Jim Fawcett
CSE681 – Software Modeling and Analysis
Fall 2016

PROGRAM STRUCTURE

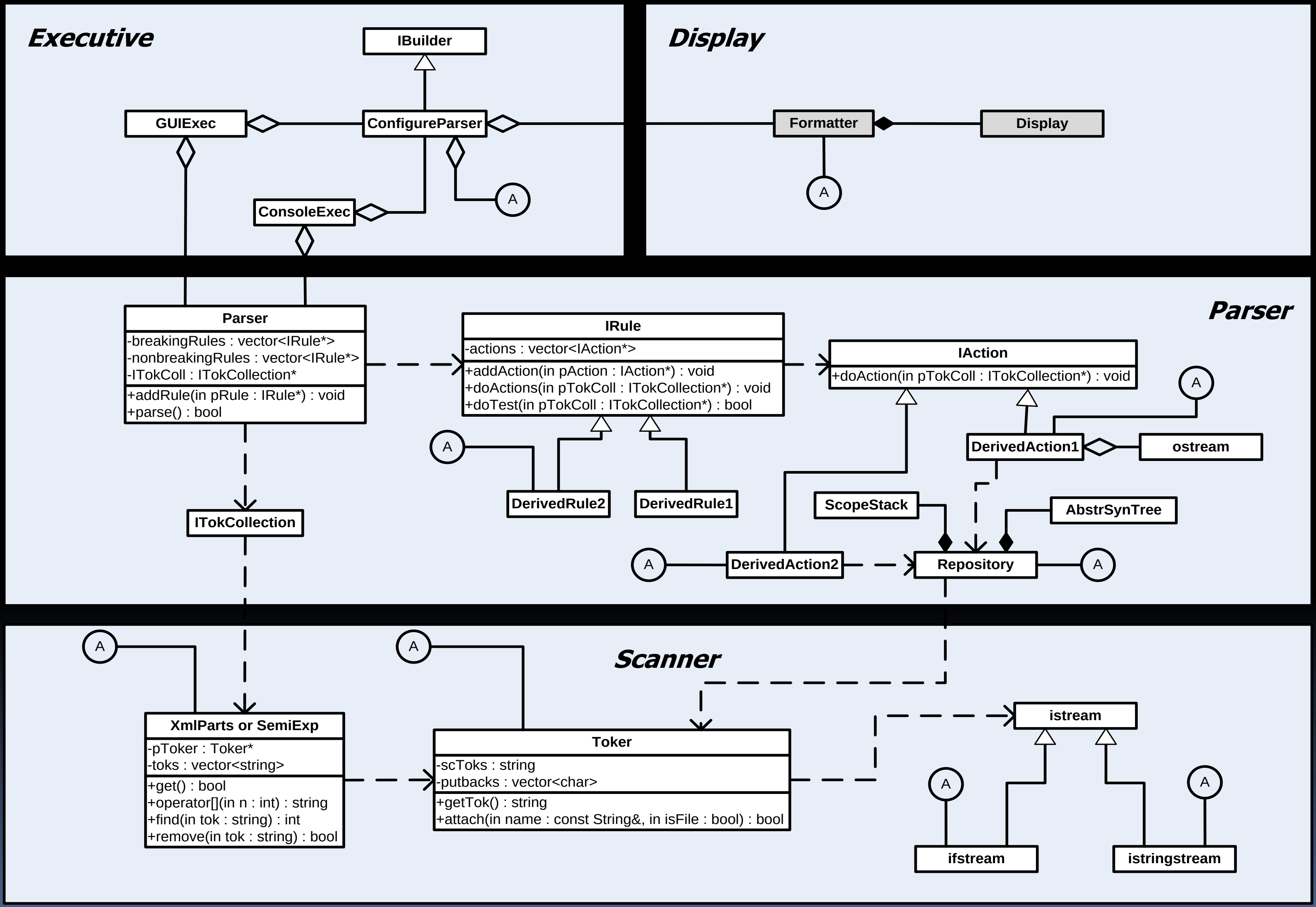
What is Program Structure?

- Partitions
  - Separation of concerns
- Communication
  - How do the parts make requests and send notifications?
- Sharing
  - How is data shared between the parts?
- Control
  - Which parts are responsible?

What is Program Structure?

- Logical:
  - Interfaces, classes, and class relationships
- Package:
  - Package dependency tree, as shown in OCD package diagrams
  - Subsystems, e.g., collection of packages separated by interfaces with each focused on specialized processing
    - For a radar those might be: signal processing, beam forming, data management, operator control, communication.
- Execution:
  - Monolithic Program, e.g., an exe
  - Program with loadable Dynamic Link Libraries (DLLs)
  - Cooperating processes, e.g., client-server, server federation, etc.

Parsing Facility



Executive
IBuilder
GUIExec
ConfigureParser
ConsoleExec
A
Display
Formatter
Display
A
Parser
Parser
-breakingRules : vector<IRule*>
-nonbreakingRules : vector<IRule*>
-ITokColl : ITokCollection*
+addRule(in pRule : IRule*) : void
+parse() : bool
IRule
-actions : vector<IAction*>
+addAction(in pAction : IAction*) : void
+doActions(in pTokColl : ITokCollection*) : void
+doTest(in pTokColl : ITokCollection*) : bool
IAction
+doAction(in pTokColl : ITokCollection*) : void
A
DerivedAction1
ostream
A
DerivedRule2
DerivedRule1
ITokCollection
ScopeStack
AbstrSynTree
A
DerivedAction2
Repository
A
Scanner
A
A
XmlParts or SemiExp
-pToker : Toker*
-toks : vector<string>
+get() : bool
+operator[](in n : int) : string
+find(in tok : string) : int
+remove(in tok : string) : bool
Toker
-scToks : string
-putbacks : vector<char>
+getTok() : string
+attach(in name : const String&, in isFile : bool) : bool
istream
A
A
ifstream
istringstream

Program Structure Contents

- Data Driven
  - Client server
  - Three tier
  - Model-View-Controller
- Layered Structure Driven
  - Components
  - Services
- Analysis Driven
  - One pass
  - Two passes
- Communication Driven
  - Client Server
  - Peer-to-peer
  - Middleware
- Thread & Event Driven
  - Single Threaded Apartment (STA)
  - Parallel execution
  - Pipeline execution
- Enterprise Computing
  - Federated systems

DATA DRIVEN STRUCTURES

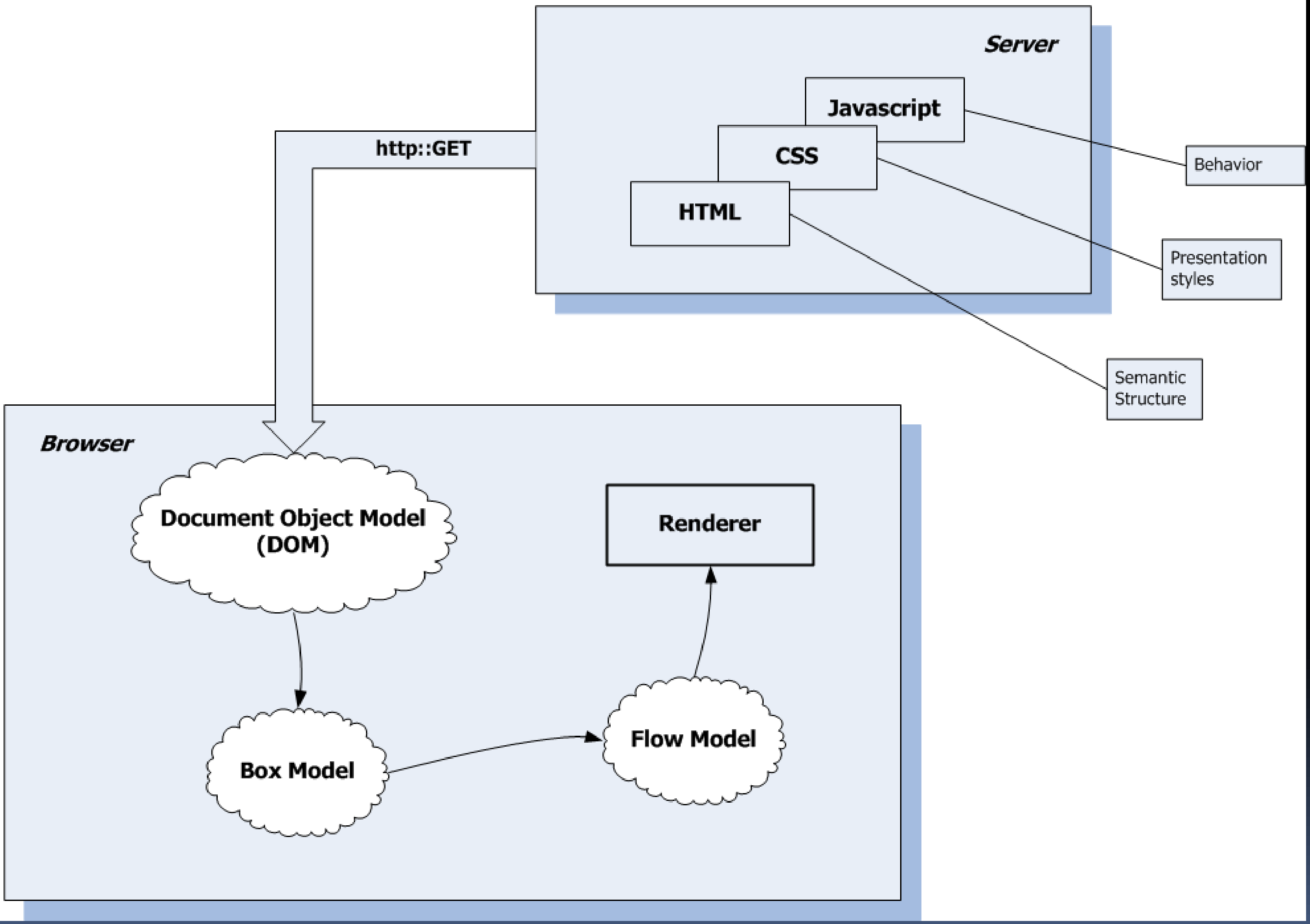
Data Driven Structures

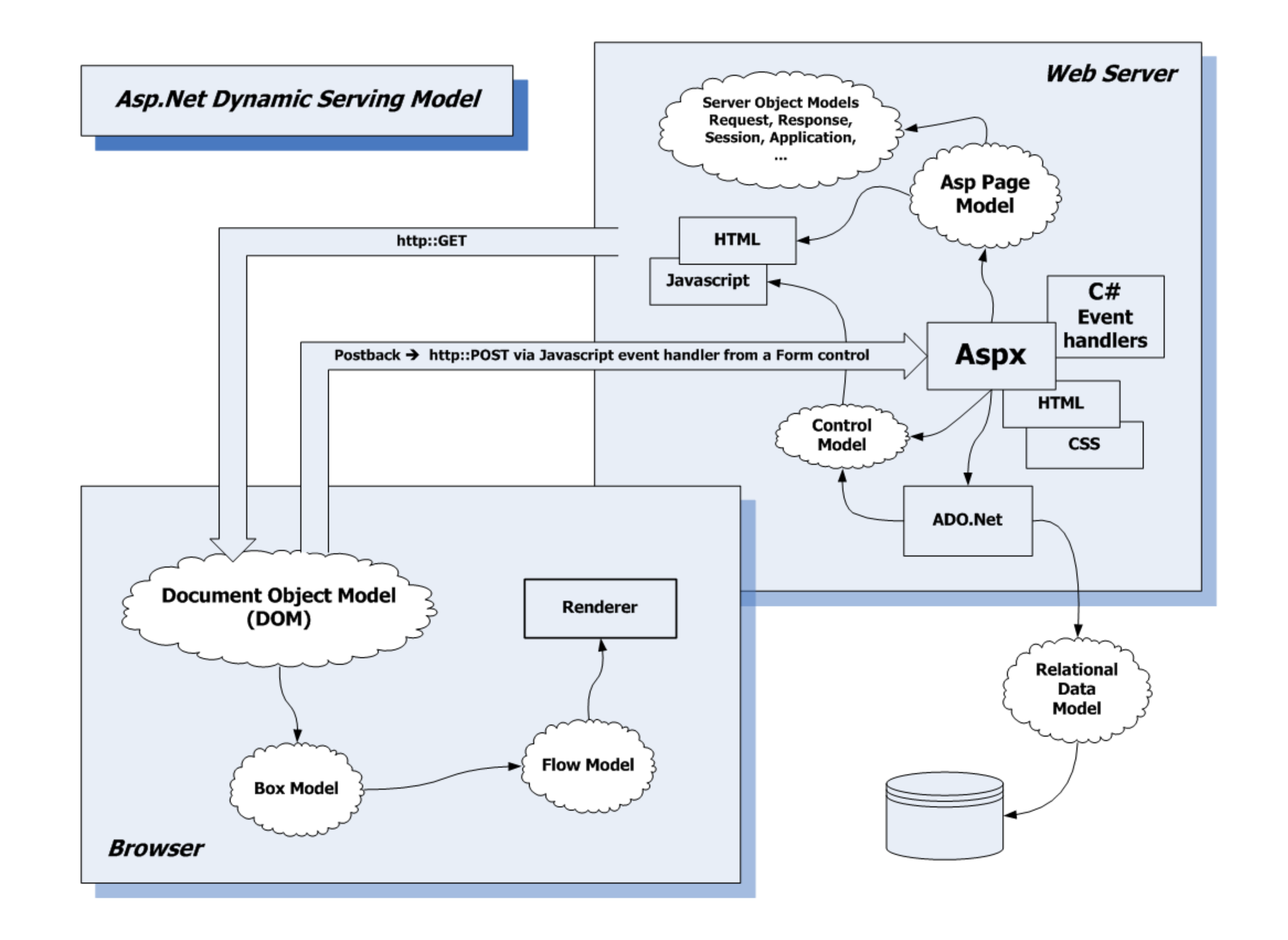
- Some program structures are driven by the presentation and management of data:
  - Client-Server
  - Three-Tier
  - Model-View-Controller

