# Fundamentals Of COM(+) (Part 2)


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# COM – The idea

- COM is based on three fundamental ideas
- Clients program in terms of interfaces, not classes
- Implementation code is not statically linked, but rather loaded on-demand at runtime
- Object implementers declare their runtime requirements and the system ensures that these requirements are met
- The former two are the core of classic COM
- The latter is the core of MTS and COM+

# Tale Of Two COMs

- COM is used primarily for two tasks
- Task 1: Gluing together multiple components inside a process
  - Class loading, type information, etc
- Task 2: Inter-process/Inter-host communications
  - Object-based Remote Procedure Calls (ORPC)
- Pros: Same programming model and APIs used for both tasks
- Cons: Same programming model and APIs used for both tasks
- Design around the task at hand

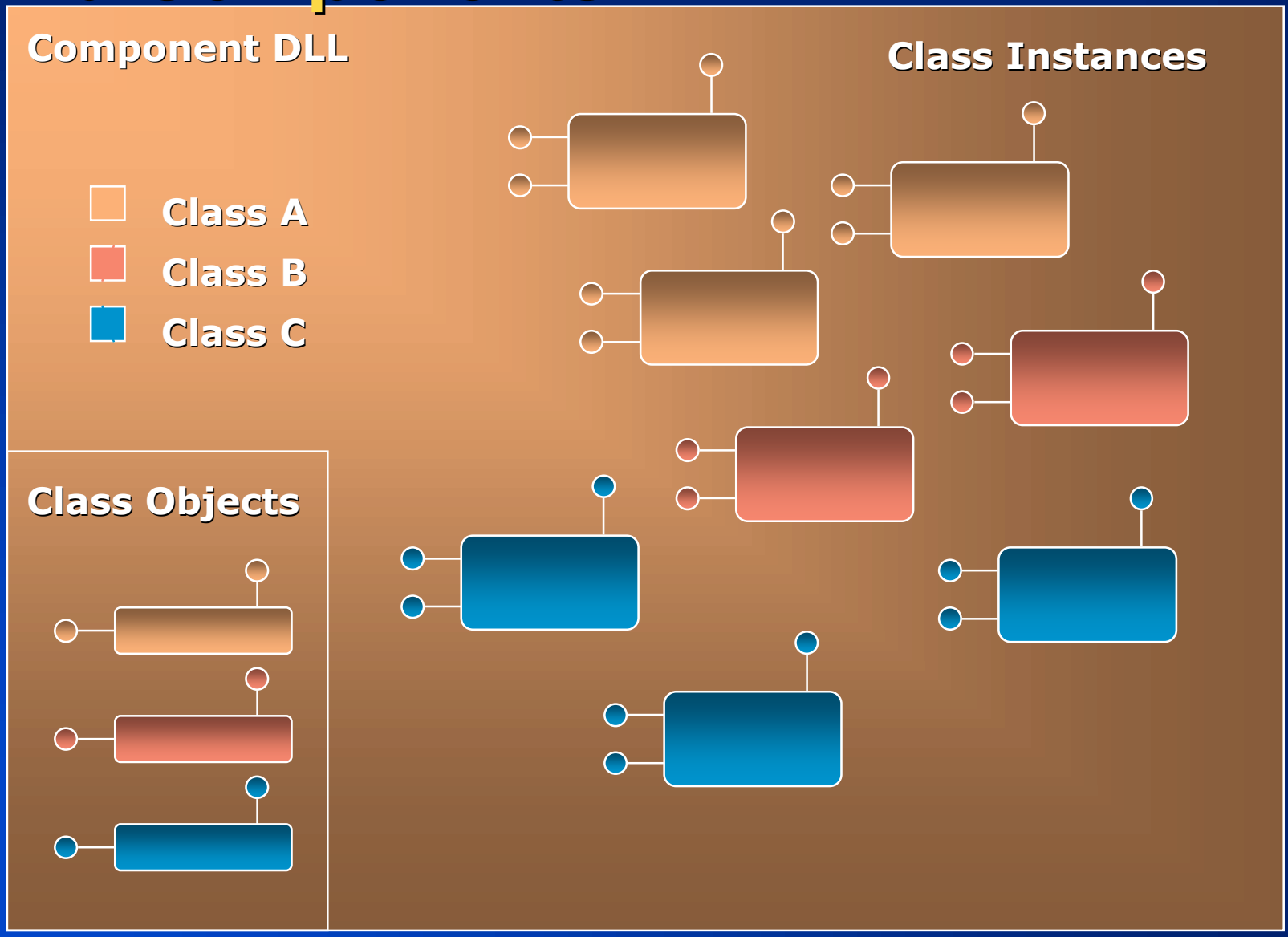
# Definitions

- Two key terms have been defined so far
- A COM Interface is a collection of abstract operations one can perform on an object
  - Must extend IUnknown directly or indirectly
  - Identified by a UUID (IID)
  - Platform-specific vptr/vtable layout
- A COM Object is a collection of vptrs in memory that follow the COM identity laws
  - Must implement at least one COM interface
  - QueryInterface ties vptrs together into cohesive object
- Objects assumed to materialize from thin air!

# Definitions

- A COM Class (or coclass) is a named body of code that can be used to produce COM objects
- All coclasses are named by a UUID (CLSID)
- All coclasses have a distinguished object that is used to create new instances
  - Called a class object or class factory
  - Typically implements IClassFactory
- All coclasses loaded on demand by class loader
  - Called the Service Control Manager or (SCM)
- For efficiency, a single component DLL can support multiple COM classes

