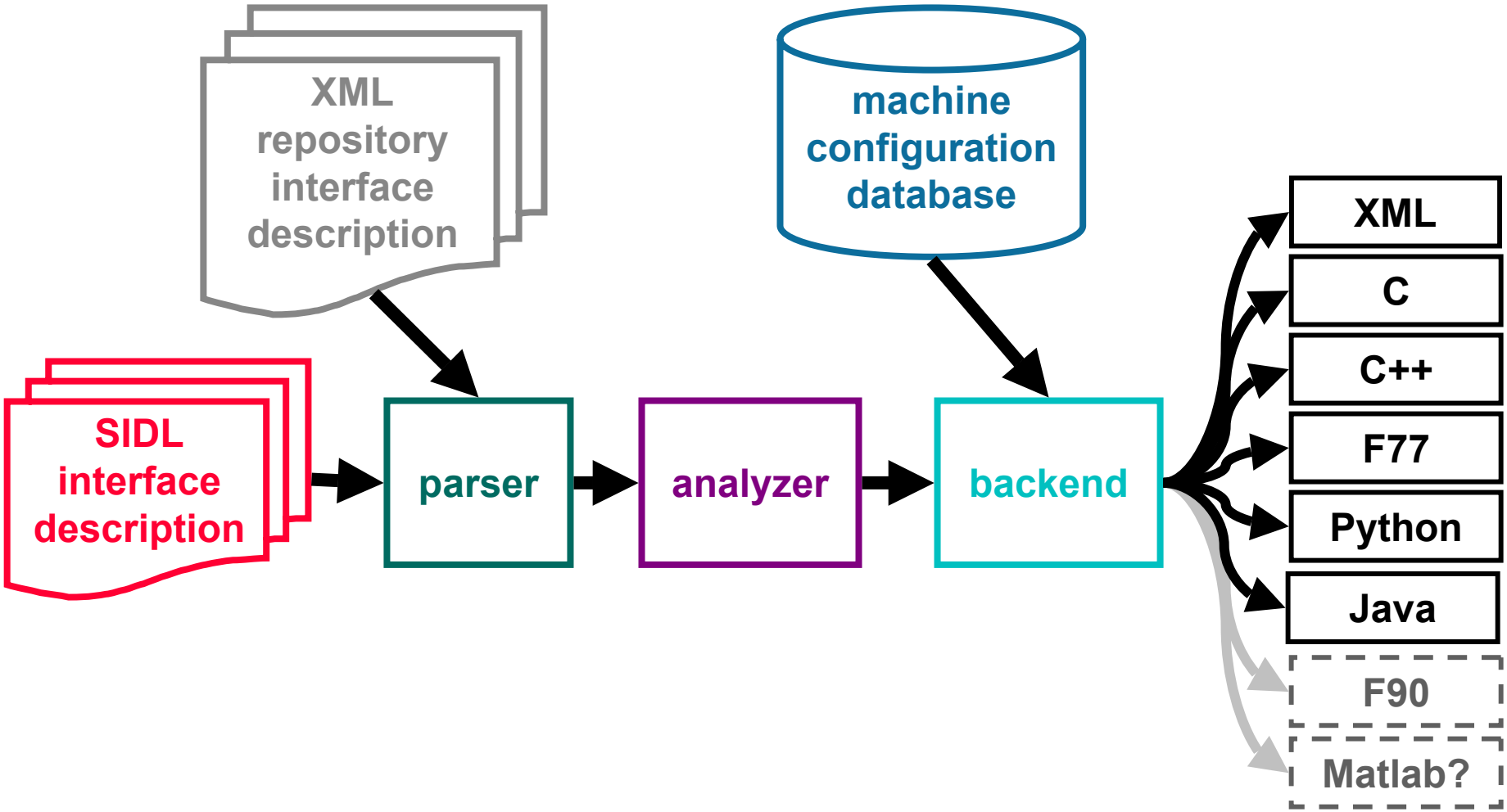
Developer Writes Interface



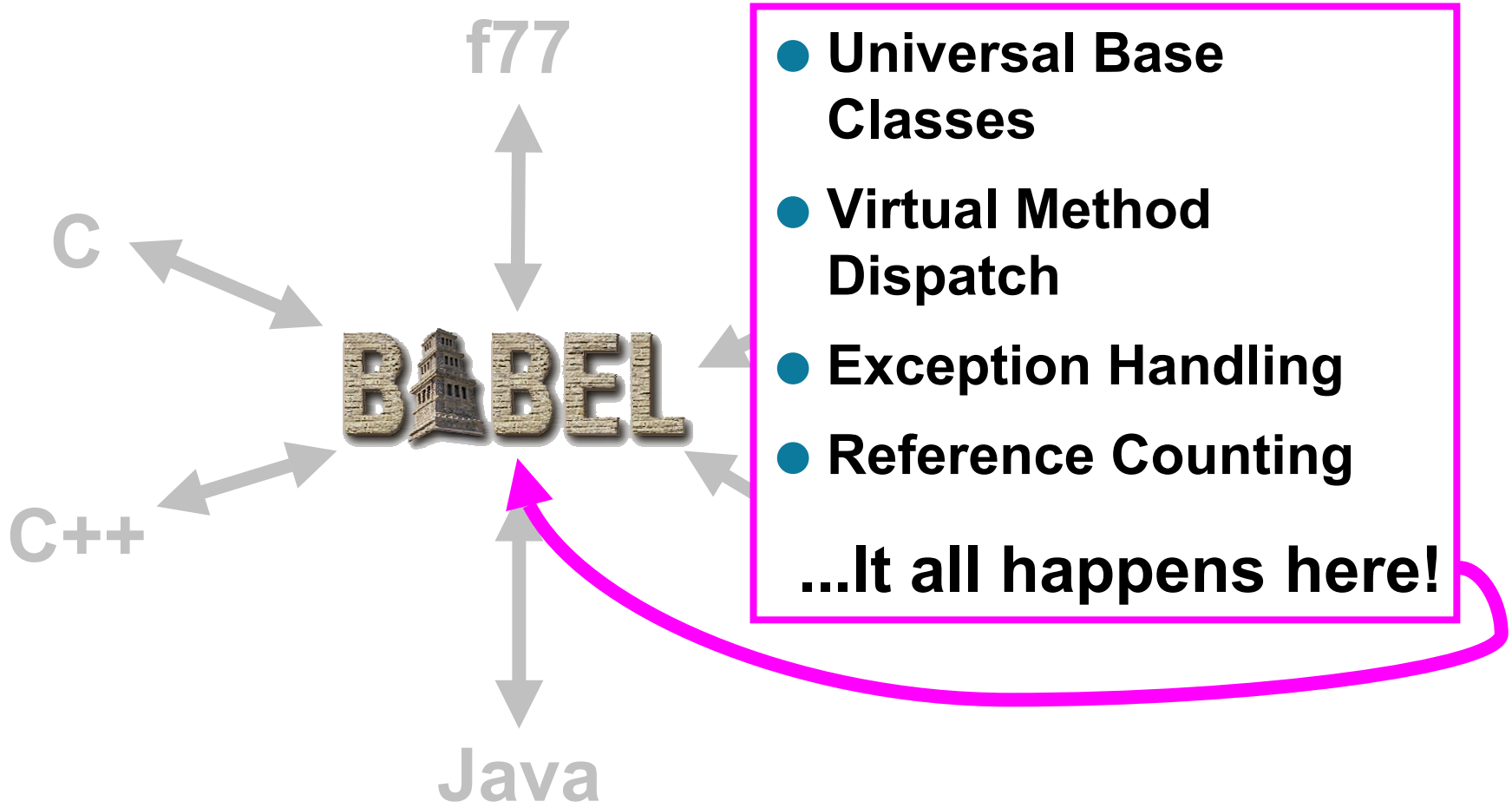
- SIDL: Scientific Interface Definition Language
- Similar to CORBA/COM IDLs...
  - Language/Platform Independent
- ...but tuned for scientific apps
  - complex numbers
  - dynamic, multidimensional arrays

```
version MySolverLib 0.1.0;

import ESI;

package MySolverLib {
  interface MatrixGenerator { ... }
  class OptionDatabase {
    void getOption( in string name,
                    out string val );
  }
  class Vector implements-all ESI.Vector {
    void setOptions( in OptionDatabase db );
  }
  class Bizarre implements MatrixGenerator {
     ...
     void setData( in array<dcomplex,2> a );
  }
}
```