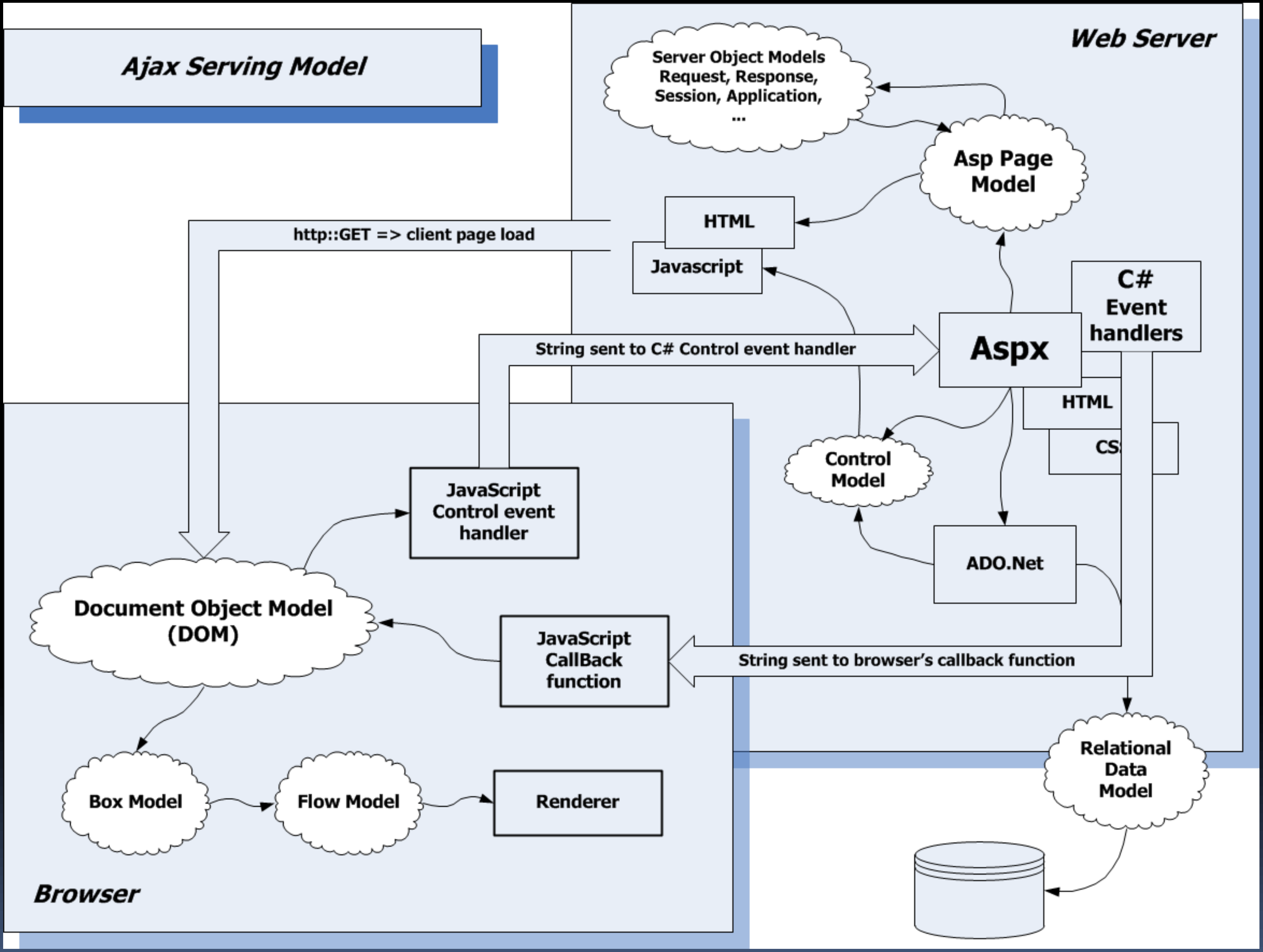
Structure: Client-Server

- Behavior:
  - Server is passive, waits for client requests
  - Server contains data shared among its clients
  - Server handles multiple concurrent clients
  - Without additional structure system may become tightly coupled and difficult to change
- Example:
  - Web server and browser clients

Static Webpage Model




Asp.Net Dynamic Serving Model
Web Server
Server Object Models Request, Response, Session, Application, ...
Asp Page Model
HTML
Javascript
http::GET
C# Event handlers
Aspx
Postback ➔ http::POST via Javascript event handler from a Form control
HTML
CSS
Control Model
ADO.Net
Document Object Model (DOM)
Renderer
Relational Data Model
Box Model
Flow Model
Browser


Ajax Serving Model
Web Server
Server Object Models Request, Response, Session, Application, ...
Asp Page Model
HTML
Javascript
http::GET => client page load
C# Event handlers
Aspx
String sent to C# Control event handler
HTML
CSS
Control Model
ADO.Net
JavaScript Control event handler
Document Object Model (DOM)
JavaScript CallBack function
String sent to browser's callback function
Relational Data Model
Box Model
Flow Model
Renderer
Browser

Sharing Data

- Relational Databases – SQL Server, mySql, …
  - ACID – Atomicity, Consistency, Isolation, Durability
  - ACID => Transactional
- No SQL Databases – Project #2 Fall 15, MongoDB, CouchDB
  - Key-Value, Document, Hierarchal
  - Very flexible data structure
  - Consistency is pushed onto the application
- File Systems
- Ad. Hoc. in-memory repositories
- Extensible Record Stores – Google's Big Table
  - Distributed partitioned tables
- Document Stores – CouchDB
  - Multi-indexed objects aggregated into domains

Separation of Concerns

- Except for the simplest of applications it’s not a good idea to bind presentation, control, and data together.
    - There often are many views, more than one application mode, many sources of data.
    - If we bind these all together we get spaghetti
        - Very hard to test, hard to maintain, hard to document.

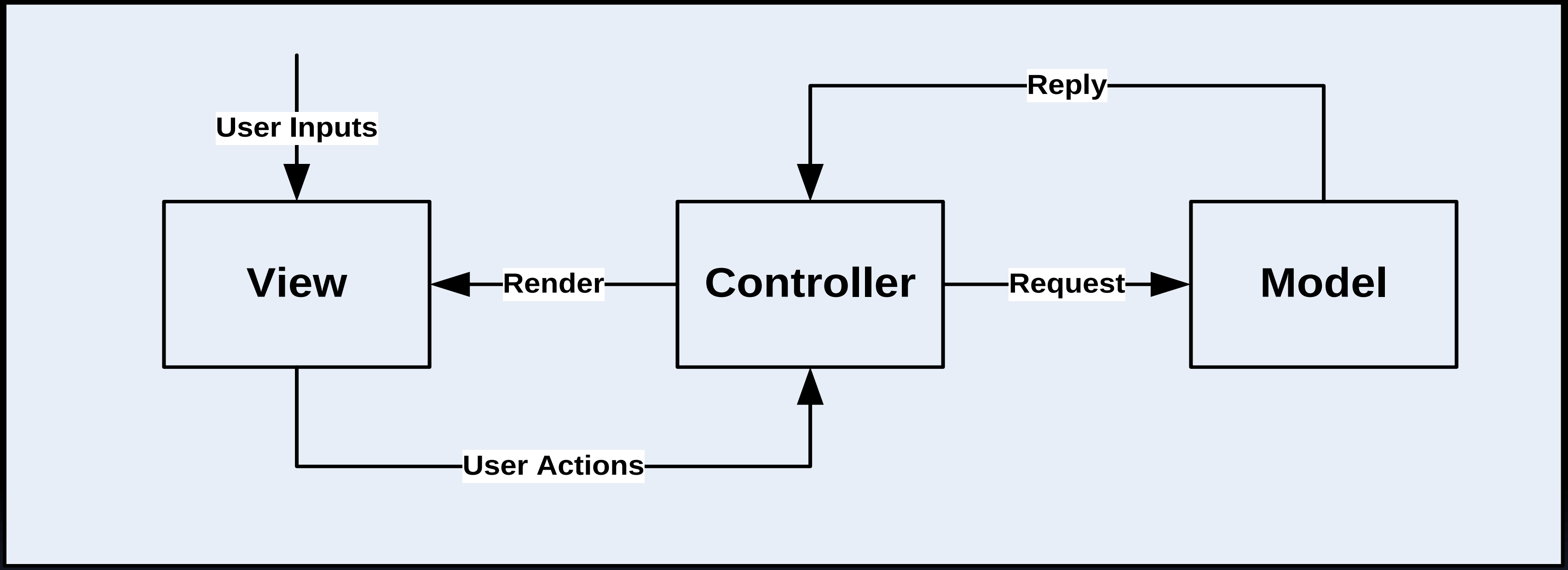
Structure: Three-Tier

- Structure:
  - Partitioned into presentation, application logic, and data management.
  - Intent is to loosely couple these three aspects of an application to make it resilient to change.
- Examples:
  - Most well-designed applications.

Model-View-Controller

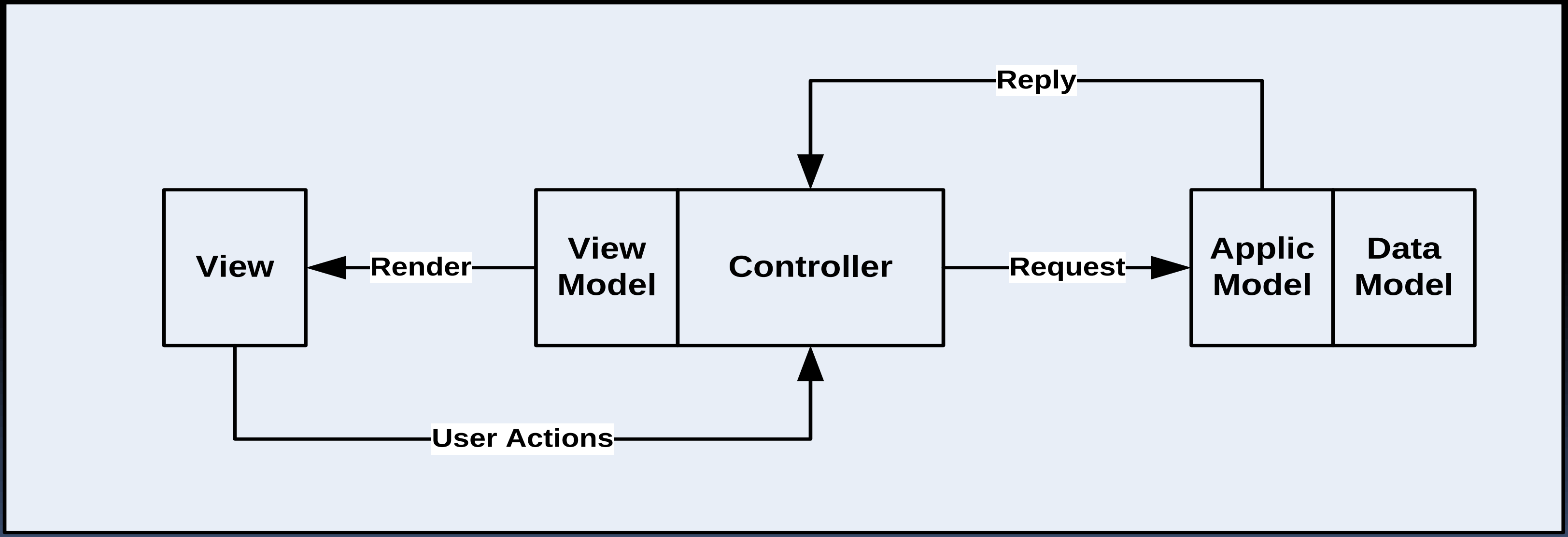
- Structure:
  - MVC is a refined version of the Three-Tier structure, intended to support multiple views and data models.
  - Models do all data storage management.
  - Views present information to user, format output but do no other transformations on data.
  - Controllers accept inputs, implement application processing, and use Models and Views to provide the application's behavior.
  - Application phases often have one controller each.
  - Models may be shared between controllers.
- Examples: Project #2 Fall '10, Asp.Net MVC