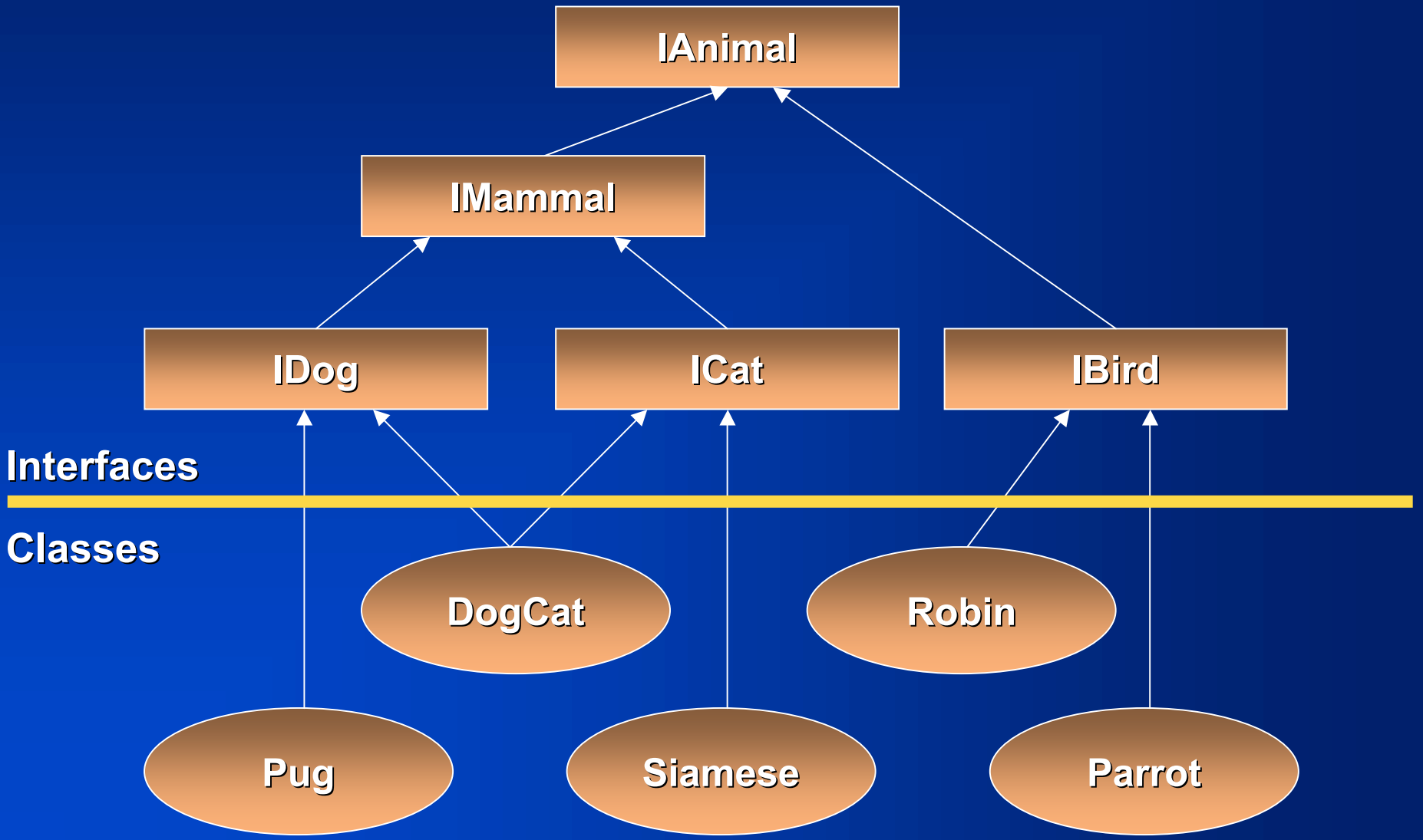
# Classes, Class Objects, And Components



# Class Versus Type

- An Interface represents a data type suitable for declaring variables
  - Non-trivial operations
  - Hierarchical with respect to one another
  - Polymorphic with respect to different objects
- A Class represents loadable concrete code used to create objects
  - Resultant objects implement one or more interfaces
- Class unsuitable for declaring variables
  - Entire motivation for interface-based programming based on relative uselessness of class

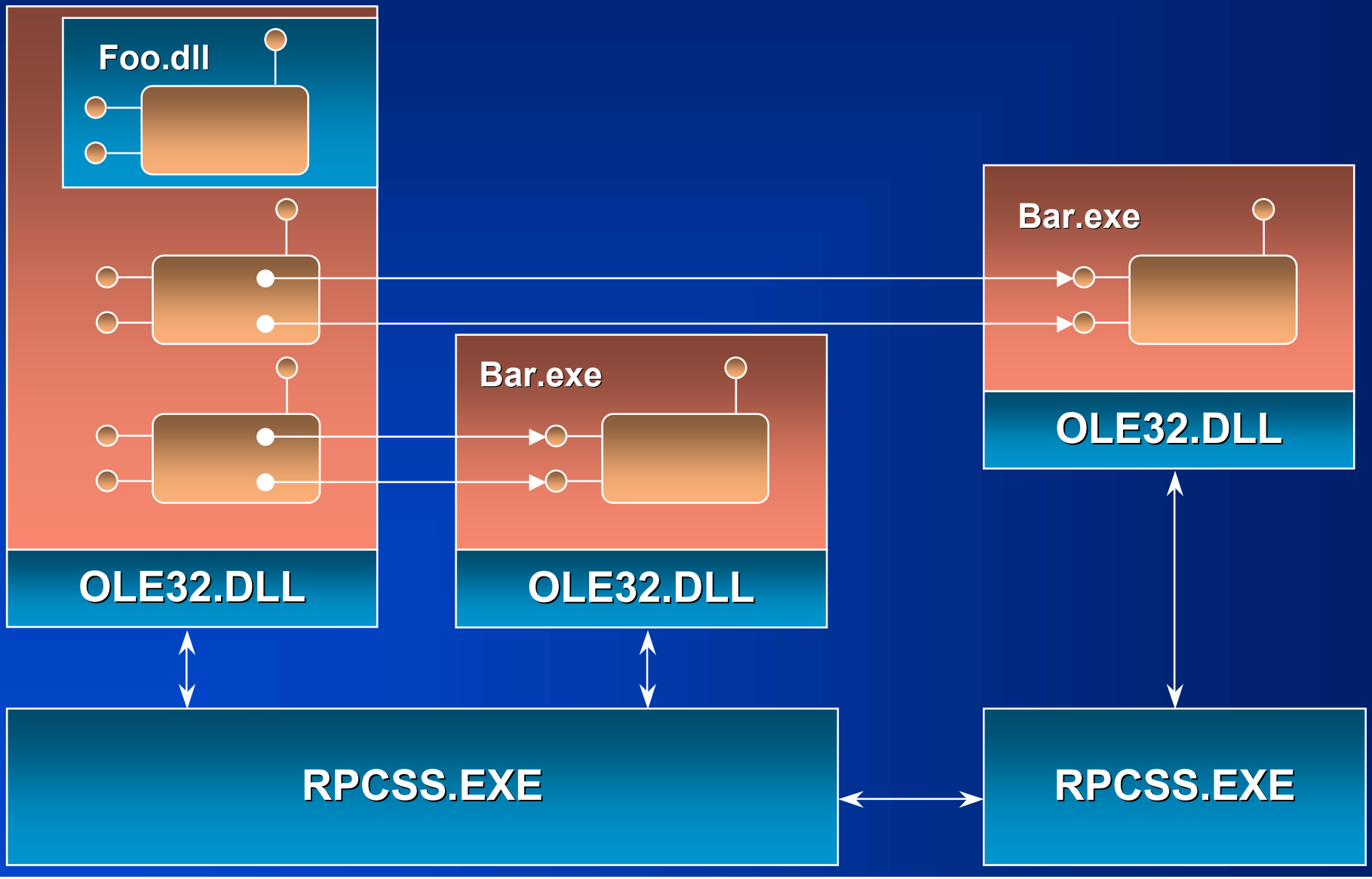
# Class Versus Type



# The COM Runtime Environment

- The infrastructure used to support COM on a given platform is called the COM library
- Each thread that uses COM library must setup/teardown thread-specific data structures
  - CoInitialize[Ex] and CoUninitialize do this for you
- The COM library implemented in several DLLs
  - OLE32.DLL – core class/interface functionality
  - OLEAUT32.DLL – Visual Basic®-centric type infrastructure
- Inproc class loading done in OLE32.DLL
- Cross-process/host class loading performed by Windows NT® Service (RPCSS.EXE)