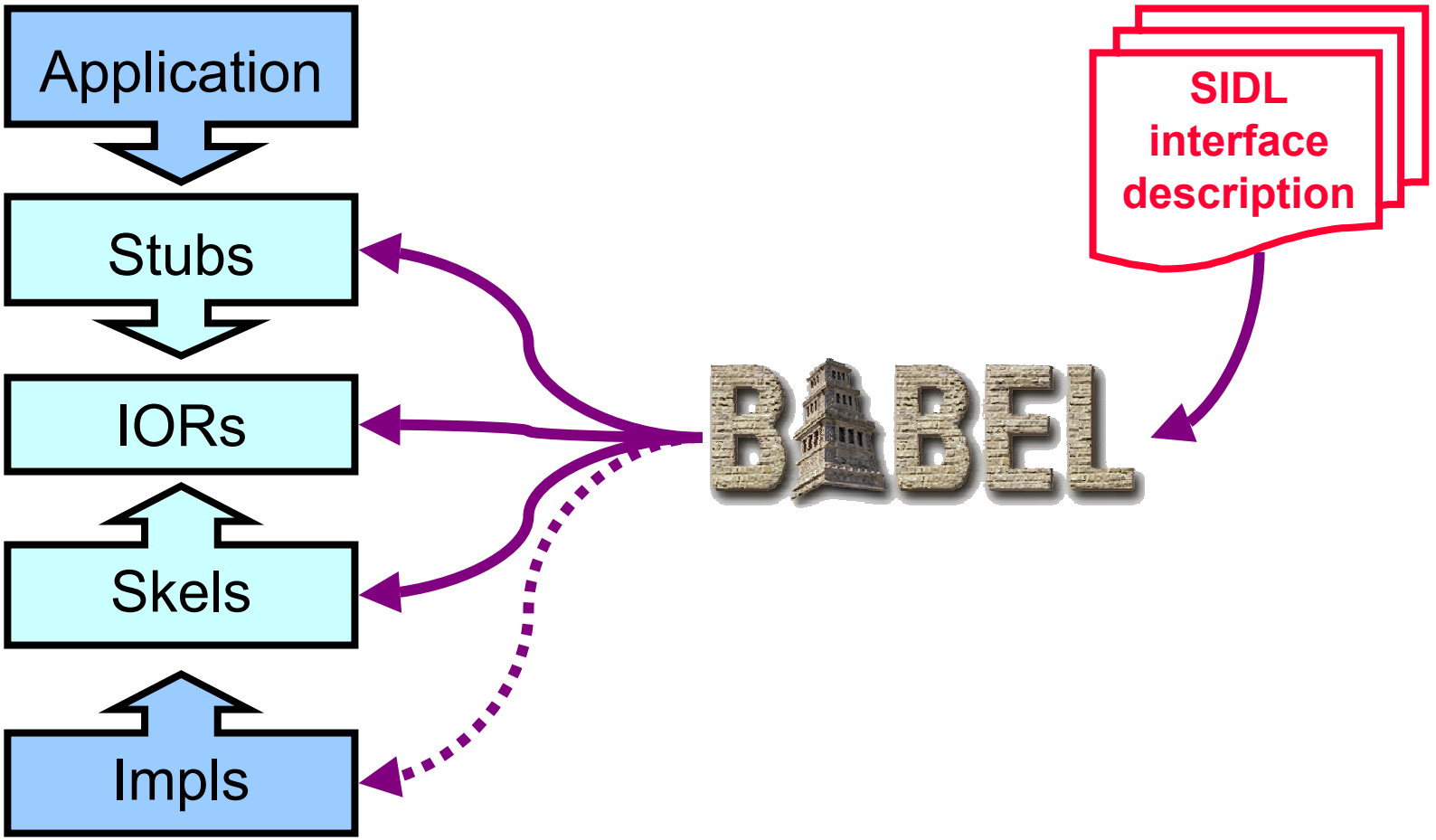
Babel Generates Glue Code



Babel Provides Uniform Object Model



Babel Provides a Firewall Between Use and Implementation



Outline

- Problem Motivation
- Babel Solution Strategy
- **SIDL**
- Using Babel
- Outstanding Problems
- Future R&D

SIDL as a text-based design tool

- Express only the public API
- Prevents discussion drift into implementation details
- Amenable to email debates
- Easier to learn than UML

The SIDL Grammar

- Packages & Versions
- Interfaces & Classes
- Inheritance Model
- Methods
- Polymorphism Modifiers
- Intrinsic Data Types
- Parameter Modes
- Gotchas

Packages

```
version foo 1.0;
package foo {
  // ...
};
```

```
package gov {
  package llnl {
    package babel {
      // ...
    };
  };
};
```

- Use SIDL packages to prevent symbol conflicts
  - packages in Java
  - namespaces in C++
  - prefixes in C / Fortran (e.g. mpi_send())
- must have version number
- lowercase symbols recommended
- Can be nested

Interfaces and Classes

- ObjectiveC and Java Inheritance Model
- Interfaces
  - pure abstract base classes in C++
  - define calling sequence only
  - provide no implementation
  - cannot be instantiated
  - can inherit (“extend”) other interfaces
- Classes
  - inherit (“extend”) from at most one class (including its implementation)
  - may inherit (“implement”) multiple interfaces