Basic MVC Structure



MVC – With View & Application Models

- Views and Models often have some substructure, e.g.:



View – View Model

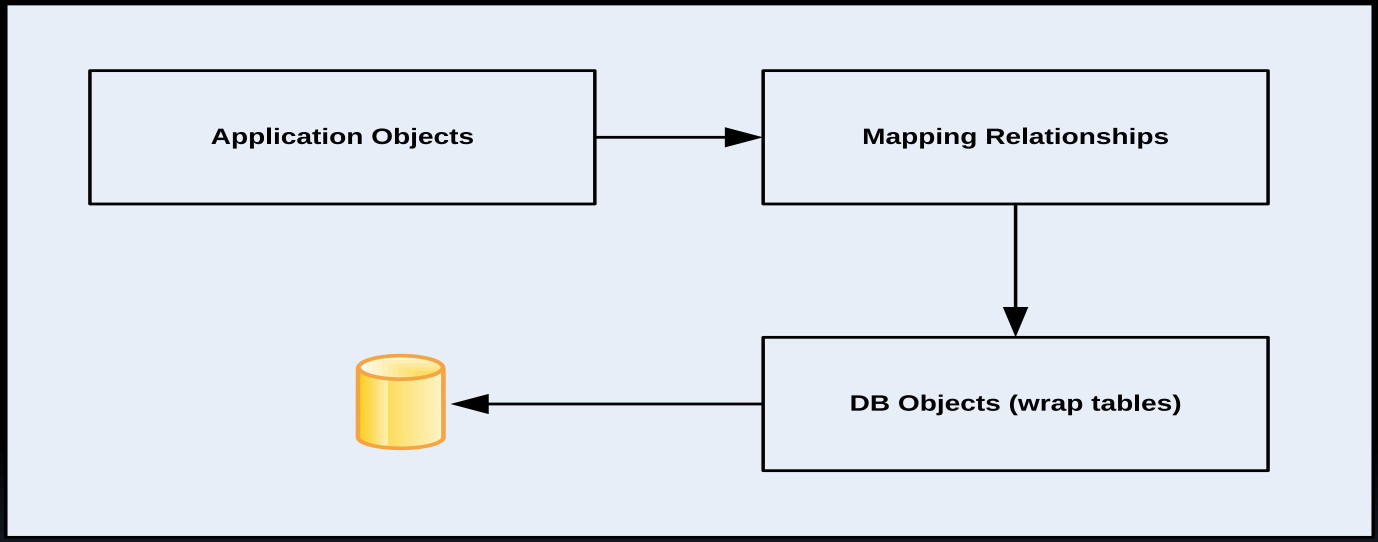
- A view is what gets rendered
- A view model is an abstraction that:
  - Defines resources that many be used in several places.
  - Defines styles that may be used in several places
  - Defines an object model for the application to manipulate

Application vs. Data Models

- Application model
  - Defines classes for all the entities a user knows and cares about, e.g., orders, customers, products, etc.
- Data model
  - Defines wrapper classes for tables and stored procedures
  - Manages connections
- Object to Relational Mapping
  - Relationships between application objects and data objects.

Object Relational Mapping

- Data Layers often have an ORM substructure

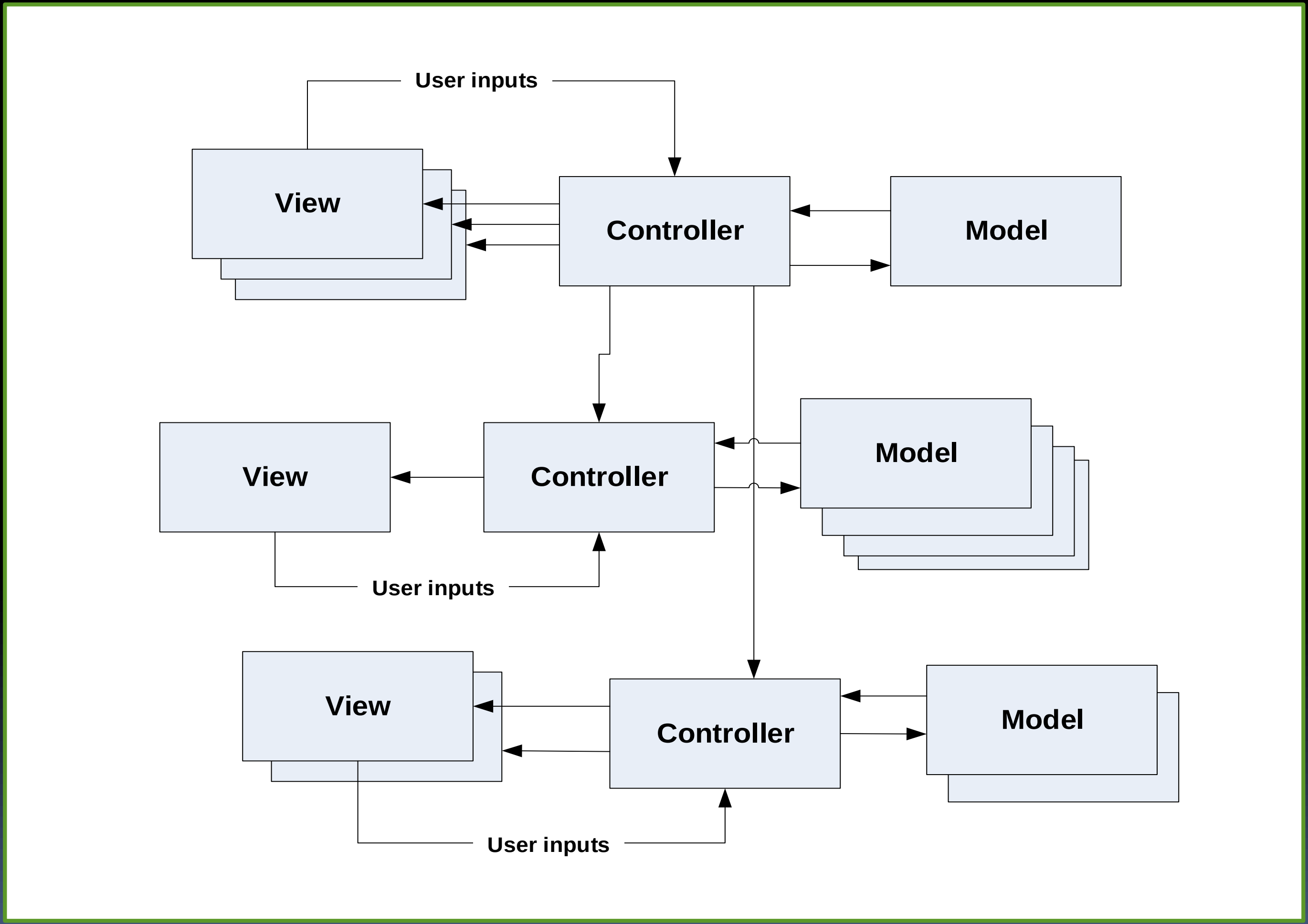


- Examples: Hibernate, Microsoft Entity Framework

N-Tier Structure

- So, the three tier MVC has morphed into a five tier V-VM-C-AM-DM
  - View – what gets rendered
  - View Model – an abstraction of the view
  - Controller – routes View events to handlers in the Application Model
  - Application Model – classes that model the "business" logic
  - Data Model – models data storage tables
    - Database, XML file, custom data structures