# The COM Runtime Environment



# COM Class Loading

- Clients issue activation calls against the SCM
- SCM responsible for locating component and loading it into memory
- SCM queries component for class object and (optionally) uses it to instantiate new instance
- Once SCM returns a reference to class instance/class object, SCM out of the picture
- Based on configuration, COM may need to load component in separate process (potentially on different machine)

# COM Class Loading And Locality

- All activation calls allow client to indicate locality
  - SCM chooses most efficient allowed by client

```
CLSCTX_INPROC_SERVER  // load in client process
CLSCTX_INPROC_HANDLER // use OLE Document rendering handler
CLSCTX_LOCAL_SERVER   // load in separate process
CLSCTX_REMOTE_SERVER  // load on distinct host machine
CLSCTX_SERVER         // CLSCTX_*_SERVER
CLSCTX_ALL            // CLSCTX_*
```

```
typedef struct _COSERVERINFO {
  DWORD dwReserved1;       // m.b.z.
  const OLECHAR *pwszName; // host name
  COAUTHINFO *pAuthInfo;   // security goo
  DWORD dwReserved2;       // m.b.z.
} COSERVERINFO;
```

# Using The SCM

- The SCM exposes two core activation APIs
- Both APIs load component automatically
- Both APIs accept a CLSID and information about component location as input parameters
- CoGetClassObject returns class object/factory
  - No new instances created
- CoCreateInstanceEx uses IClassFactory interface on class object to create new instance
  - Class object never returned to client

# CoGetClassObject/IClassFactory

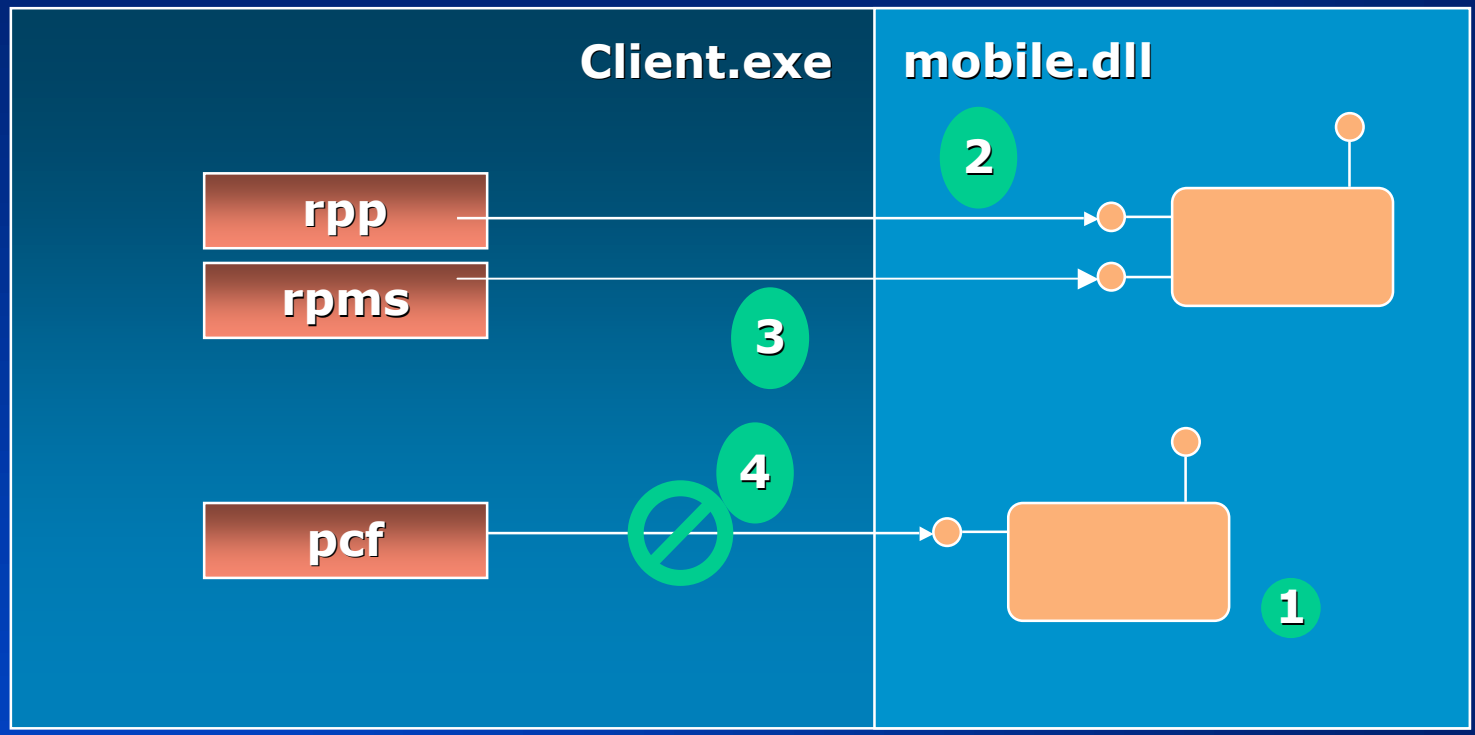
```
interface IClassFactory : IUnknown {
// create a new com object
  HRESULT CreateInstance([in] IUnknown *pUnkOuter,
                         [in] REFIID riid,
    [out,retval,iid_is(riid)] void **ppv);
// hold component code in memory
  HRESULT LockServer([in] BOOL bLock);
}
```

```
 HRESULT CoGetClassObject(
      [in] const CLSID& rclsid, // which class?
      [in] DWORD dwClsCtx,      // locality?
      [in] COSERVERINFO *pcsi,  // host/sec info?
      [in] REFIID riid,         // which interface?
      [out, iid_is(riid)] void **ppv // put it here!
 );
```