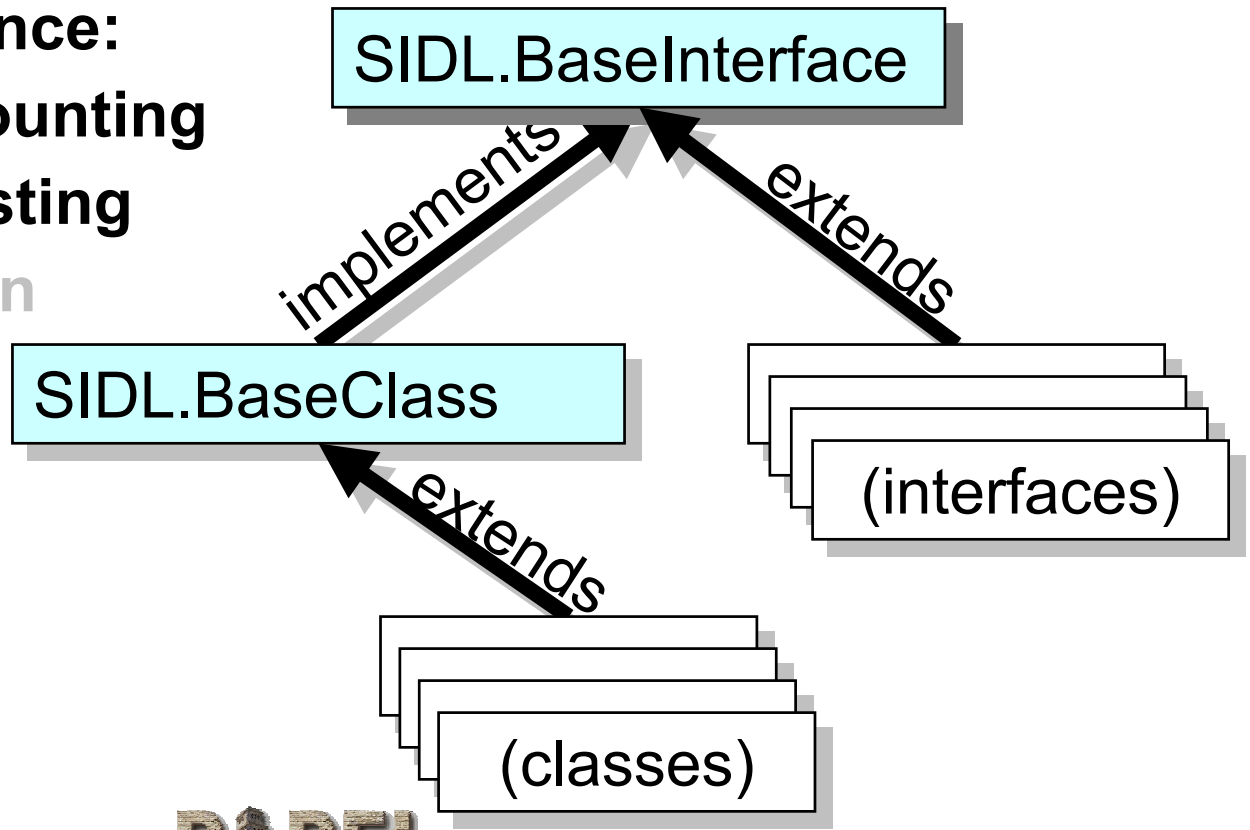
Interfaces and Classes (Example)

```
version their 1.0;
package their {
  interface Foo {/* .. */};
  interface Bar {/* .. */};
  interface Baz  {/* .. */};
};
```

```
version my 1.12;
import their;
package my {
  interface Foo extends their.Foo { };
  class CFoo implements Foo { };
  class Bar extends CFoo implements their.Bar { };
  class Baz extends CFoo implements their.Bar,
                                    their.Baz { };
};
```

Inheritance Model

- Interfaces form contracts between implementor and user.
- Default Inheritance:
  - reference counting
  - dynamic casting
  - introspection
  - reflection



Abstract Class– Partially Implemented Class

```
interface Foo {
   int doThis( in int i );
   int doThat( in int i );
}

abstract class Bar implements Foo {
   int doThis( in int i );
};

class Grille implements-all Foo {
   // int doThis( in int i );
   // int doThat( in int i );
};
```

```
interface
   int do
   int do
}

abstract
   int do
};

class Grille implements Foo {
   int doThis( in int i );
   int doThat( in int i );
};
```

Methods (a.k.a. “member functions”)

- Belong to both Interfaces and Classes
- SIDL has no sense of method “access” specifiers
  - (e.g. private, protected, public)
  - All methods are public
  - Makes sense for an “Interface Definition Language”
- In classes only, methods can also be
  - static -- independent of an instance
  - final -- not overridden by derived classes
- No Method Overloading. (yet?)

Method Modifiers

- static
  - avoid OOP altogether:
    make one class full of static methods.

```
class Math {
  static double sin( in double x );
  static double cos( in double x );
};
```

- final
  - prevent function from being overridden
  - In C++
    - methods are final by default
    - must be declared “virtual” to be overridden

Intrinsic Data Types

- Standard Types
  - bool
  - char
  - int
  - long
  - float
  - double
  - fcomplex
  - dcomplex
- Advanced Types
  - string
  - enum
  - object (interface or class)
  - array< Type, Dimension >
  - opaque
- NOTES:
  - Mapped to different types in different languages
  - No General Template Mechanism (maybe later?!?)

Parameter Modes

- Unique to IDLs
- Each parameter in a method call has a mode declared
  - in
  - out
  - inout
- Intent:
  - Communication optimization for distributed components
  - Copy minimization when copy is unavoidable
- Benefit:
  - Easy to understand intent when reading

Parameter Modes II

- “in”
  - pass by value semantics (not const!)
- “out”
  - pass by reference semantics
  - no initialization required
  - information returned
- “inout”
  - pass by reference semantics
  - initialization required
  - new information returned
  - instance may be destroyed and replaced

Parameter Modes III

```
package util { // SIDL FILE
  class String {
    static void reverse( inout string );
  };
};
```

```
#include <stdio.h>
#include “util_String.h”

int main () {
  char * hi = “Hello.”;
  util_String_reverse( &hi ) ;
  printf(“%s\n”, hi );
}
```

DANGER:

“inout” parameters may be destroyed and replaced under the covers.

Do you want to risk a “free(hi);” in the stubs???

Parameter Modes IV

```
package util { // SIDL FILE
  class String {
    static void appendReverse(inout string);
  };
};
```

```
#include <stdio.h>
#include “util_String.h”

int main () {
  char * hi = “Hello.”;
  util_String_appendReverse( &hi ) ;
  printf(“%s\n”, hi );
}
```

Parameter Modes V

```
package util { // SIDL FILE
  class String {
    static void appendReverse(inout string);
```

```
#include <stdio.h>
#include <string.h>
#include "util_String.h"

int main () {
  char * hi = strdup( "Hello." );
  util_String_appendReverse( &hi ) ;
  printf("%s\n", hi );
  free( hi );
}
```

```
// This is a comment

/* This is a Comment Too */

/** This is a DocComment for the package */
package Hello {

   /**
    * This class has one method
    */
    class World {


     /** result = “hello” + name */
     string getMsg( in string name );
   };
};
```

SIDL Gotchas

- Case Sensitive
  - SIDL is
  - F77 is not
- Reserved Words:
  - union of C, C++, Fortran
  - C++ has 90+ reserved words!
- Forbidden Method Names
  - same as class name (reserved in C++)
- Built-in method names start with "_" to avoid collisions with user defined names.