MVC – Multiple Controllers

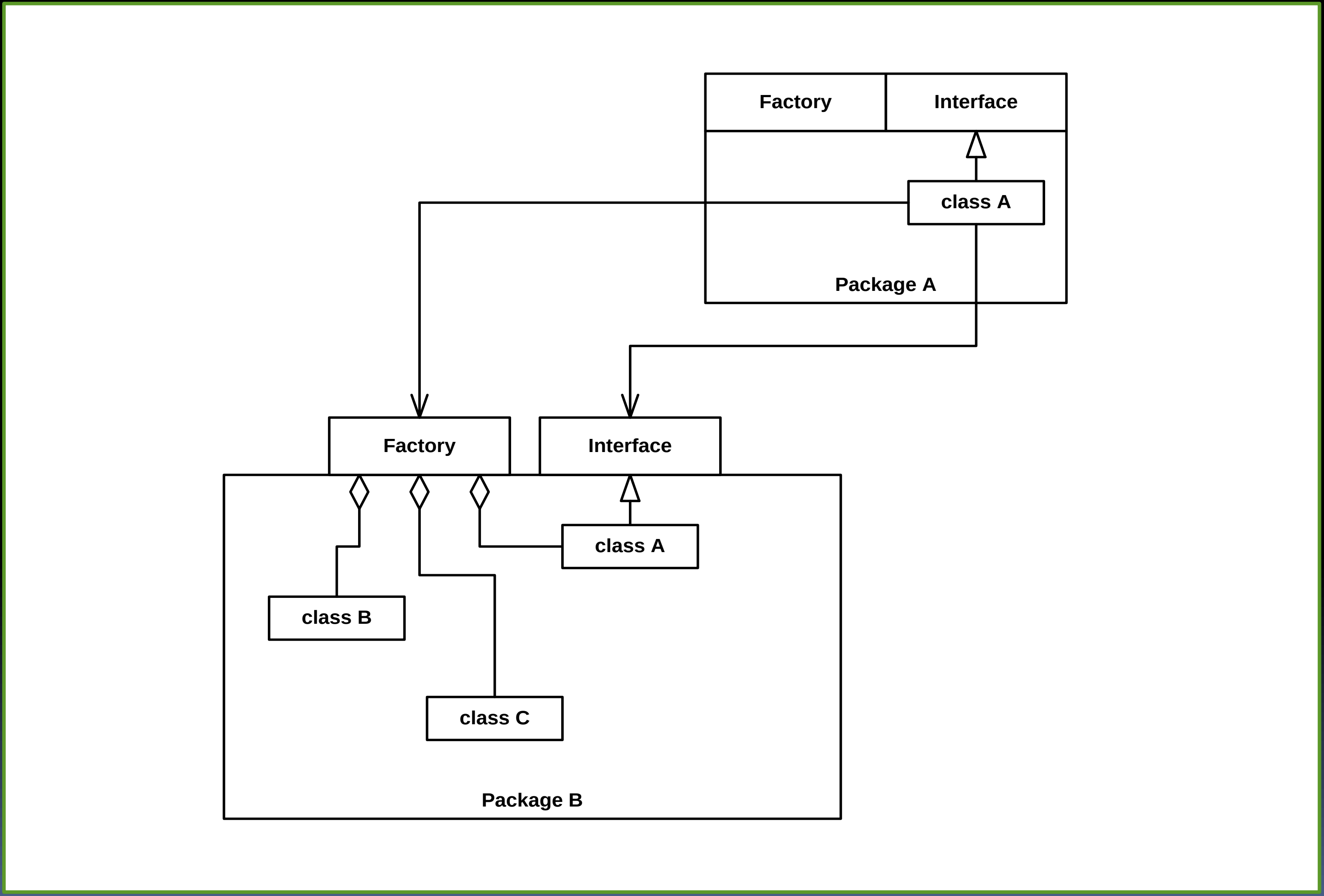


LAYER-DRIVEN STRUCTURES

Component Layered Structure

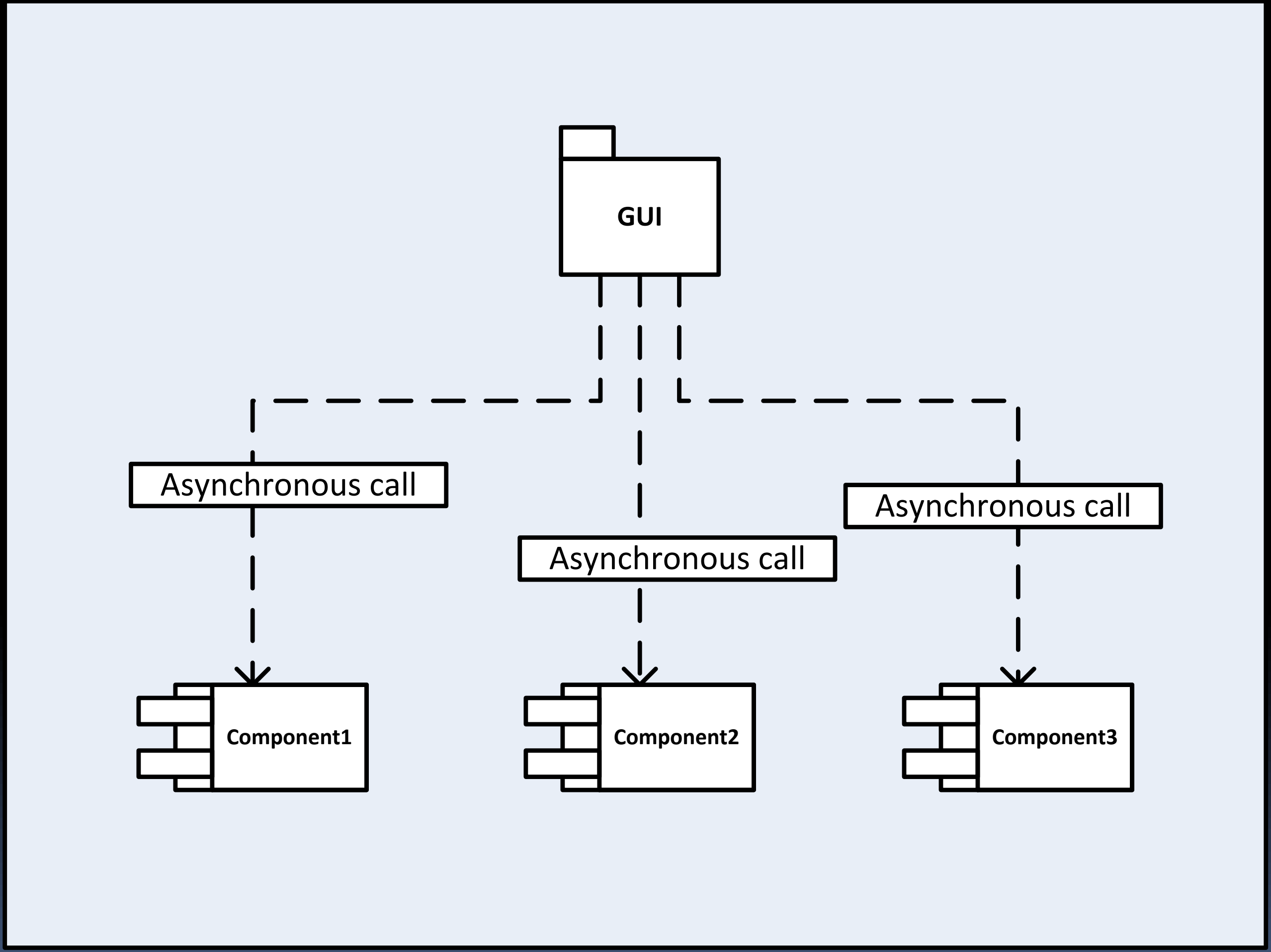
- Structure:
  - A componentized system is composed of an application with many pluggable component parts.
  - A component is pluggable if it implements a plug-in interface, published by the application, provides an object factory for activating its internal objects, and is packaged as a dynamic link library (DLL).
- Example:
  - http://www.ecs.syr.edu/faculty/fawcett/handouts/CSE681/code/Parser/ almost implements.

Hiding Implementation Details



Example Componentized System

Separate presentation from application logic

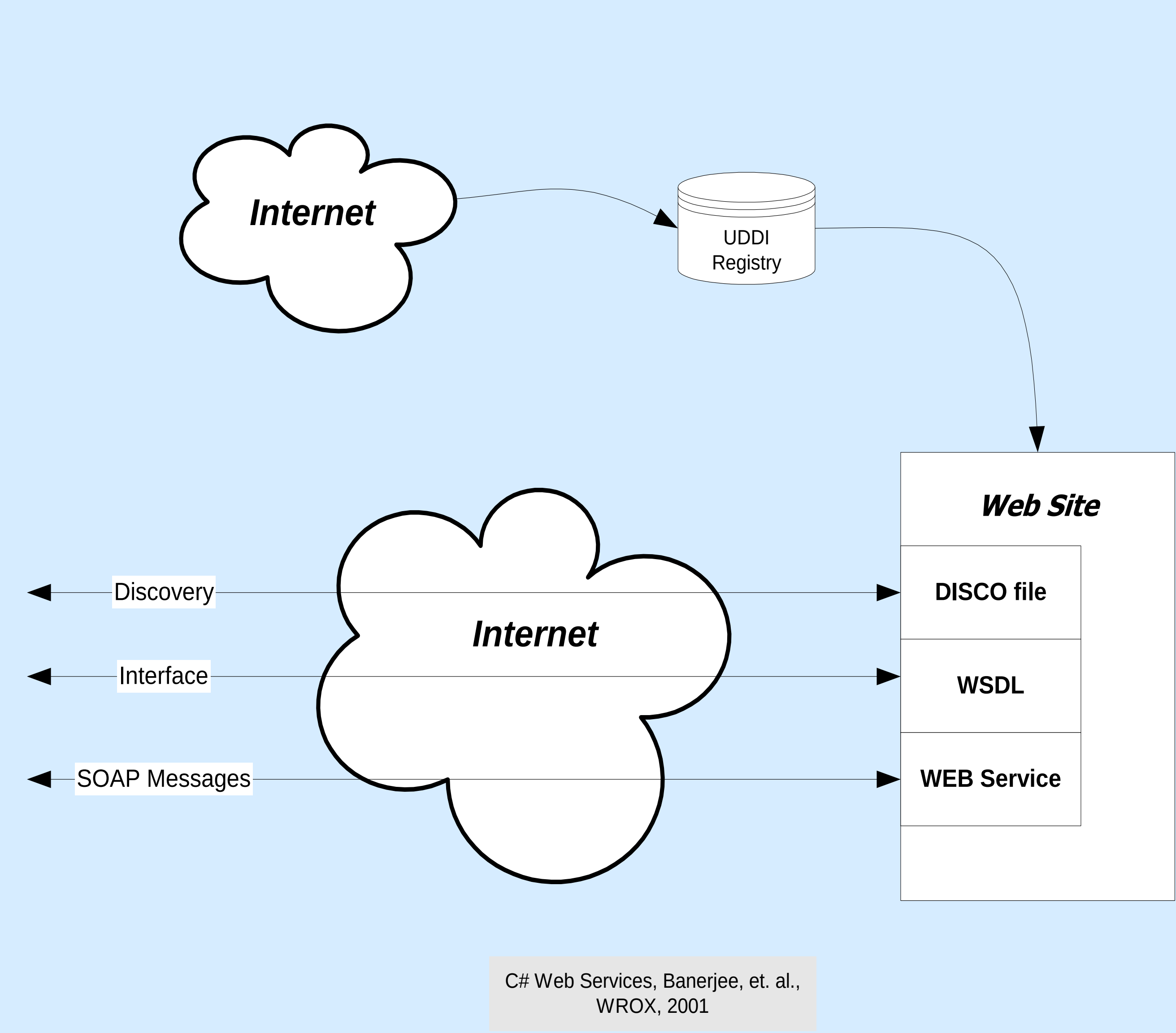


Service Layered Structure

- Provides a structure based on:
  - System Services – things the user doesn’t think about
    - Communication, storage, security, file caching, …
  - User Services – things the user manipulates as part of the use of the system
    - Input, Display, Check-in/Check-out, …
  - Ancillary – Things that are not part of the system mission but are necessary
    - Logging, extension hooks, test hooks, …

Distributed Services

- Structure:
  - Service oriented systems are simply client server.
  - Usually the server is implemented with a web service or operating system service.
    - Web service is a web application that provides an interface for client software to access.
    - OS service is a system application that provides an interface for requests and an administration interface for setting service startup and shutdown policies.
  - Windows Communication Foundation (WCF) has extended that model to support hosting in:
    - desktop application
    - windows service hosted with Windows Service Control Manager (SCM)
    - web service hosted by Internet Information Server (IIS).



C# Web Services, Banerjee, et. al., WROX, 2001

WCF Protocols

- WCF supports:
  - Http – SOAP over Http in clear text - BasicHttp
  - Http – SOAP with security extensions – WsHttp
  - NetTcp, SOAP over TCP
- SOAP – Simple Object Access Protocol
  - An XML body for HTTP or TCP messages
  - Usually contains a message body in XML defined by a Data Contract
- WCF is a very flexible, relatively easy to use, but heavy weight communication mechanism

REpresentational State Transfer

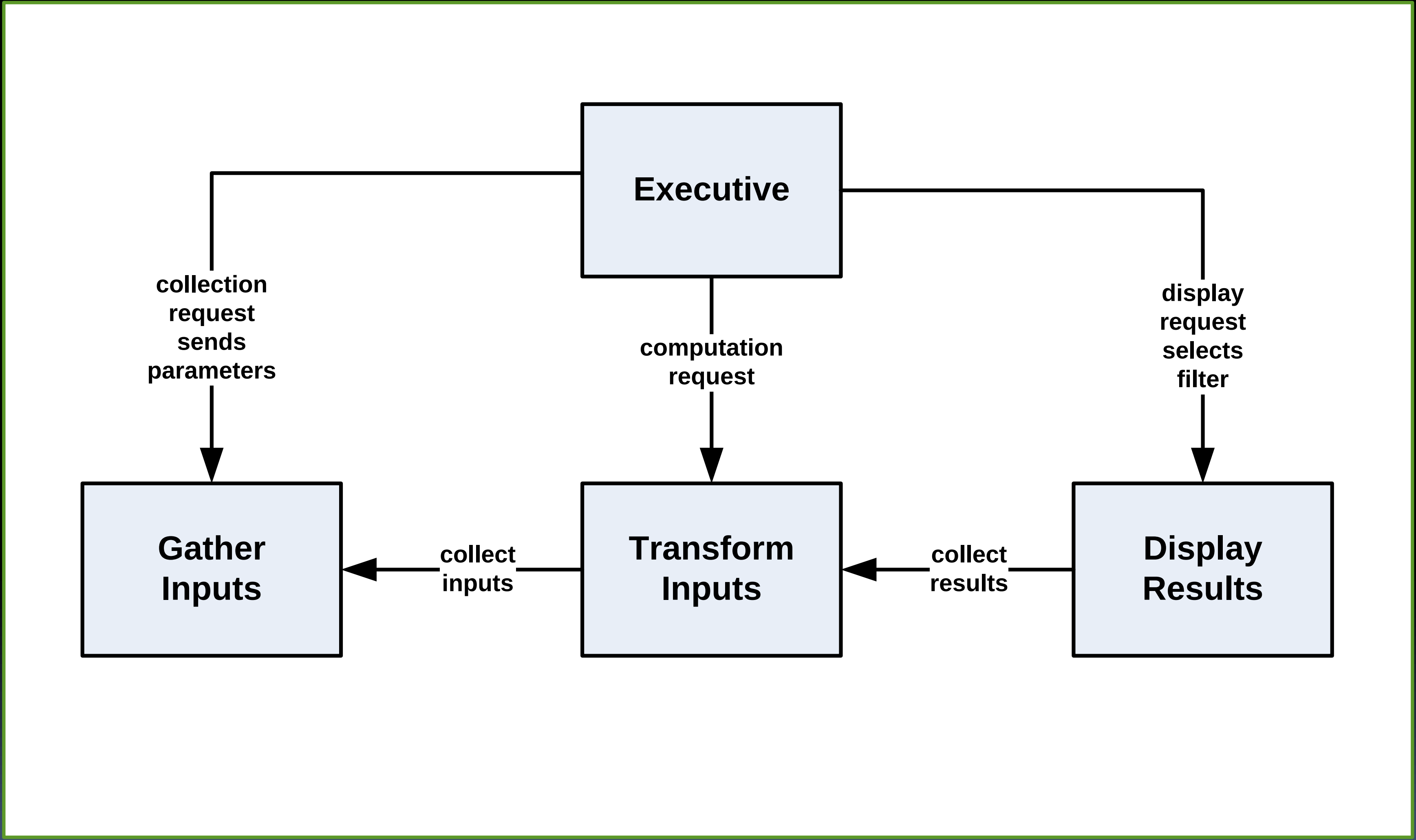
- REST is a message-passing communication system built on the HTTP protocol, using the Web verbs:
  - Get – retrieve a resource without changing the state of the server.
  - Post – send information to the server that may change its state.
  - Put – place a resource on the server.
  - Delete – remove a resource from the server.
- Its encoding is UTF text, not SOAP or some other complex messaging format, but may use encryption, as in HTTPS.