# Example

```
void CreatePager(IPager *&rpp, IMessageSource *&rpms) {
  IClassFactory *pcf = 0; rpp = 0; rpms = 0;
// ask SCM to load class code for Pager
  HRESULT hr = CoGetClassObject(CLSID_Pager, CLSCTX_ALL, 0,
                        IID_IClassFactory, (void**)&pcf);
  if (SUCCEEDED(hr)) {
// ask class code to create new class instance
    hr = pcf->CreateInstance(0, IID_IPager, (void**)&rpp);
    if (SUCCEEDED(hr))
      hr = rpp->QueryInterface(IID_IMessageSource,
                               (void**)&rpms);
    pcf->Release();
  }
}
```

# Example




1. Client calls CoGetClassObject
2. Client calls CreateInstance on Class Object
3. Client calls QueryInterface on Class Instance
4. Client calls Release on Class Object

# CoGetClassObject Pitfalls

- Previous example made at least four round-trips in distributed case
  - One for CoGetClassObject
  - One for CreateInstance
  - One for QueryInterface
  - One for IClassFactory::Release
- Superior solution would perform class loading and object creation in one round trip
- Solution: CoCreateInstance[Ex]

# CoCreateInstanceEx

```
typedef struct {
  const IID *pIID;
  IUnknown  *pItf;
  HRESULT    hr;
} MULTI_QI;
```

```
HRESULT CoCreateInstanceEx(
    [in] const CLSID& rclsid, // which class?
    [in] IUnknown *pUnkOuter, // used in aggregation
    [in] DWORD dwClsCtx,      // locality
    [in] COSERVERINFO *pcsi,  // (opt) host/sec. info
    [in] ULONG cItfs,         // # of interfaces
[in, out] MULTI_QI *prgmqi    // put them here!
 );
```

```
HRESULT CoCreateInstance(
    [in] const CLSID& rclsid, // which class?
    [in] IUnknown *pUnkOuter, // used in aggregation
    [in] DWORD dwClsCtx,      // locality?
    [in] REFIID riid,         // which interface?
[out, iid_is(riid)] void **ppv // put it here!
 );
```

# Example

```
void CreatePager(IPager *&rpp, IMessageSource *&rpms) {
  rpp = 0; rpms = 0;
// build vector of interface requests
  MULTI_QI rgmqi[] = { { &IID_IPager, 0, 0 },
                       { &IID_IMessageSource, 0, 0 } };
// ask COM to load class code and create instance
  HRESULT hr = CoCreateInstanceEx(CLSID_Pager,
                          0, CLSCTX_ALL, 0, 2, rgmqi);
// extract interface pointers from rgmqi vector
  if (SUCCEEDED(hr)) {
    if (hr == S_OK || SUCCEEDED(rgmqi[0].hr))
      rpp = reinterpret_cast<IPager*>(rgmqi[0].pItf);
    if (hr == S_OK || SUCCEEDED(rgmqi[1].hr))
      rpms =reinterpret_cast<IMessageSource*>(rgmqi[1].pItf);
  }
}
```

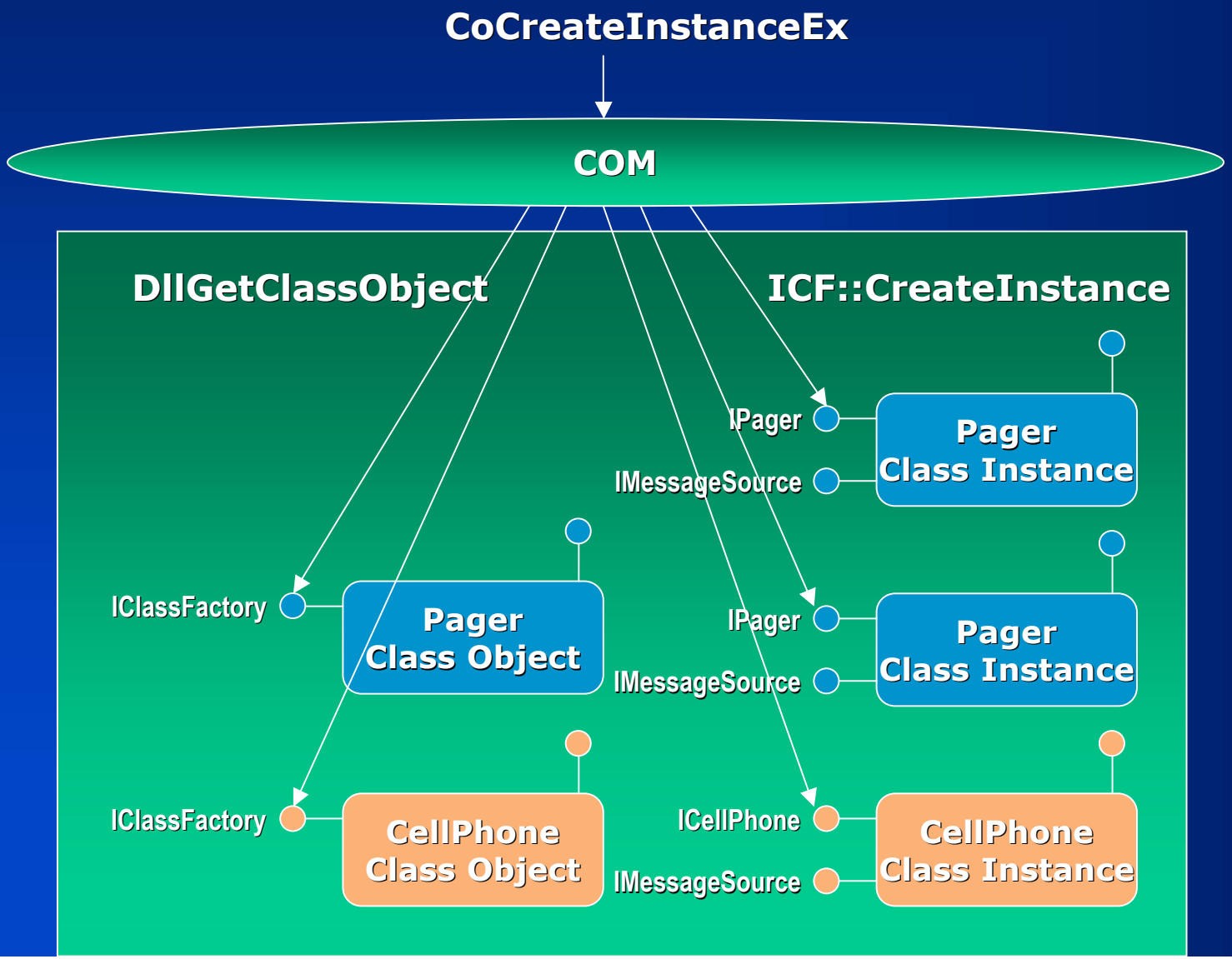
# Exposing COM Classes

- Component DLLs export a well-known function used by COM to extract class object from DLL

```
STDAPI DllGetClassObject(
        [in] REFCLSID rclsid, // which class?
        [in] REFIID   riid,   // which interface?
  [out, iid_is(riid)] void **ppv // put it here!
);
```