Outline

- Problem Motivation
- Babel Solution Strategy
- SIDL
- **Using Babel**
- Outstanding Problems
- Future R&D

Getting The Software

- Grab tarball
  - http://www.llnl.gov/CASC/components/software.html
  - Current release: babel-0.6.0.tar.gz
- Typical build/install (using VPATH)
  - gtar zxvf babel-0.6.0.tar.gz
  - cd babel-0.6.0-build/
  - ../babel-0.6.0/configure --prefix=${HOME}/babel
  - gmake all check install
- Platforms Tested Nightly:
  - Linux (GNU)
  - Solaris (GNU, Sun, KCC)

The Babel Compiler – commandline options

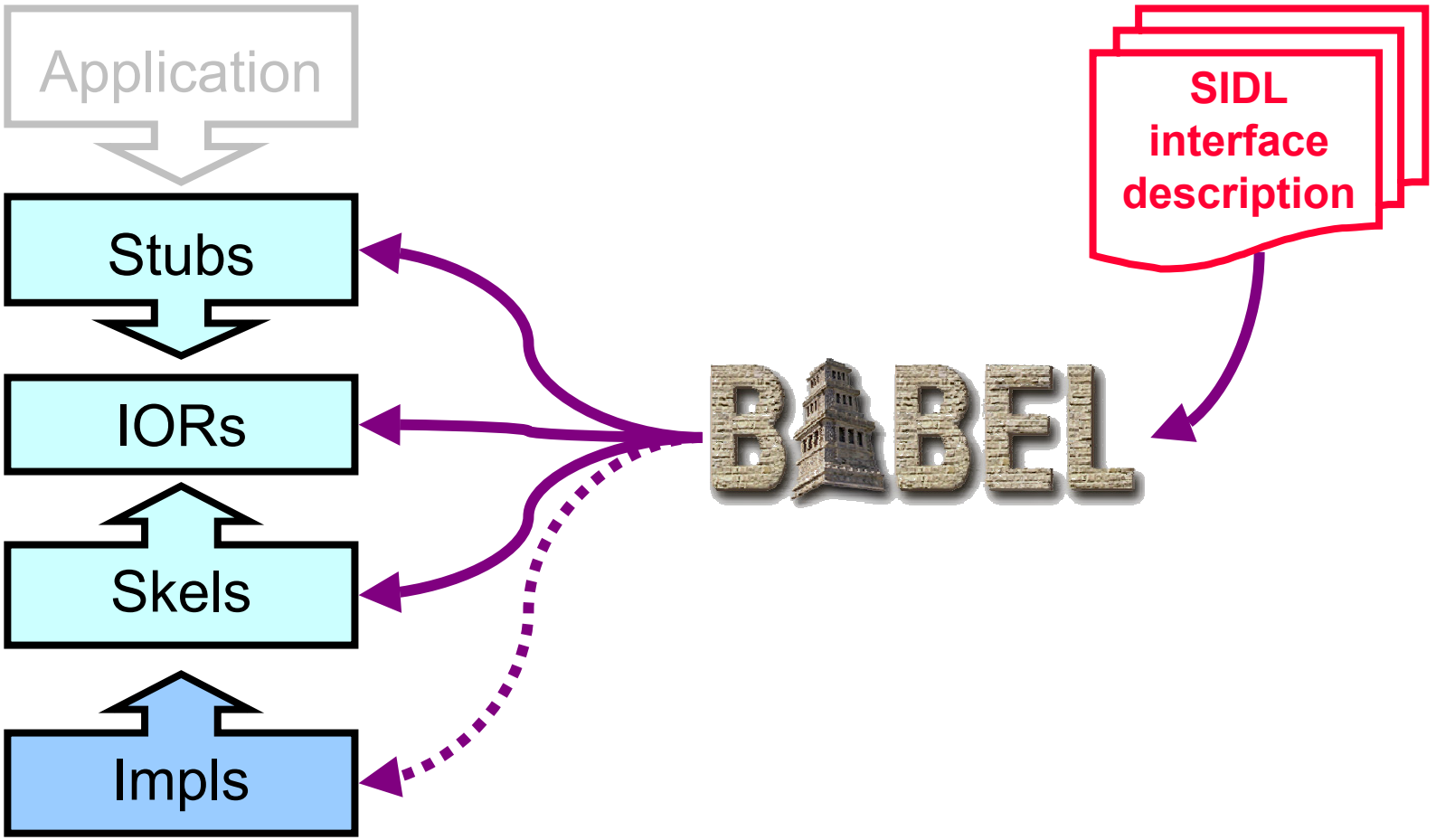
- **Choose exactly one of the following:**

`--help`	Display more info
`--version`	Babel Version
`--parse-check`	Parse SIDL, no output
`--xml`	Generate XML
`--client=[lang]`	User of Babel Object
`--server=[lang]`	Developer of Babel Object

- **Other Options**

`--output-directory=[dir]`	Default = .
`--repository-path=[path]`	Semicolon separated URLs
`--generate-subdirs`	

Babel from a developer's POV



hello.sidl

```
/** This is a DocComment for the package */
version hello 1.0;

package hello {

  class World {
    void setName( in string name );

    /** result = “hello” + name */
    string getMsg( );
  };
};
```

Babel Generates LOTS of Code!!!

hello.sidl	9
Generated C/C++ code (wc –l *)	4,107
Hand added Implementation	4

Adding the Implementation

```
namespace hello {
class World_impl {
  private:
    // DO-NOT-DELETE splicer.begin(hello.World._implementation)
    // Put additional implementation details here...
    // DO-NOT-DELETE splicer.end(hello.World._implementation)
```

```
string
hello::World_impl::getMsg ()
throw ()
{
  // DO-NOT-DELETE splicer.begin(hello.World.getMsg)
  // insert implementation here
  // DO-NOT-DELETE splicer.end(hello.World.getMsg)
}
```