Analysis Driven Structure

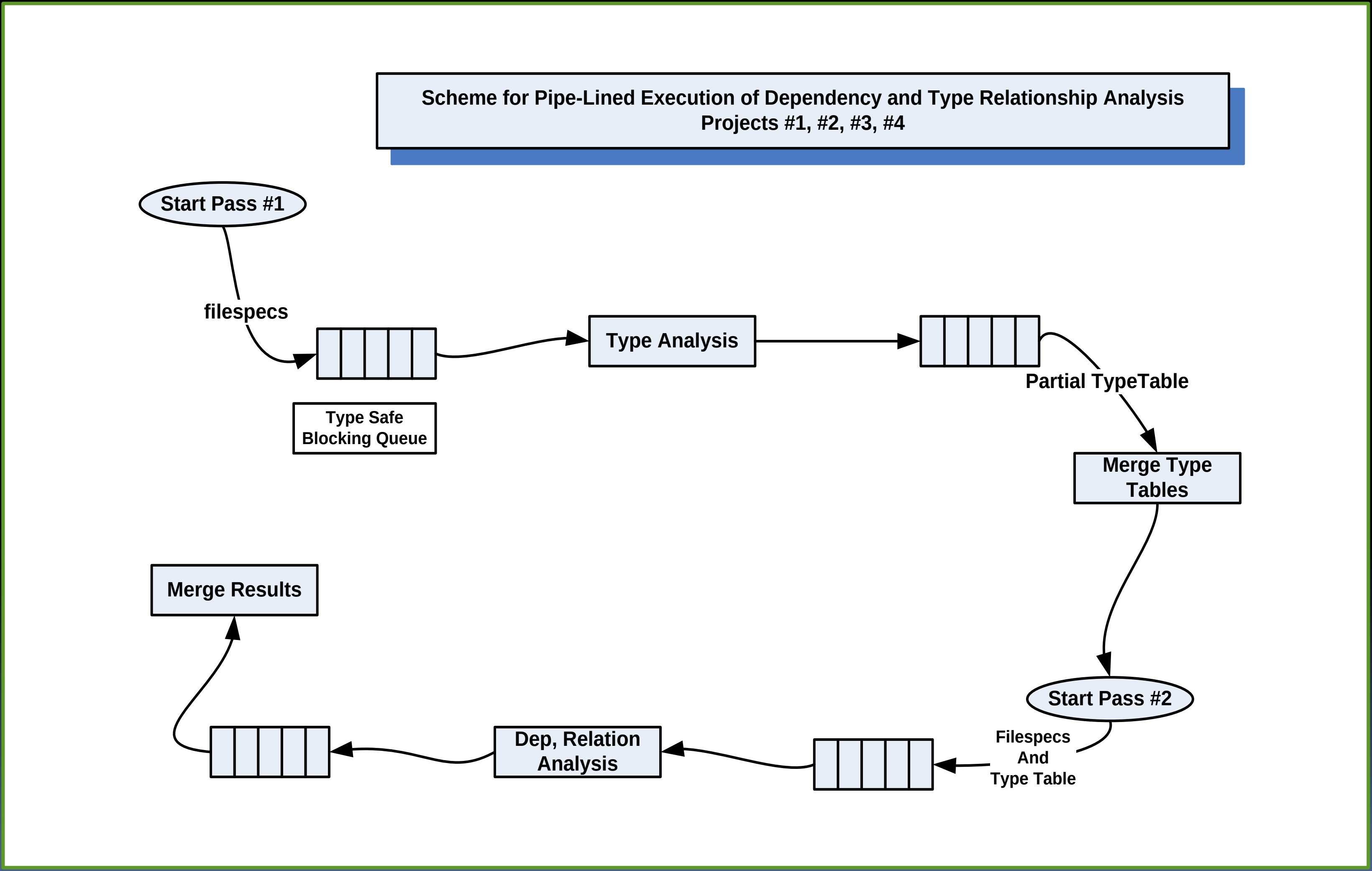
Analysis Driven Structure

- Packages
  - Gather working set (inputs needed for analysis)
  - Execute one or more phases of analysis
  - filter and interpret resulting data to provide information
  - Present the analysis information

Package Structure – Analysis Driven



Projects #1-#4 – Fall 2014



Communication Driven Structure

Communication Driven Structure

- When users, data, and application logic are distributed across processes and machines communication becomes important:
  - Client-Server
  - Peer-to-peer
  - Communication Middleware
    - RPC (RMI)
    - Message-Passing

Performance

- Suppose that processing a request takes T units of time if requester and provider are in the same process.
- Executing the same request across processes takes about 10 T units of time.
- Executing the same request across a network takes about 100 T units of time.
- Executing the same request across the internet takes about 1000 T units of time.

Structure: Client-Server

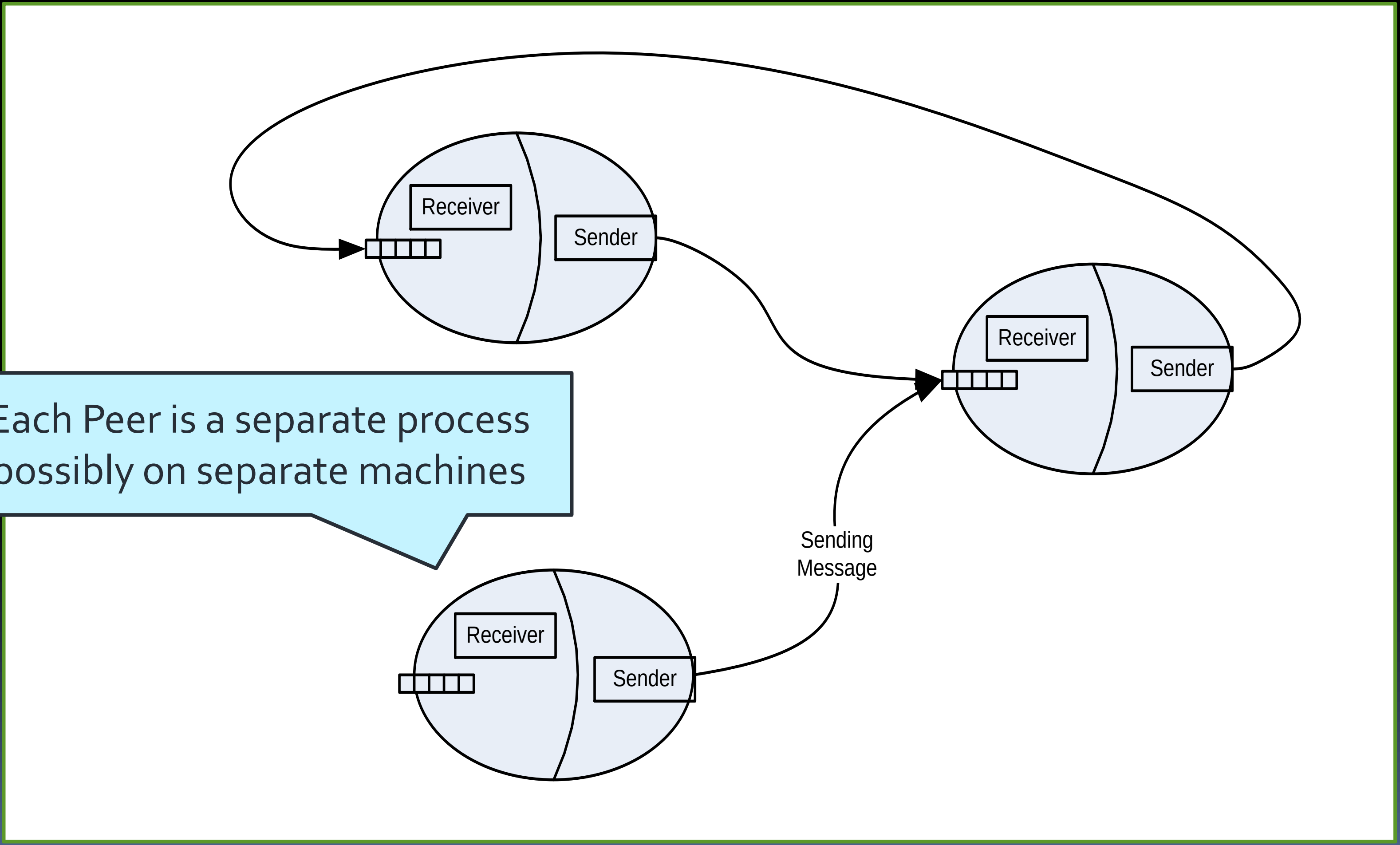
- Behavior:
  - Server is passive, waits for client requests
  - Server handles multiple concurrent clients
  - Without additional structure system may become tightly coupled and difficult to change

- Example:
  - Web server and browser clients
  - Every class that holds a reference to another thread-safe class

Structure: Peer-To-Peer

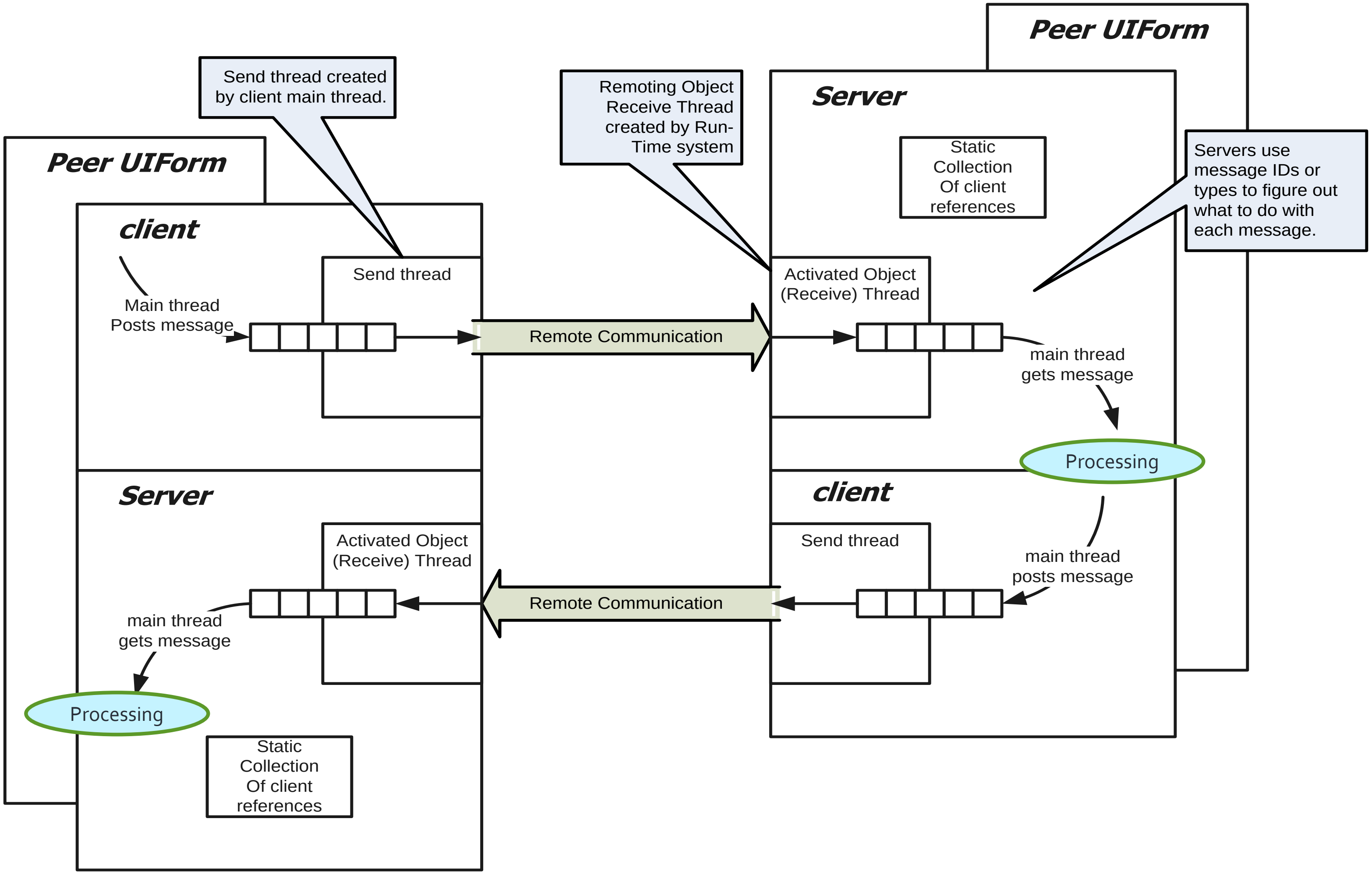
- Behavior:
  - Peers interact, sending and receiving messages from each other.
  - Peers are sometimes identical.
  - Many Peer-to-Peer models support central or distributed locater services.
- Examples:
  - http://www.ecs.syr.edu/faculty/fawcett/handouts/CoreTechnologies/SocketsAndRemoting/code/WCF_Fawcett_Examples/WCF_Peer_Comm/
  - Bit-Torrent
  - Napster

Peer-To-Peer Asynchronous Message-Passing Structure



Each Peer is a separate process possibly on separate machines

A Reusable Communication Structure



Send thread created by client main thread.