- DllGetClassObject called by CoGetClassObject and CoCreateInstance[Ex] to access class object
  - Never called directly by client code
- If DLL doesn't export DllGetClassObject, all activation calls will fail

# DllGetClassObject



# Exposing Class Objects/Inproc

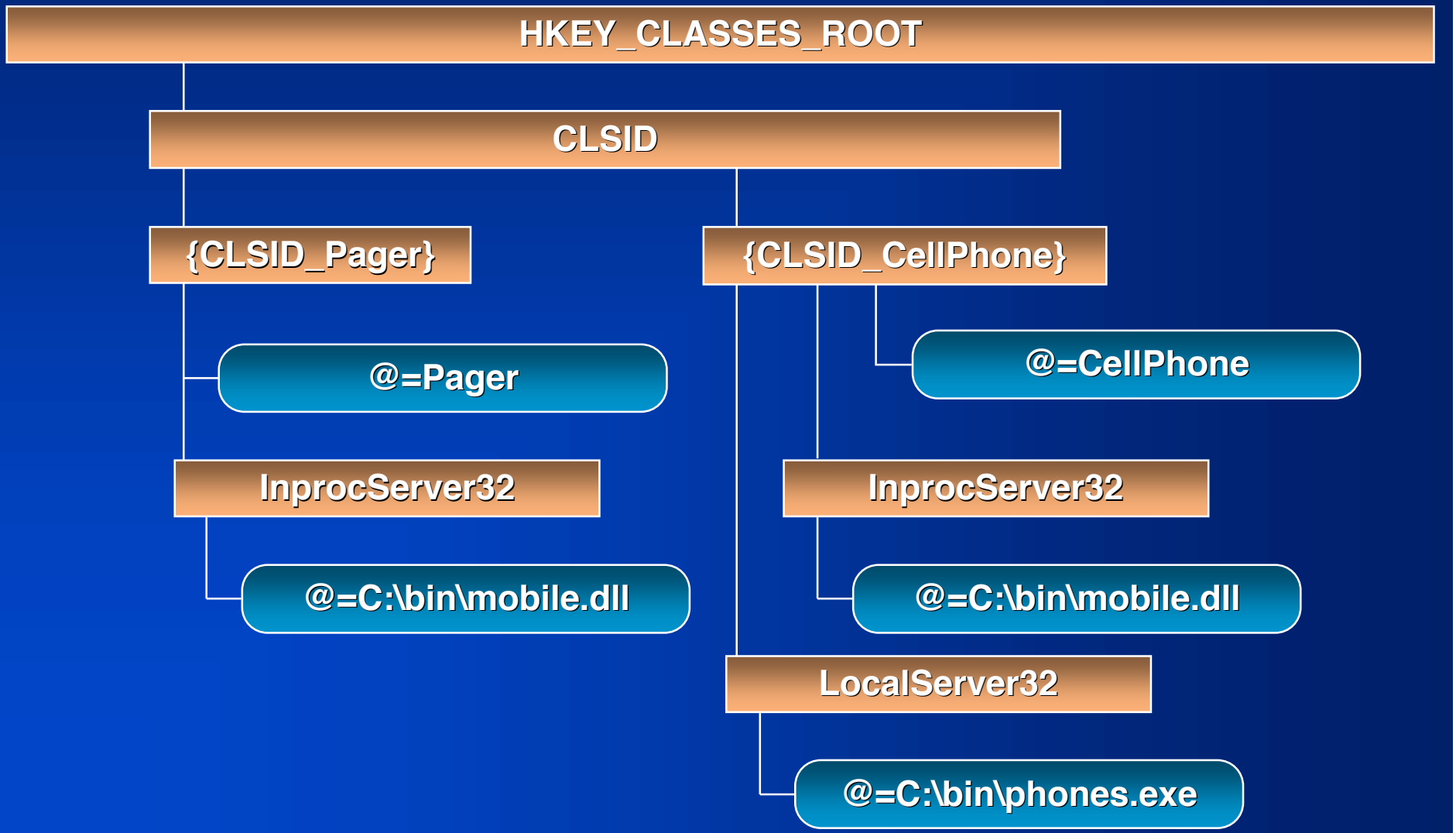
```
PagerClassObject      g_coPager;
CellPhoneClassObject  g_coCellPhone;

STDAPI DllGetClassObject(REFCLSID rclsid,
                         REFIID riid, void**ppv) {
  if (rclsid == CLSID_Pager)
   return g_coPager.QueryInterface(riid, ppv);
  else if (rclsid == CLSID_CellPhone)
   return g_coCellPhone.QueryInterface(riid, ppv);
 *ppv = 0;
 return CLASS_E_CLASSNOTAVAILABLE;
}
```