Adding the Implementation

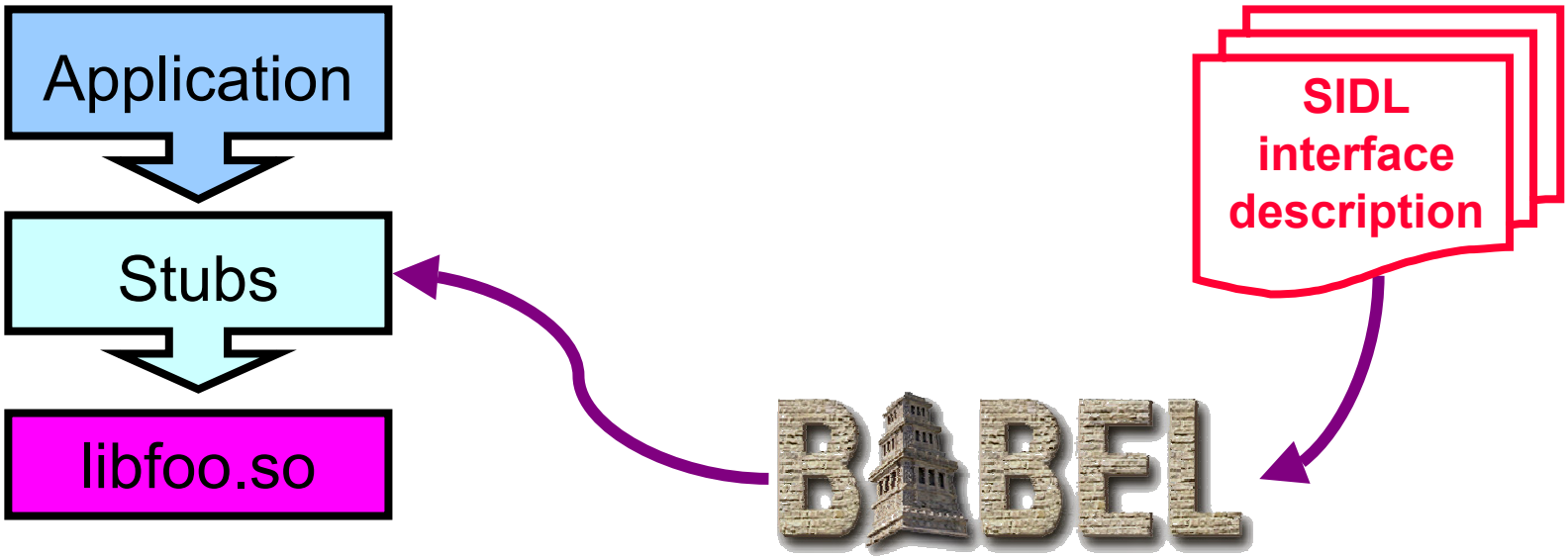
```
namespace hello {
class World_impl {
  private:
    // DO-NOT-DELETE splicer.begin(hello.World._implementation)
    string d_name;
    // DO-NOT-DELETE splicer.end(hello.World._implementation)
```

```
string
hello::World_impl::getMsg ()
throw ()
{
  // DO-NOT-DELETE splicer.begin(hello.World.getMsg)
  string msg("hello ");
  return msg + d_name + "!";
  // DO-NOT-DELETE splicer.end(hello.World.getMsg)
}
```

Methods Beginning with "_"

- method names cannot start with "_" in SIDL
- Babel uses leading underscores for internal stuff
  - e.g. IOR-level methods "_create()"
  - e.g. binding specific methods "PKG::CLASS::_get_ior()"
- Note: Things that look like a double underscore
  e.g. hello_World__create()
  is really normal convention with internal method

Babel from a user's POV



A driver in C

```
#include <stdio.h>
#include "SIDL.h"
#include "hello.h"

int main(int argc, char ** argv ) {
  hello_World hw;
  hw = hello_World__create();
  hello_World_setName( hw, argv[1] );
  fprintf(stdout, "%s", hello_World_getMsg( hw ) );
  hello_World_deleteReference( hw );
}
```

A driver in Python

```
import hello.World

if __name__ = '__main__':
  h = hello.World.World()
  h.setName( 'Gary' )
  print h.getMsg()
```

Outline

- Problem Motivation
- Babel Solution Strategy
- SIDL
- Using Babel
- **Outstanding Problems**
- Future R&D

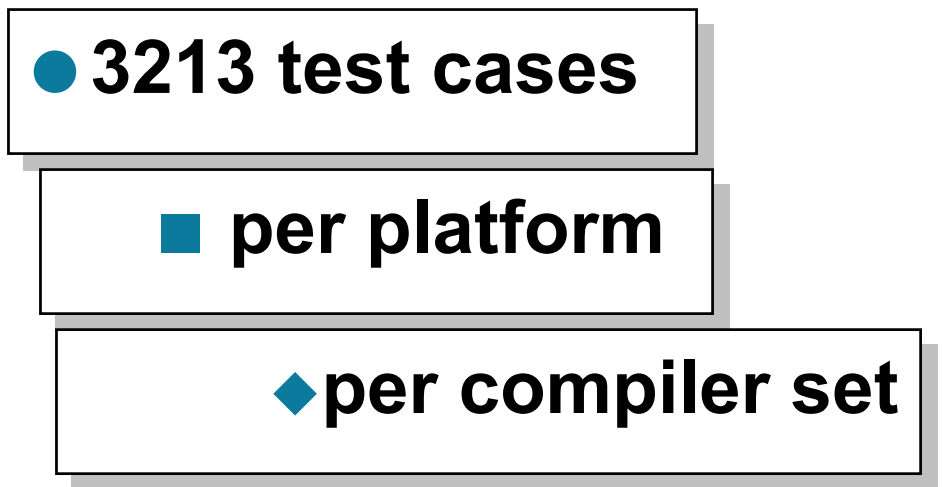
Common Problems

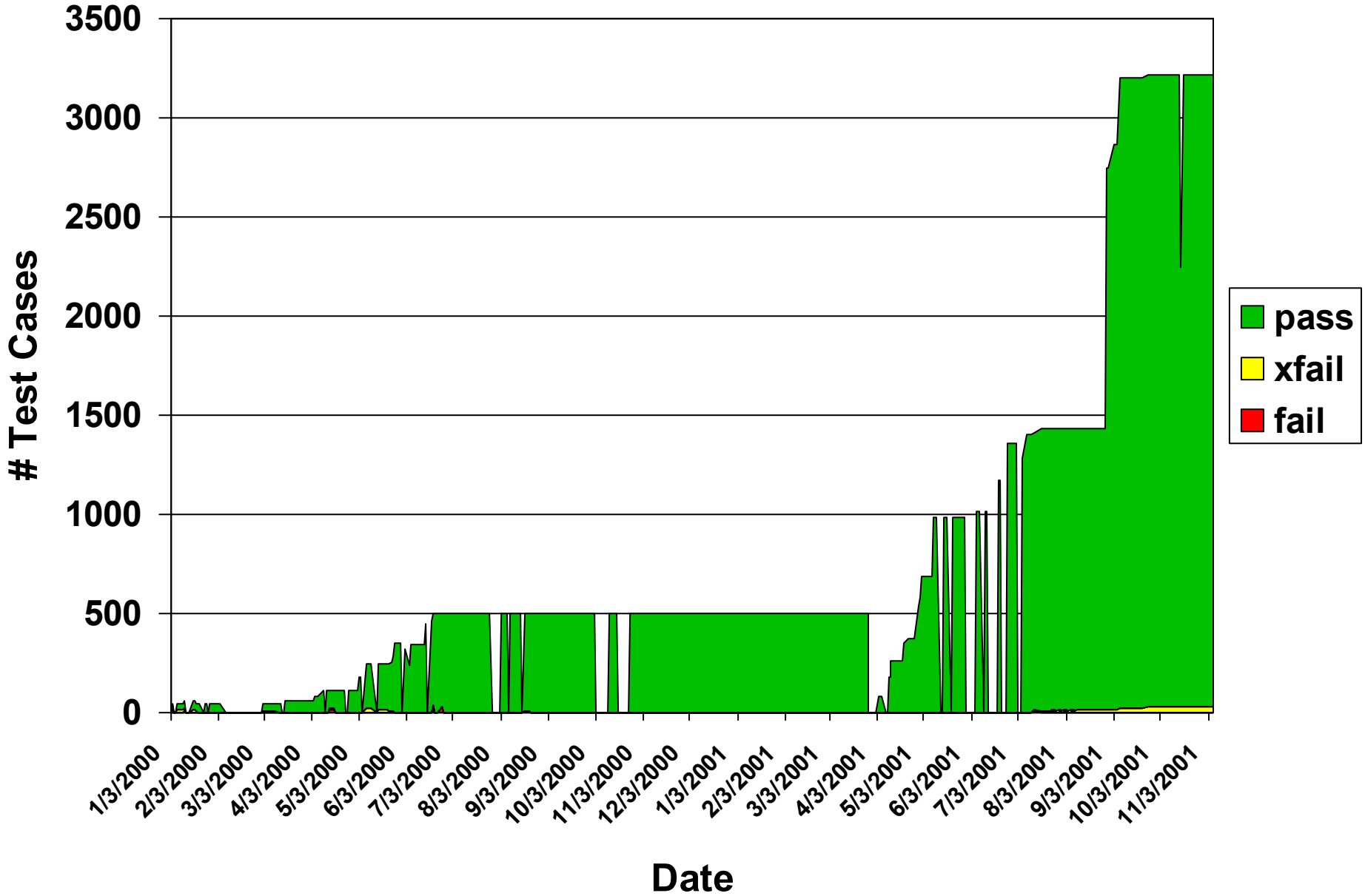
- $CLASSPATH not set
- compilers not found ($CC, $CXX, $F77)
- Python or NumPy not installed
- Server-side Python requires libpython.so
  (Not in standard distributions)
- LD_LIBRARY_PATH issues with shared libraries
- C++ and shared libraries