Remoting Object Receive Thread created by Run-Time system

Servers use message IDs or types to figure out what to do with each message.

Communication Types

- Remote Procedure Call (RPC):
  - Supports function call semantics between processes and machines.
  - Sends messages over wire but provides stack frames for client and server to support the function call model.
  - Examples: COM, CORBA, WCF
- Message Passing:
  - Sends message with encoded request and/or data
  - Message contains endpoint information for routing
  - Directly supports asynchronous processing
  - Examples: Internet, Web, SMA and OOD projects

Communication Patterns

- TwoWay:
  Synchronous Request, wait for reply
- Duplex:
  asynchronous request, reply sent as callback
- OneWay:
  Send Message and forget
  - Receiver may send result back to requester as a subsequent OneWay message
- Examples:
  - All of the above are supported by WCF

Communication Style

- Push Model
  - Send information to a remote endpoint via a service call, perhaps via a message:

```
void PostMessage(Message msg);
```

- Pull Model
  - Retrieve information from a remote endpoint via a service call, perhaps by a streaming download:

```
Stream downLoad(string filename);
```

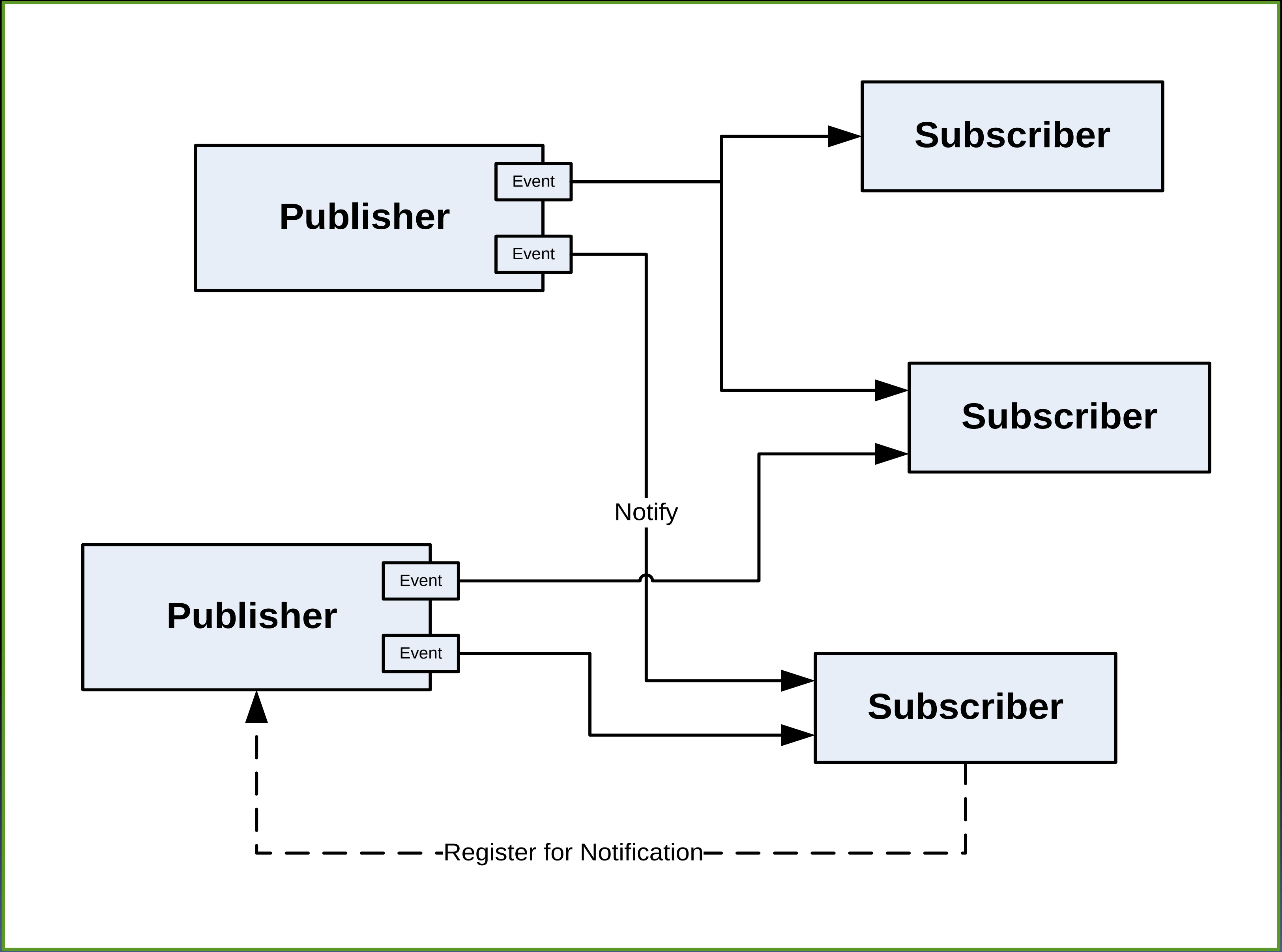
Communication Style

- Pull Service and Caching
  - A Software Repository could expose a WCF service that provides information about its package contents including dependencies.
  - That allows a client, for example, to pull from the Repository all files in a package dependency list that are not already in its file cache.

Thread & Event Driven Structure

Structure: Publish & Subscribe

- Structure:
  - Many to many connection of Publishers and Subscribers.
  - Each subscriber registers for notifications with a specific interface.
  - Publishers send notifications to all enrolled subscribers when a publisher event occurs.
  - Publishers can support multiple events.
  - Publishers don’t need to know anything about the subscriber.


Subscriber
Publisher
Event
Event
Subscriber
Notify
Publisher
Event
Event
Subscriber
Register for Notification

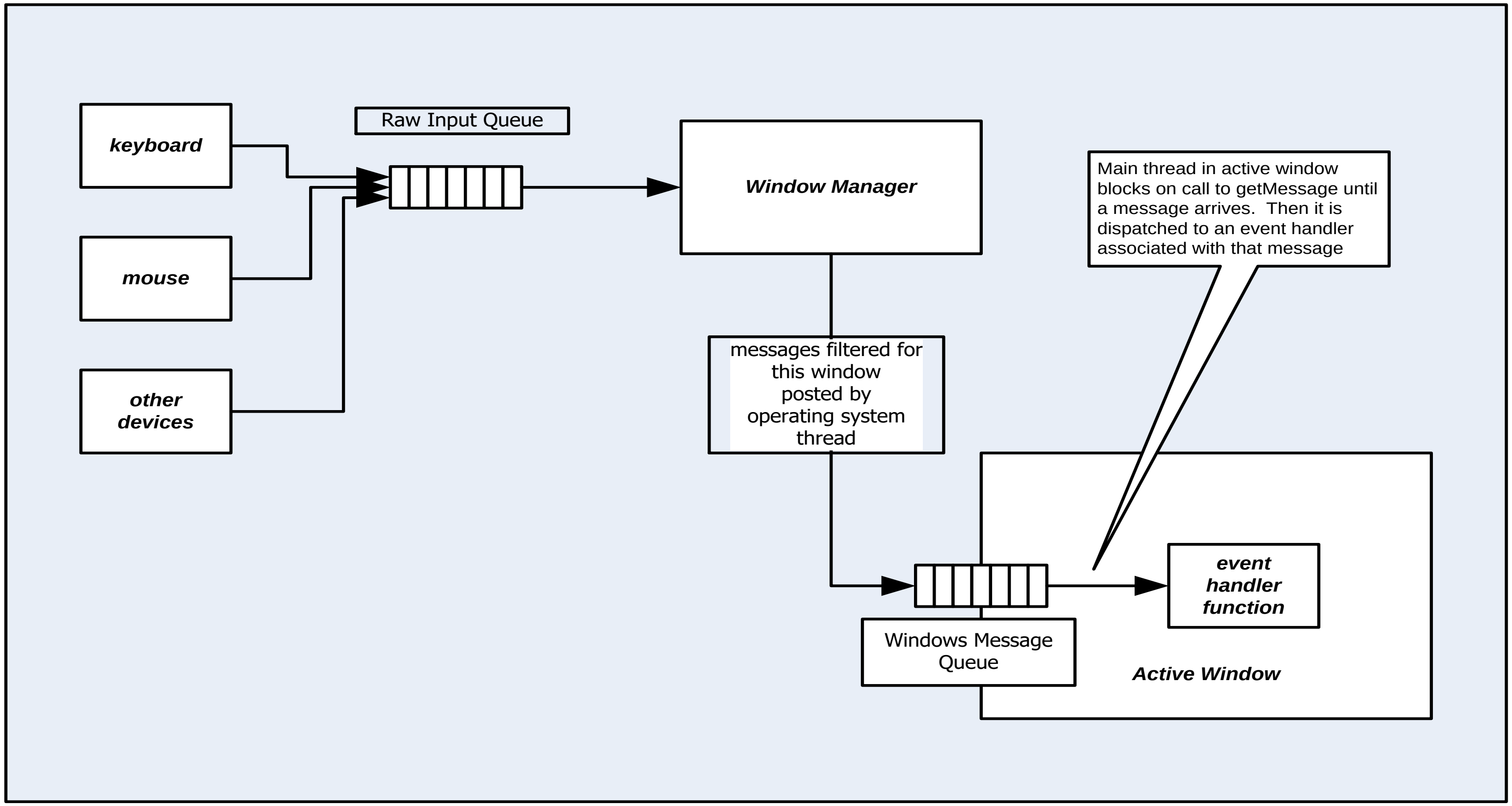
Threading Driven Structure

- Some program structures are a consequence of specific threading models
  - Event-driven and Single Threaded Apartment (STA)
  - Parallel execution
  - Pipelined execution

Structure: Event-Driven

- Structure:
  - Events from multiple concurrent sources generate messages which are enqueued, and typically are processed by a single handling thread.
  - Messages are dispatched to event-handlers for processing.
- Example:
  - Windows processing

Event-Driven



Main thread in active window blocks on call to getMessage until a message arrives. Then it is dispatched to an event handler associated with that message