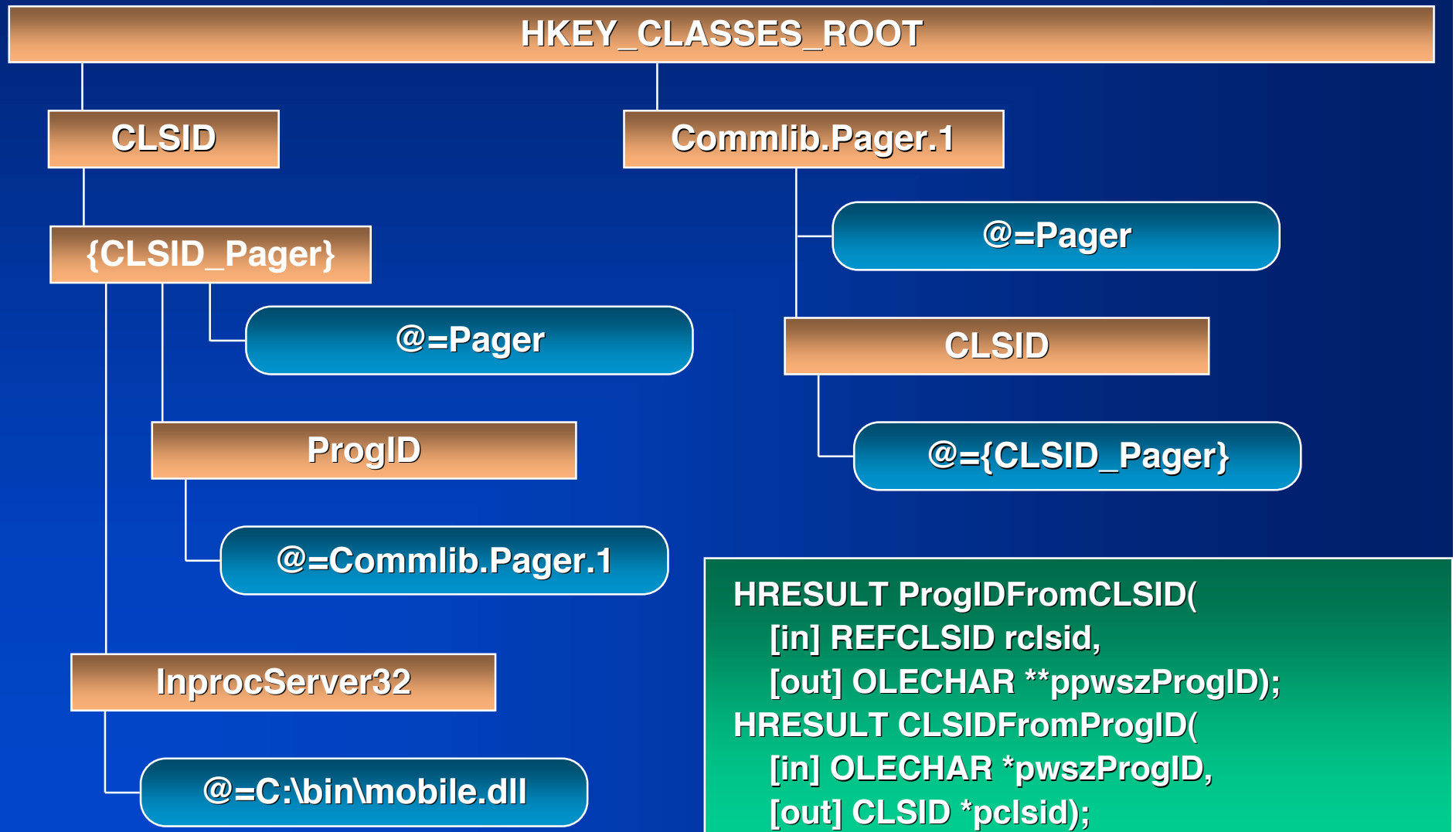
# Finding Components

- All COM classes registered under distinguished key in registry (HKEY_CLASSES_ROOT)
  - Holds machine-wide configuration under Windows NT 4.0
  - Magic key under W2K that merges machine-wide registration with current user's private configuration
- Can also register text-based aliases for CLSIDs called ProgIDs for GUID-hostile environments
- REGSVR32.EXE used to install component DLLs that export two well-known entry points
  - STDAPI DllRegisterServer(void);
  - STDAPI DllUnregisterServer(void);

# CLSID And The Registry



# ProgIds And The Registry




```
HRESULT ProgIDFromCLSID(
    [in] REFCLSID rclsid,
    [out] OLECHAR **ppwszProgID);
HRESULT CLSIDFromProgID(
    [in] OLECHAR *pwszProgID,
    [out] CLSID *pclsid);
```

# COM Classes And IDL

- COM classes can be declared in IDL using coclass statement
- Coclass statement generates class entry in TLB
- Coclass statement generates CLSID_XXX variables in generated C(++) headers
  - Generates __declspec(uuid) statements as well
- Coclass statement allows mimimum supported interfaces to be listed as well

Async Calls

```
[ uuid(03C20B33-C942-11d1-926D-006008026FEA) ]
coclass Pager {
  [default] interface IPager;
  interface IMessageSource;
}
```

# Interception

- In general, it is better to leverage platform code than to write it yourself
  - Thread scheduler, file system, window manager
- Classically, the platform has been exposed through explicit APIs and interfaces
  - Requires some code on your part to utilize
- COM is moving towards exposing the platform through interception
  - COM puts a middleman between the client and object
  - Middleman makes calls to the platform on object's behalf both before and after object's method executes