Achilles' Heel

- Babel Generates Correct Code
- It does nothing about correct compilation

How Much Language Interoperability Have We Achieved?




sun-sparc-solaris2.7-gcc2.95.x
Test Cases
3500
3000
2500
2000
1500
1000
500
0
1/3/2000
2/3/2000
3/3/2000
4/3/2000
5/3/2000
6/3/2000
7/3/2000
8/3/2000
9/3/2000
10/3/2000
11/3/2000
12/3/2000
1/3/2001
2/3/2001
3/3/2001
4/3/2001
5/3/2001
6/3/2001
7/3/2001
8/3/2001
9/3/2001
10/3/2001
11/3/2001
Date
pass
xfail
fail

Babel Development Tools

- development platforms
  - sun-sparc-solaris2.7
  - intelx86-redhat-linux
  - cygwin
- Compilers
  - Python 2.1
  - Sun jdk-1.3
  - gcc 2.95.x
  - sunpro 5.0
  - KCC
- Build Tools
  - make
  - autoconf
  - automake
  - libtool
- Testing
  - in-house tool
- Bug-Tracking
  - in-house/bugzilla mods

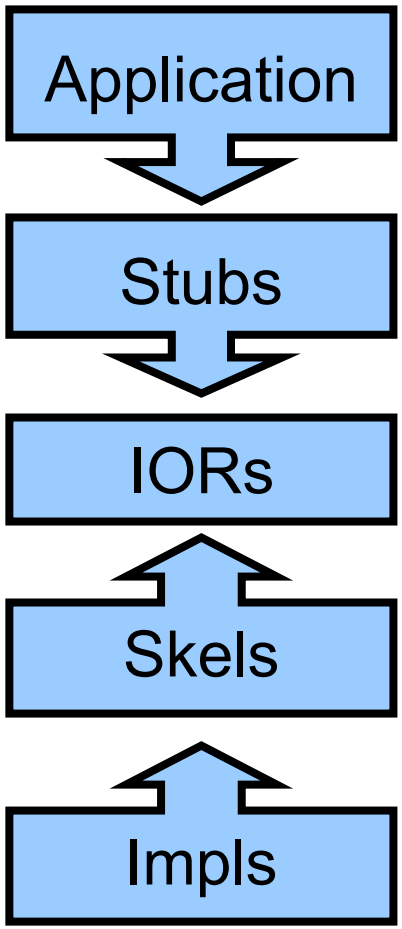
Outline

- Problem Motivation
- Babel Solution Strategy
- SIDL
- Using Babel
- Outstanding Problems
- **Future R&D**

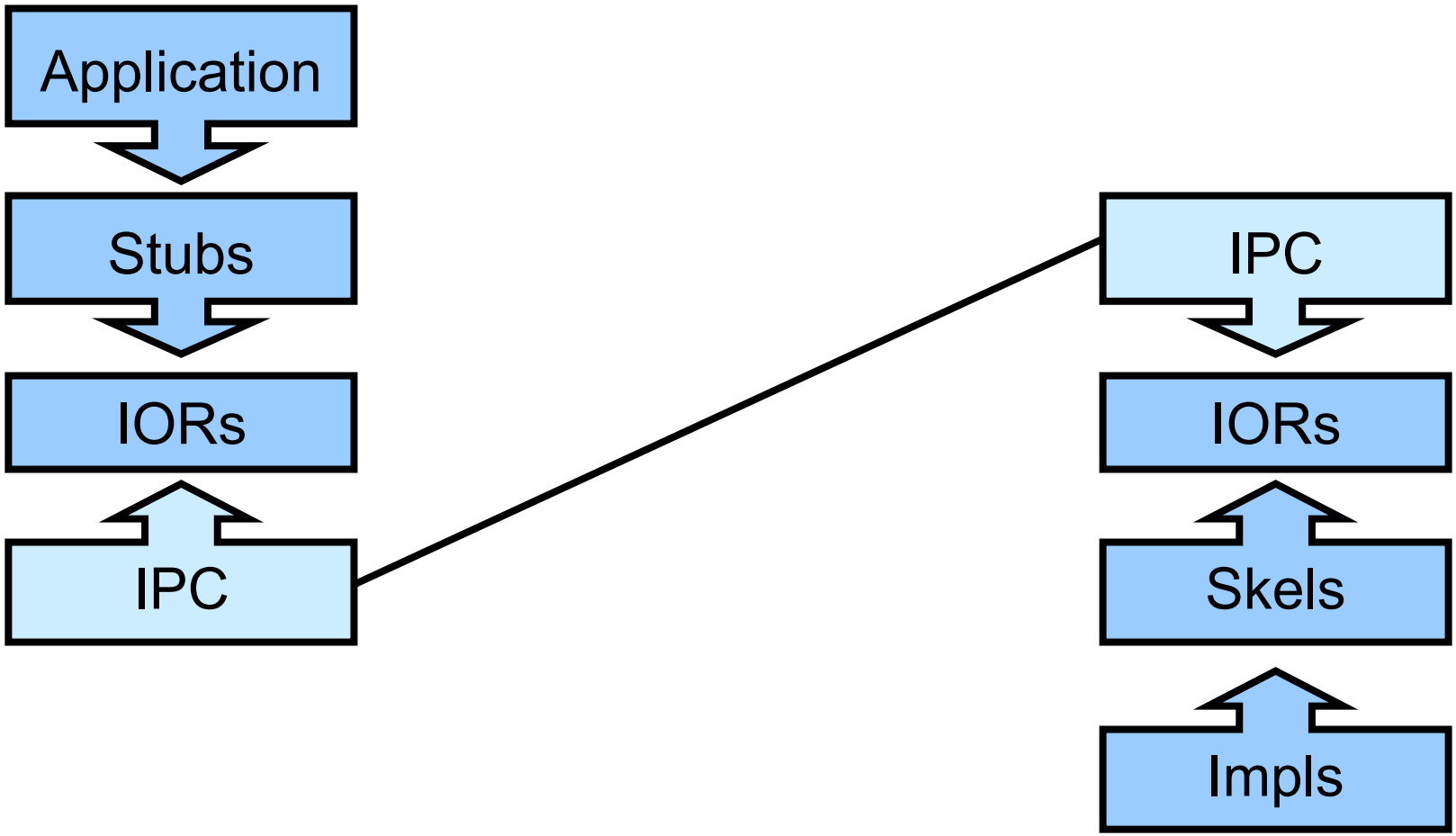
Platform Independence

- Encourage Locality for Maximum Performance
- Connect to separate process space
  - to avoid symbol conflicts at link time
- Connect to separate machine
  - to utilize special hardware
  - to use platform specific code
    (Babel doesn't get Windows apps to run on UNIX!)
  - To distribute work