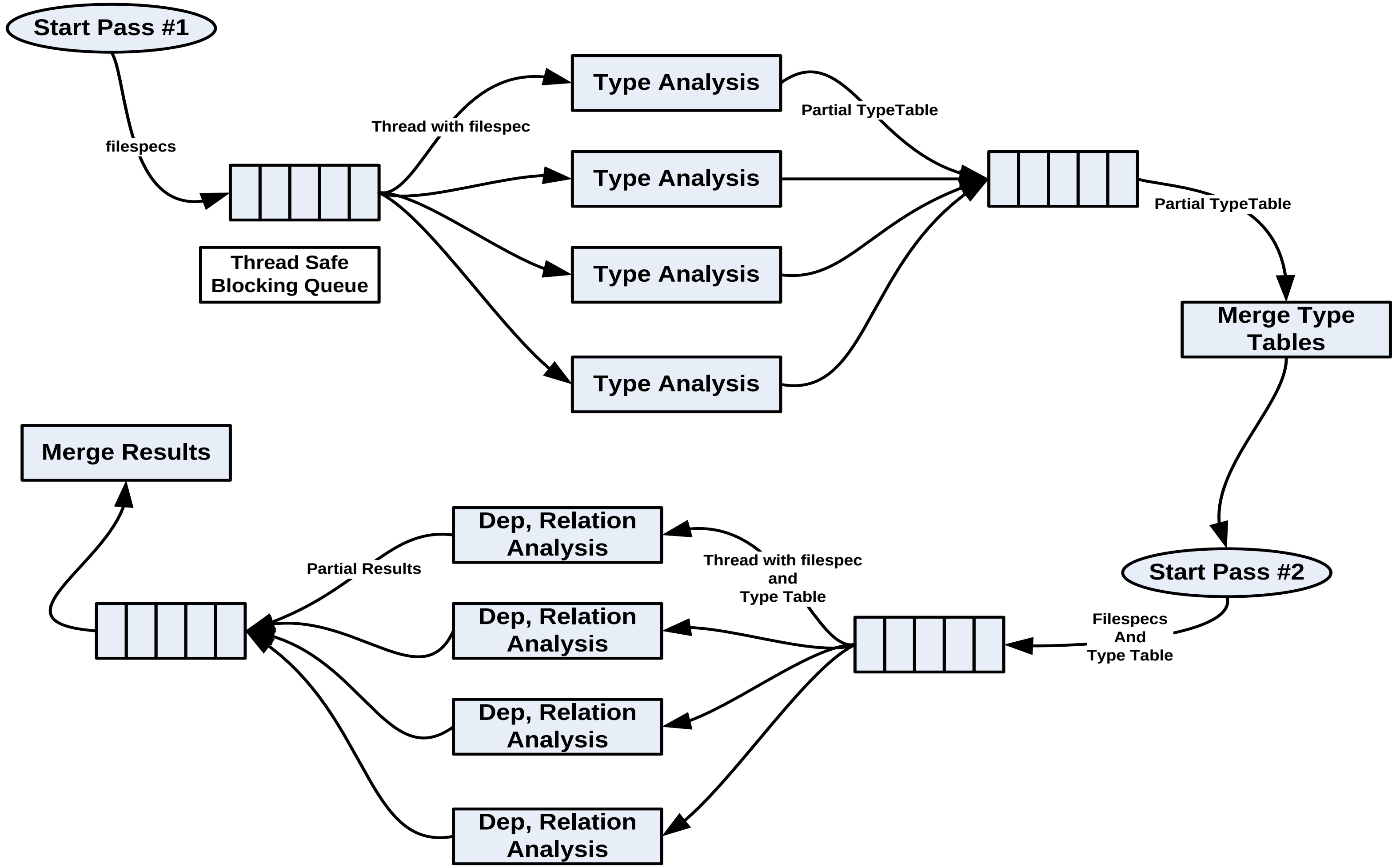
Single Threaded Apartment

- Graphical User Interfaces all use the STA model.
  - Possibly concurrent clients send messages to the GUI's message queue.
  - All messages are retrieved by a single thread, the one that created the window.
  - Child threads, often used to execute tasks for the GUI, are not allowed to directly interact with the window.
  - Instead they must send or post messages to the window's message queue.
  - This is often done with Form.Invoke or Dispatcher.Invoke.

Parallel Execution

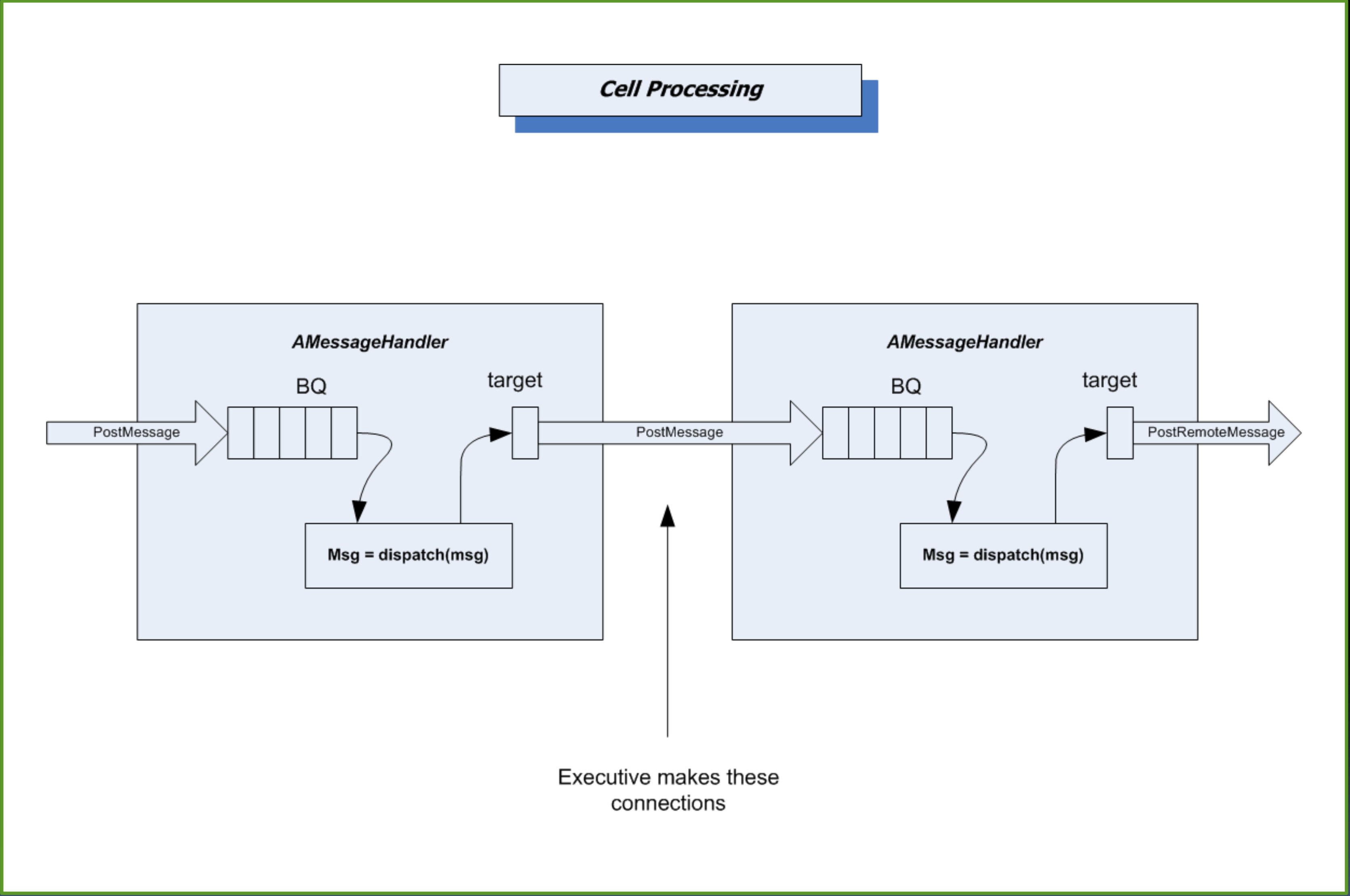
- Structure:
  - Often concurrent programs provide enqueued task requests.
  - Threads, perhaps from a thread pool, are dispatched to handle each task.
  - Tasks must be independent in order to fully realize the benefits of concurrency.
- Example:
  - Concurrent execution of dependency analysis tasks.

Scheme for Parallel Execution of Dependency and Type Relationship Analysis Projects #1, #2, #3, #4



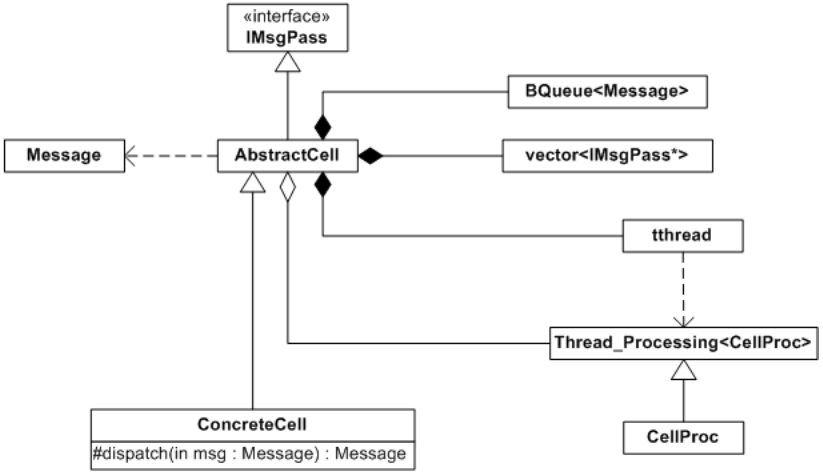
Pipeline Execution

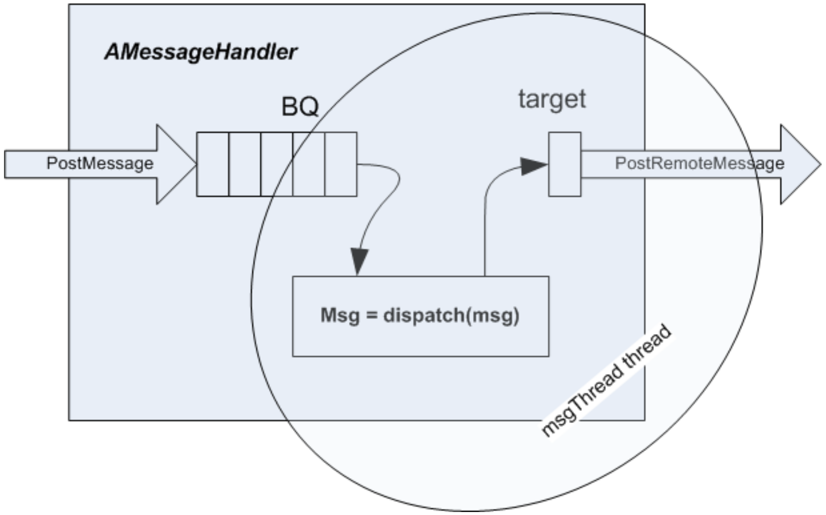
- Structure:
  - Composed of cells.
  - Each cell has a message queue and a child thread that processes messages.
  - Result messages may be sent on to another cell.
  - Each cell type is defined by the way it overrides a virtual message processing function.
- Example:
  - Project #4, CSE687 – OOD, Spring 2010



Executive makes these connections

Cell Structure

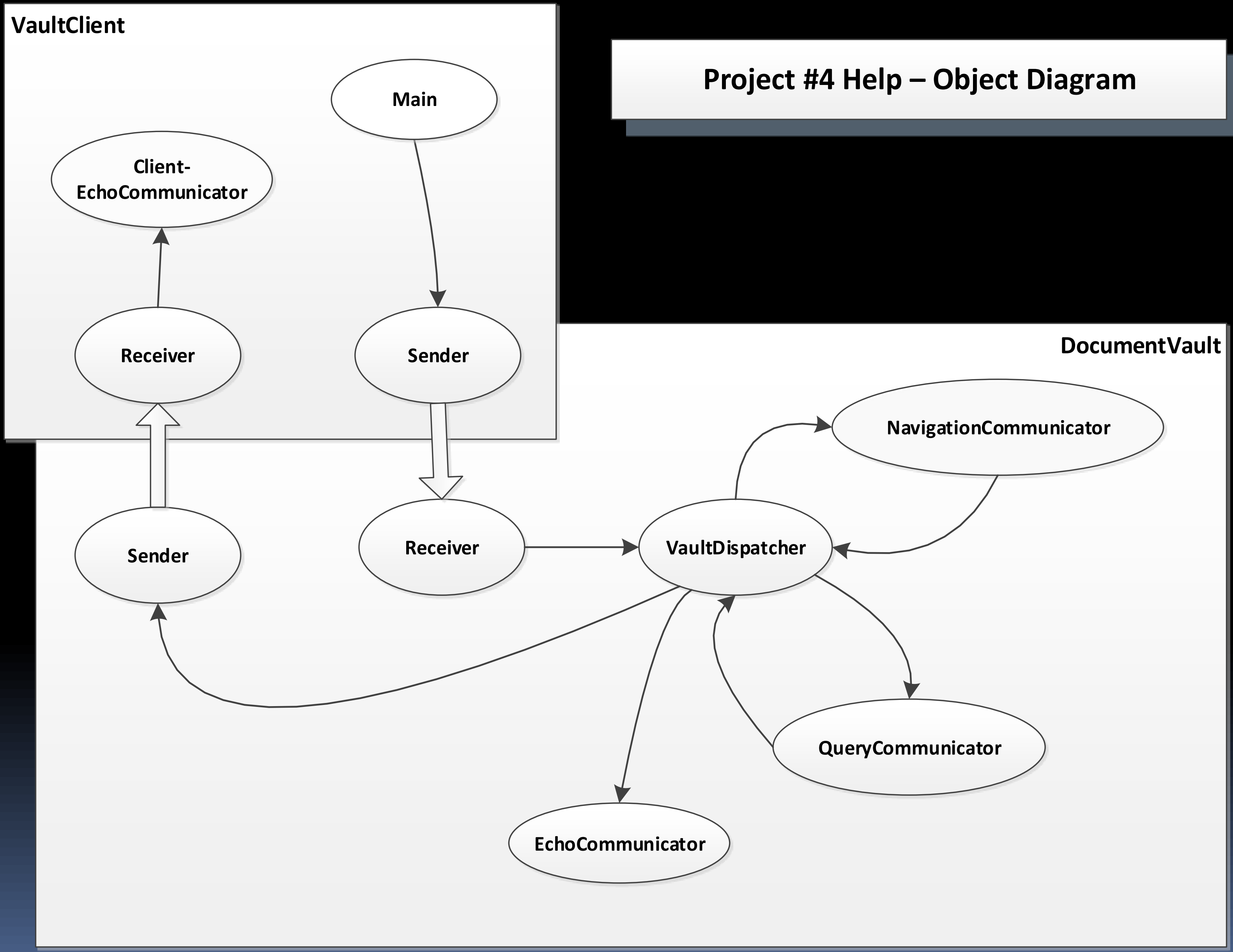




Pipe-lined Cell Communicators

- Document Vault (Project #4 – Fall 2013)
  - Uses pipe-lined cells as communicators
  - Mediator (dispatcher) controls routing of messages
  - Each cell has capability to send and receive messages
  - Makes very flexible configuration of client and server capabilities