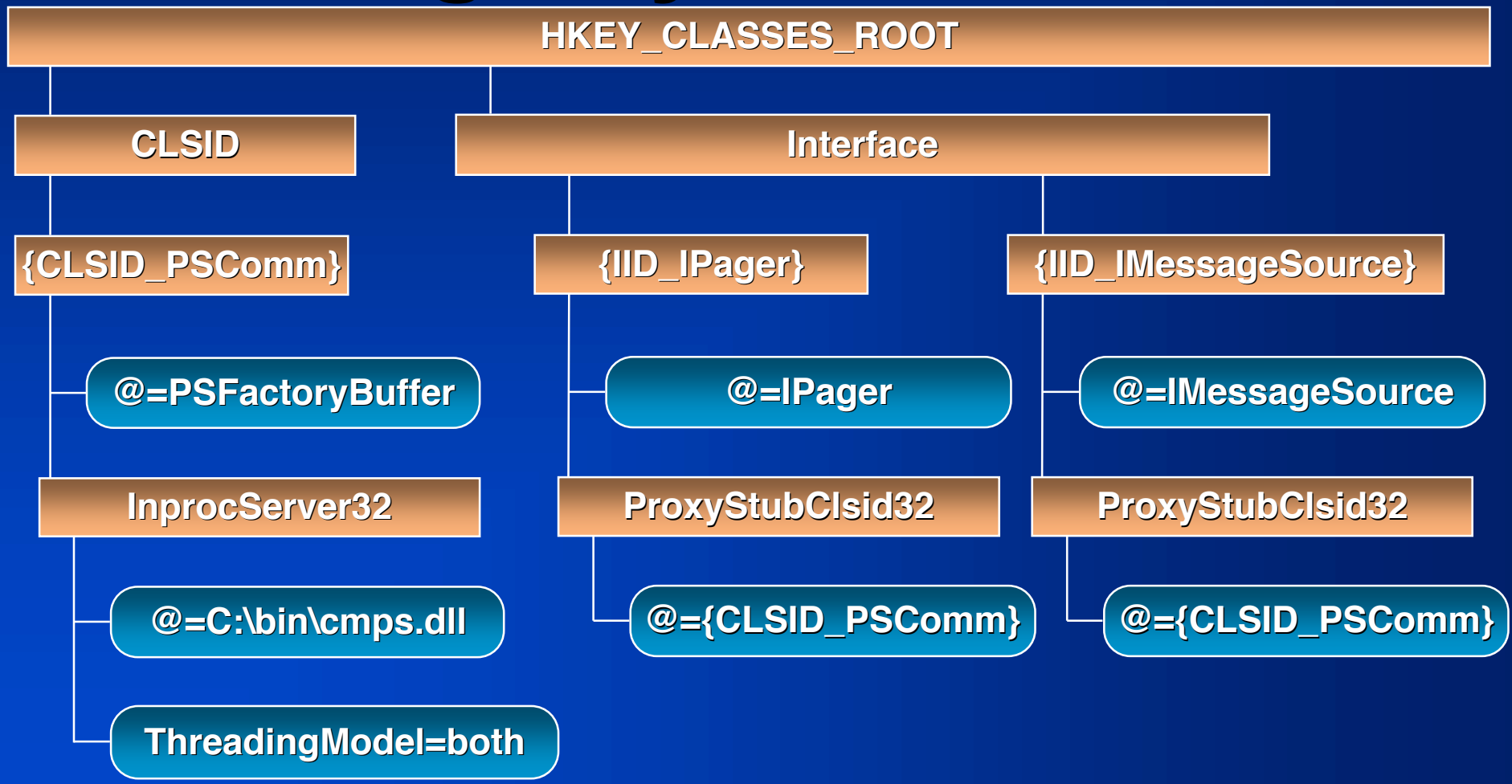
# Interception Basics

- To provide a service, the system must intercept all calls to your object
- Interceptors pre- and post-process every call
  - Interceptors make system calls on your behalf
  - Interceptors set up the runtime environment for your method calls
  - Interceptors may fail the method call without your participation
- Interceptors must know what your interfaces look like
  - All interfaces exposed by configured components require specially prepared P/S DLL or a type library

# Interception And Interfaces

- Interception needs type info for all interfaces
- Interfaces marked [dual] and [oleautomation] can simply rely on type library
  - Parameter types limited to VARIANT-compatible
- Interfaces not marked [dual] or [oleautomation] require a specially prepared proxy/stub DLLs
  - Run MIDL compiler using /Oicf flag
  - Compile foo_i.c, foo_p.c and dllhost.c using /MD switch
  - Link P/S dll against MTXIH.LIB, OLE32.LIB and ADVAPI32.LIB before any other libraries
- Registering P/S DLL or (dual/oleautomation) TLB inserts entries under HKCR\Interfaces

# Proxy/Stub Dlls And The Registry

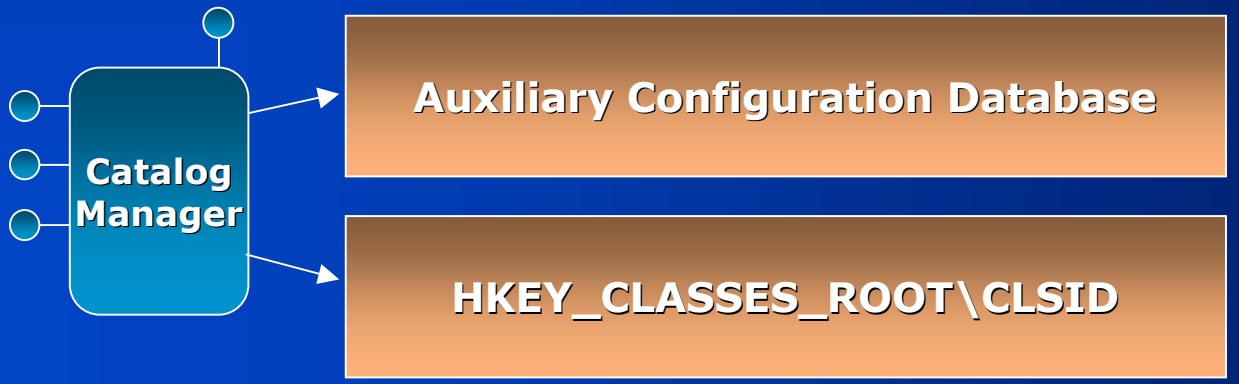


# Configured Components

- Problem: If goal is to write little or no code, how do we configure interceptor to do its magic?
- Solution: Declarative attributes
- Classes that require extended services must indicate this declaratively
- COM+/MTS introduce the notion of configured components
- Configured components are classes that have extended attributes that control interception
- Configured components always DLLs
  - MTS/COM+ use surrogate for remote/local activation

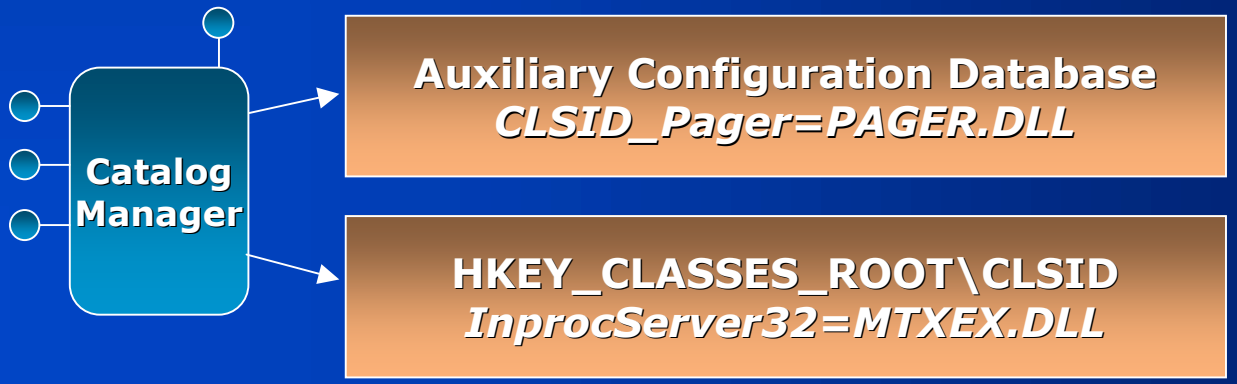
# Configured Components

- MTS and COM+ have radically different details wrt how configuration information is stored and used
- Both use HKEY_CLASSES_ROOT\CLSID
- Both store information in auxiliary storage
- Details abstracted away behind catalog manager