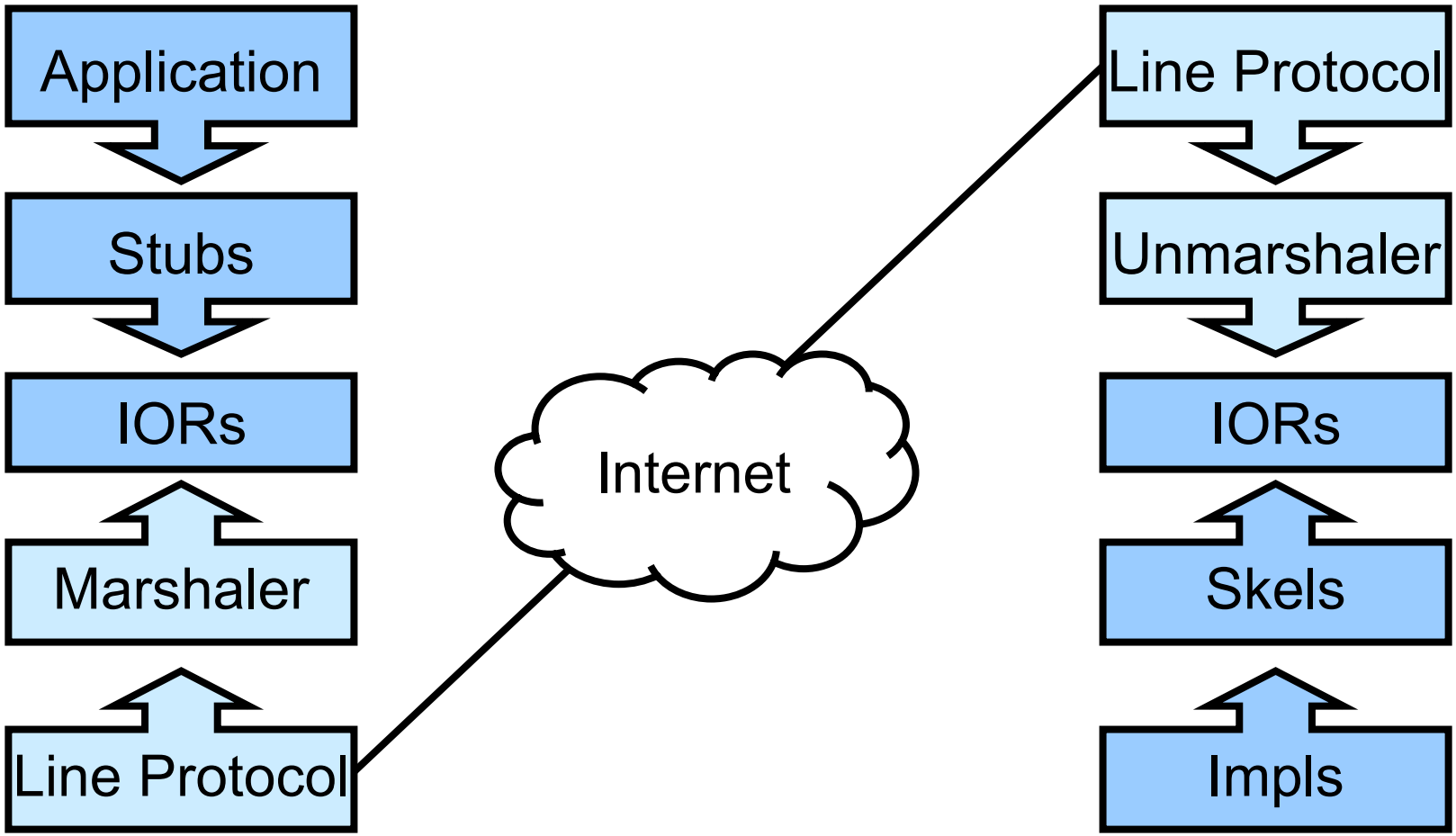
Same Process Space Components



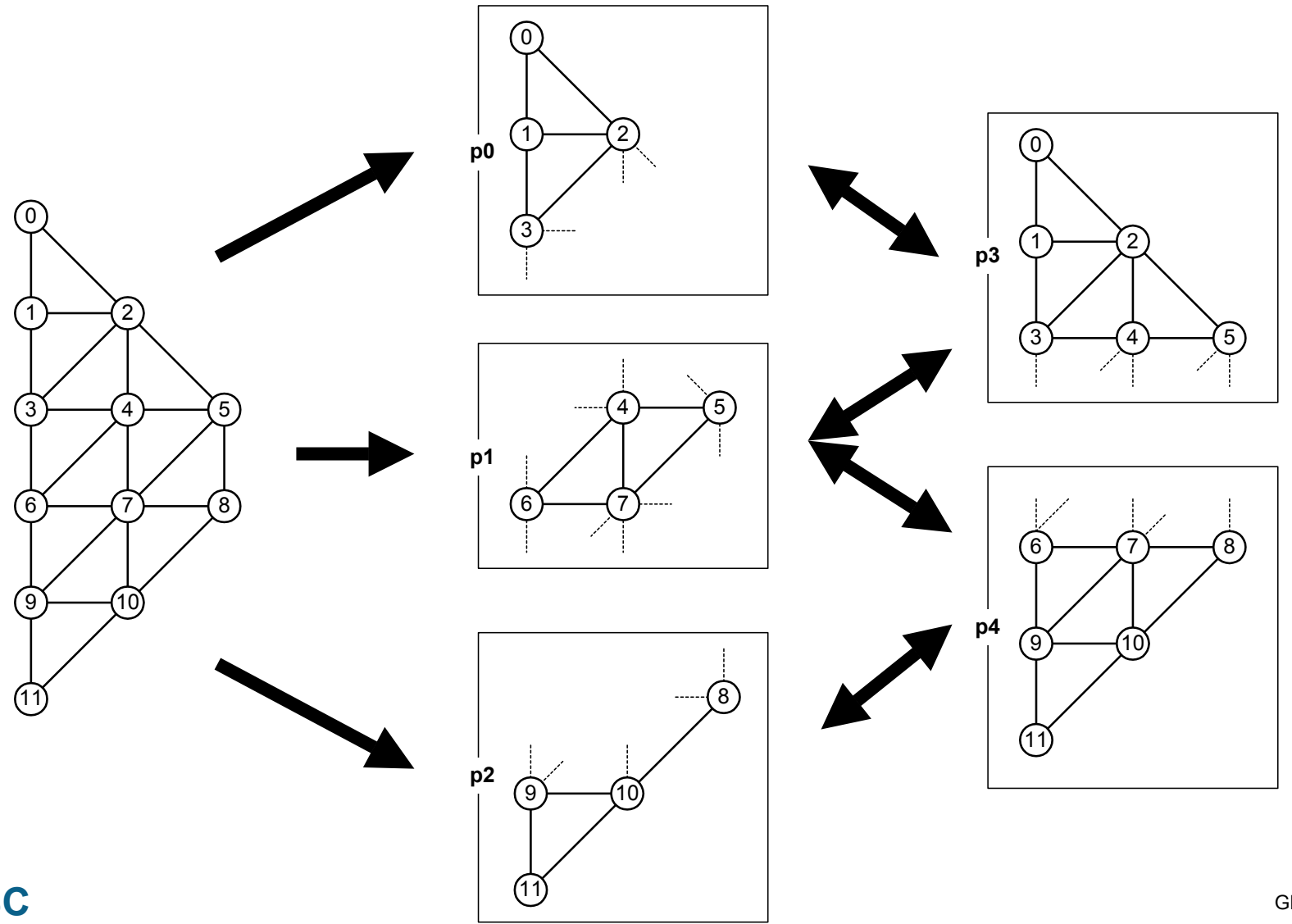
Out of Process Components



Remote Components



Parallel Components: MxN Communication



Problem Motivation

- Code Reuse is Hard.
- Scientific Code Reuse is Harder!
- Barriers to Reuse...
  - Language Interop[illegible]bility
  - Semantics
  - Software Portabil[illegible]
  - Lack of Standards
  - More...

Problem Motivation

- Code Reuse is Hard.
- Scientific Code Reuse is Harder!
- Barriers to Reuse...
  - Language Interoperability
  - Semantics
  - Software Portability
  - Lack of Standards
  - More...

How do I find out more???

- Website http://www.llnl.gov/CASC/components
- User's Guide
- Download Code
- Email Reflectors (subscribe via majordomo@lists.llnl.gov)
  - babel-users@llnl.gov
  - babel-announce@llnl.gov
- Email the team
  - components@llnl.gov
- Tutorial for CASC tomorrow
  - B451 White Room at 3:30pm Fri, Nov 9

The End

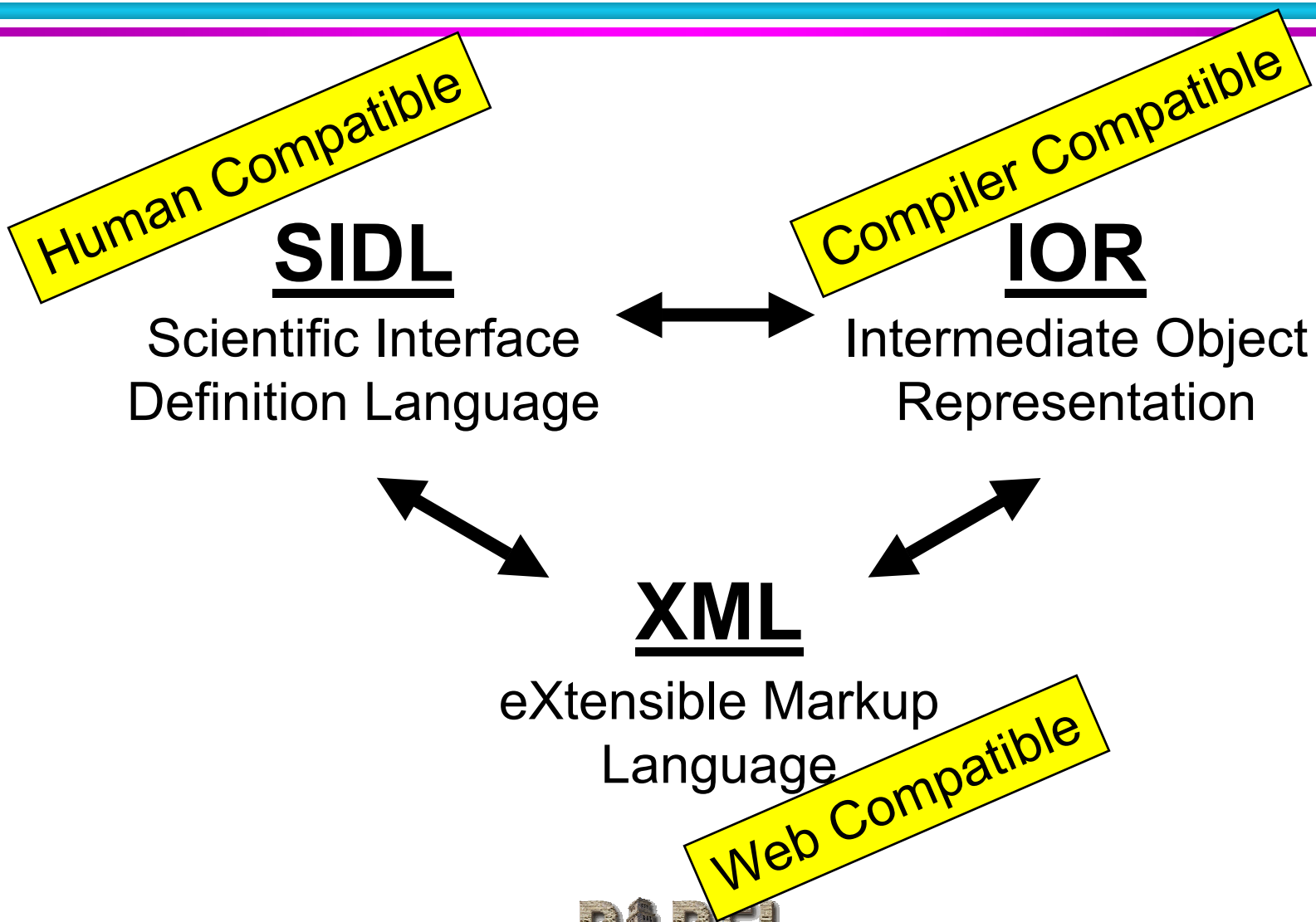
Business Component Frameworks

- CORBA
  - Language Independent
  - Wide Industry Acceptance
  - Primarily Remoting Architecture
- COM
  - Language Independent
  - Most Established
  - In Process Optimization
  - Network Transparent
- Enterprise Java Beans (EJB)
  - Platform Independent
  - Runs wherever Java does

~~Business~~ Science Component Frameworks

- CORBA
  - Language Independent
  - Wide Industry Acceptance
  - Primarily Remoting Architecture
  - Huge Standard
  - No In-Process Optimization
- COM
  - Language Independent
  - Most Established
  - In Process Optimization
  - Network Transparent
  - not Microsoft Transparent
  - Relies on sophisticated development tools
- Enterprise Java Beans (EJB)
  - Platform Independent
  - Runs wherever Java does
  - Language Specific
  - Potentially highest overhead
- All The Above
  - No Complex Intrinsic Datatype
  - No Dynamic Multidimensional Arrays
  - No Fortran77/90/95 bindings
  - No Parallel Components

Key to Babel's Interoperability...



UCRL-VG-??????

Work performed under the auspices of the U. S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-Eng-48