Project #4 Help – Object Diagram



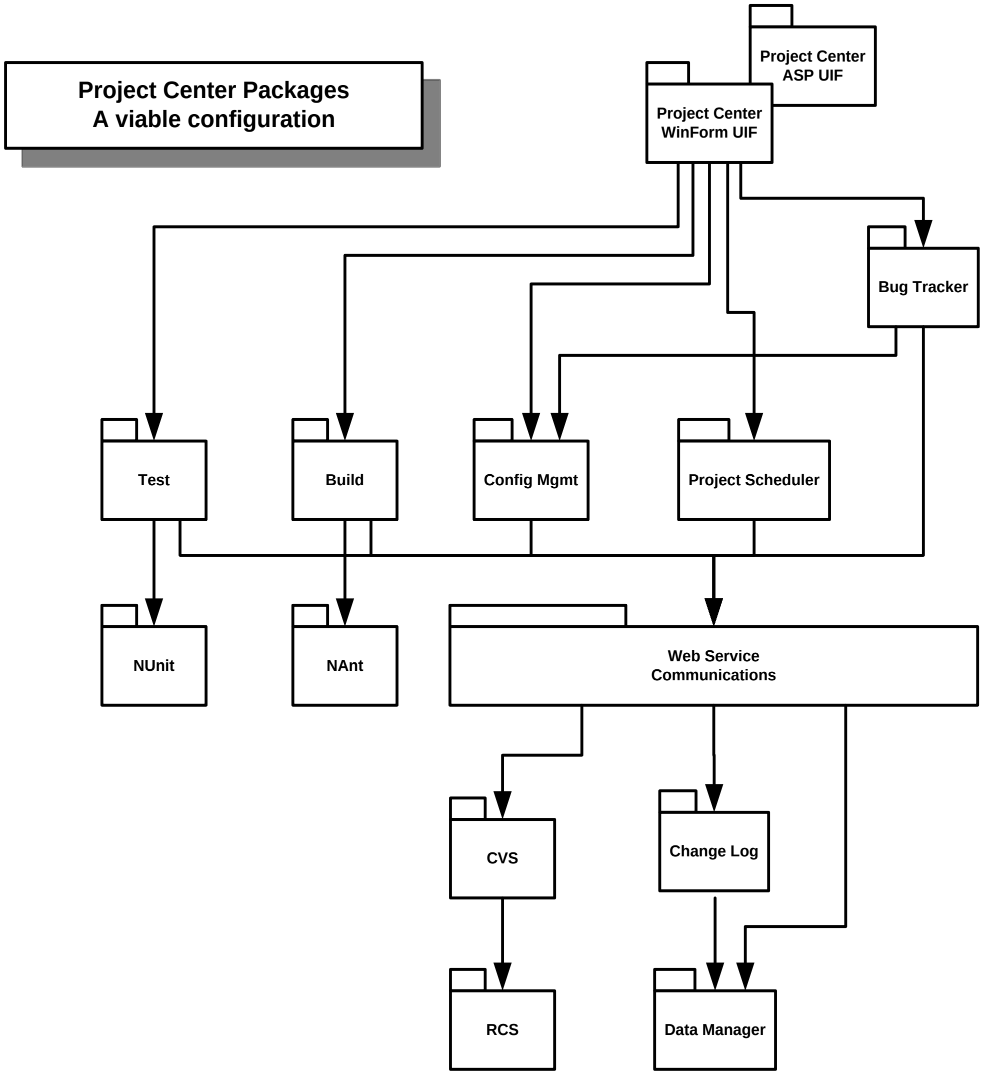
Enterprise Computing

Enterprise Computing

- Large Enterprise Applications are usually constructed as a federation of lower level systems and subsystems.
  - The federation is glued together with network based middleware, or more commonly now, with web services.
- Example: PeopleSoft, used by S.U.
  - Payroll and accounting
  - Academic planning and record keeping
  - Employee services
  - A variety of web applications, like mySlice.

Enterprise App: Project Center

- Federation of tools supporting Software Development
  - Open source tools with integrating wrappers:
    - CVS – configuration managment
    - Nant – sofware builds
    - Nunit – software testing
  - Newly developed and legacy tools:
    - Bug tracker, change tracker, project scheduler
- http://www.ecs.syr.edu/faculty/fawcett/handouts/webpages/ProjectCenter.htm



Project Center Packages
A viable configuration

Project Center ASP UIF

Project Center WinForm UIF

Bug Tracker

Test

Build

Config Mgmt

Project Scheduler

NUnit

NAnt

Web Service Communications

CVS

Change Log

RCS

Data Manager

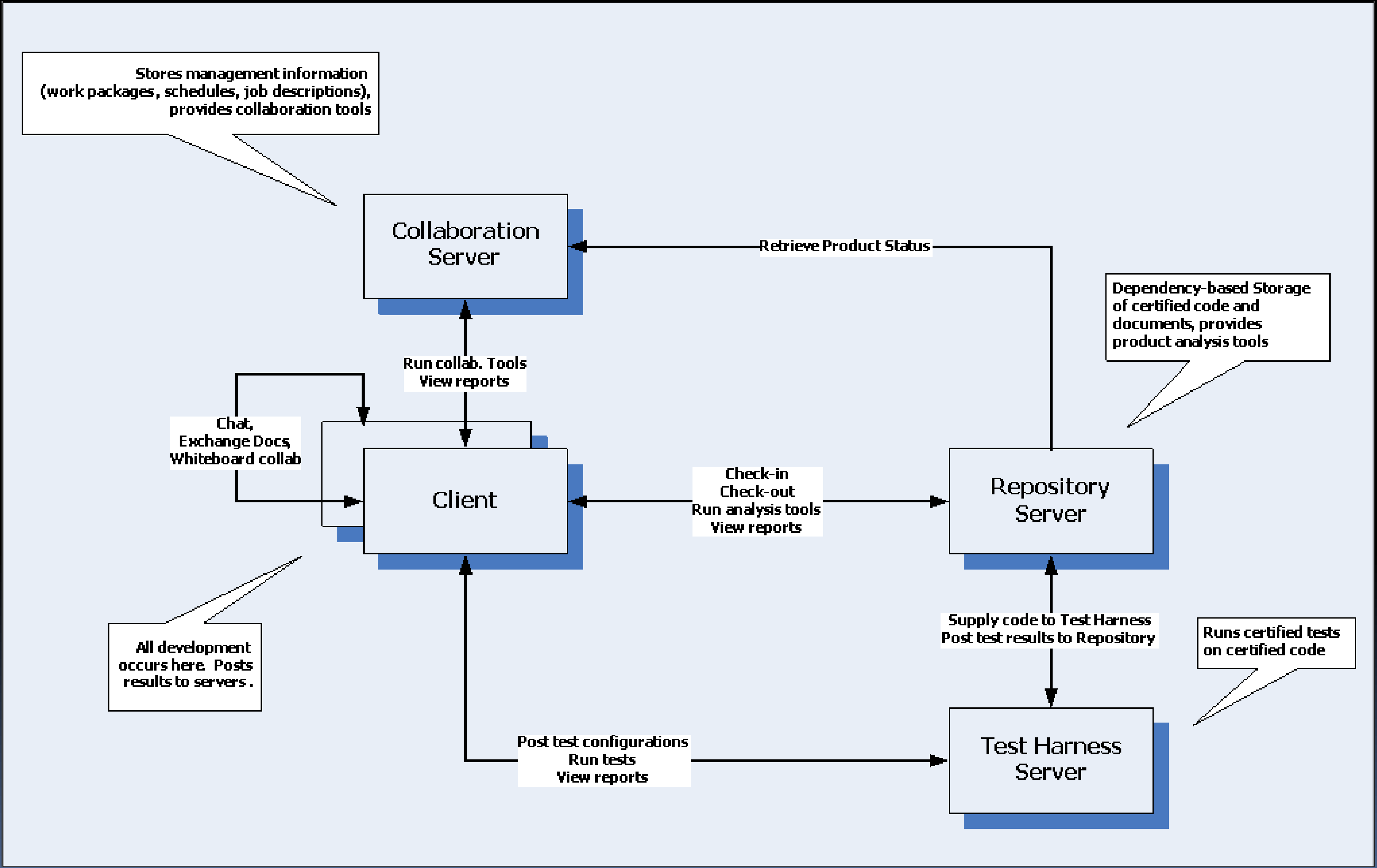
Federation Structure

- Federated Systems often are based on one of two design patterns:
  - ***Façade*** provides an integrating interface that consolidates a, possibly large, set of system interfaces into a single application interface in an attempt to make the system easier to use than working directly with its individual parts.
  - ***Mediator*** serves as a communication hub so that all the various subsystems need know only one interface, that of the mediator.

Collaboration System

- System that focuses on sharing of processes and products among peers with a common set of goals.
  - Primary focus is organizing and maintaining some complex, usually evolving, state:
    - Software development baseline
    - Set of work plans and schedules
    - Documentation and model of obligations
    - Communication of events
- Example:
  - Collab – CSE784, Fall 2007, http://www.ecs.syr.edu/faculty/fawcett/handouts/webpages/CServ.htm

Example Collaboration System



Other System Structures

Agent-Based

- System uses Software Agents
  - Semi-autonomous, mobile, task oriented software entities. Crawl web, or network, or data structure
  - May be scheduled
  - Provide scriptable user specific services
    - Collect information from a large set of data
    - Perform analyses on changing baseline and report
    - Conduct specific tests
    - Make narrowly specified modifications to baseline
- Example:
  - CSE681 Project #5, summer 2009, http://www.ecs.syr.edu/faculty/fawcett/handouts/CSE681/Projects/Pr5Su09.doc

Master's Thesis Research Examples

- The following are all based on Software Matrix structure – Autonomous cells often used with mediator
  - Software Matrix – Gosh, 2004
  - Self Healing Systems – Anirudha, 2005
  - Cross Platform Development – Appadurai, 2007
  - Model-Driven Development – Patel, 2007
- http://www.ecs.syr.edu/faculty/fawcett/handouts/webpages/research.htm

Other Structures

- TeraScale computing:
  - Buzzword defined by Intel to describe parallel execution on a many core processor.
    - Expectations are chips with scores of processors
- Cloud Computing
  - Term adopted by many to describe remote execution and storage of applications defined locally. The cloud provides a stable endpoint that may map onto any one of a large set of computing resources.
  - Example:
    - Microsoft's Azure platform
    - Amazon Web Services
    - Google Cloud

SMA Projects - 2015

- Project #2 – Fall 2015
  - NoSql Database
    - Key/Value store
    - Provides cloning, persistence, querying, views
- Project #4 – Fall 2015
  - Client-Server
    - Focus on NoSqlDb performance testing
    - May have multiple concurrent clients
    - Both client and server may use DLLs for significant processing
- Project #5 – Fall 2015
  - Federation of clients and servers
    - Focuses on data service layer
    - May have a dedicated virtual server with child services on each of the Federation servers

SMA Projects – Before 2015

- Project #2 – Fall 2013
  - Cooperating monolithic processes
    - Composite Text analyzer
    - Metadata generator
- Project #4 – Fall 2014
  - Client-Server
    - May have multiple concurrent clients
    - Both client and server use DLLs for significant processing
- Project #5 – Fall 2013
  - Federation of clients and servers
    - Focuses on Software Repository server
    - May wish to use virtual servers

THE END