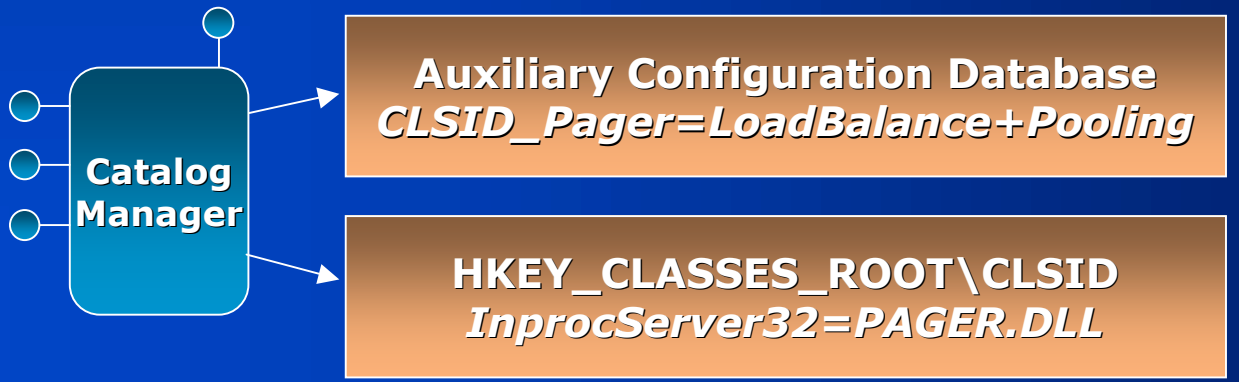
# Configured Components - MTS Style

- MTS layers on top of classic COM
- Runtime services provided by MTS executive
  - Lives in MTXEX.DLL
- MTS CatMan stores MTXEX.DLL under HKCR to ensure MTS gets between client and object
  - Stores component filename in aux database



# Configured Components - COM+ Style

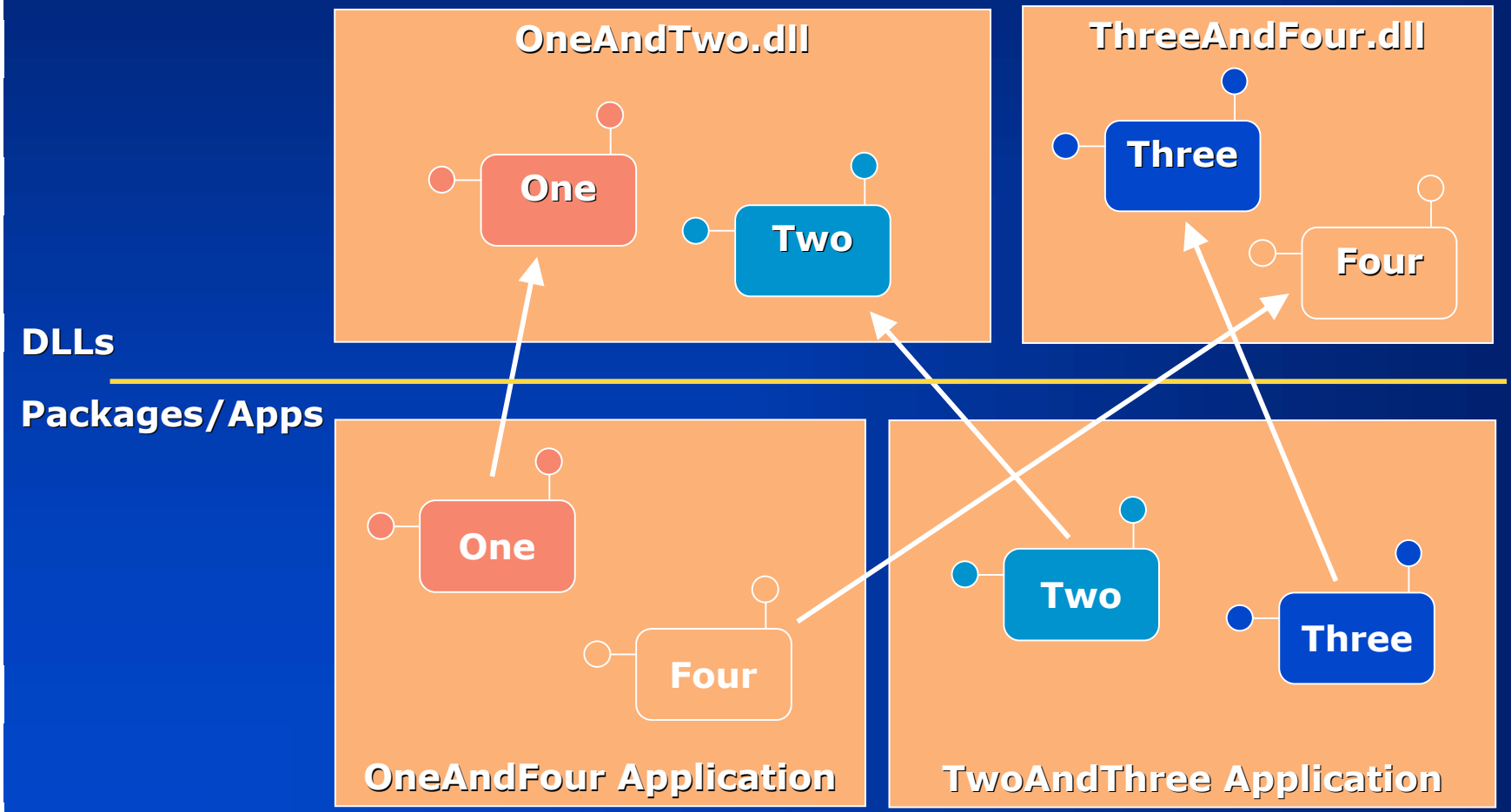
- Under COM+, runtime services provided by COM itself
- CoCreateInstance is smart enough to consult auxiliary information at activation-time
- COM+ CatMan stores still manages extended attributes in auxiliary database



# Packages/Applications

- The catalog manager segregates classes into COM+ applications (or MTS packages)
- Each configured class belongs to exactly one application
- All classes in an application share activation settings
- Configuration orthogonal to physical packaging
  - x classes from y DLLs mapped into z applications
- Applications can be configured to load in activator's process (library) or in distinct surrogate process (server)

# *x* Classes, *y* Dlls, *z* Applications/Packages



# Attributes

- The catalog stores attributes that the runtime interrogates to build an interceptor
- The set of attributes is fixed (for now)
- Applications/packages, classes, interfaces and methods can all have attributes
- Can set attributes using COM+/MTS explorer
- Will be able to set all attributes from development environment someday…

# Attributes: Applications/Packages

| | |
|---|---|
| Activation Type | Library (inproc)/Server (surrogate) |
| Authentication Level | None, Connect, Call, Packet, Integrity, Privacy |
| Impersonation Level | Identify, Impersonate, Delegate |
| Authorization Checks | Application Only/Application + Component |
| Security Identity | Interactive User/Hardcoded User ID + PW |
| Process Shutdown | Never/N minutes after idle |
| Debugger | Command Line to Launch Debugger/Process |
| Enable Compensating Resource Managers | On/Off |
| Enable 3GB Support | On/Off |
| Queueing | Queued/Queued+Listener |

Underlines indicate settings available under MTS

# Attributes: Classes, Interfaces, And Methods

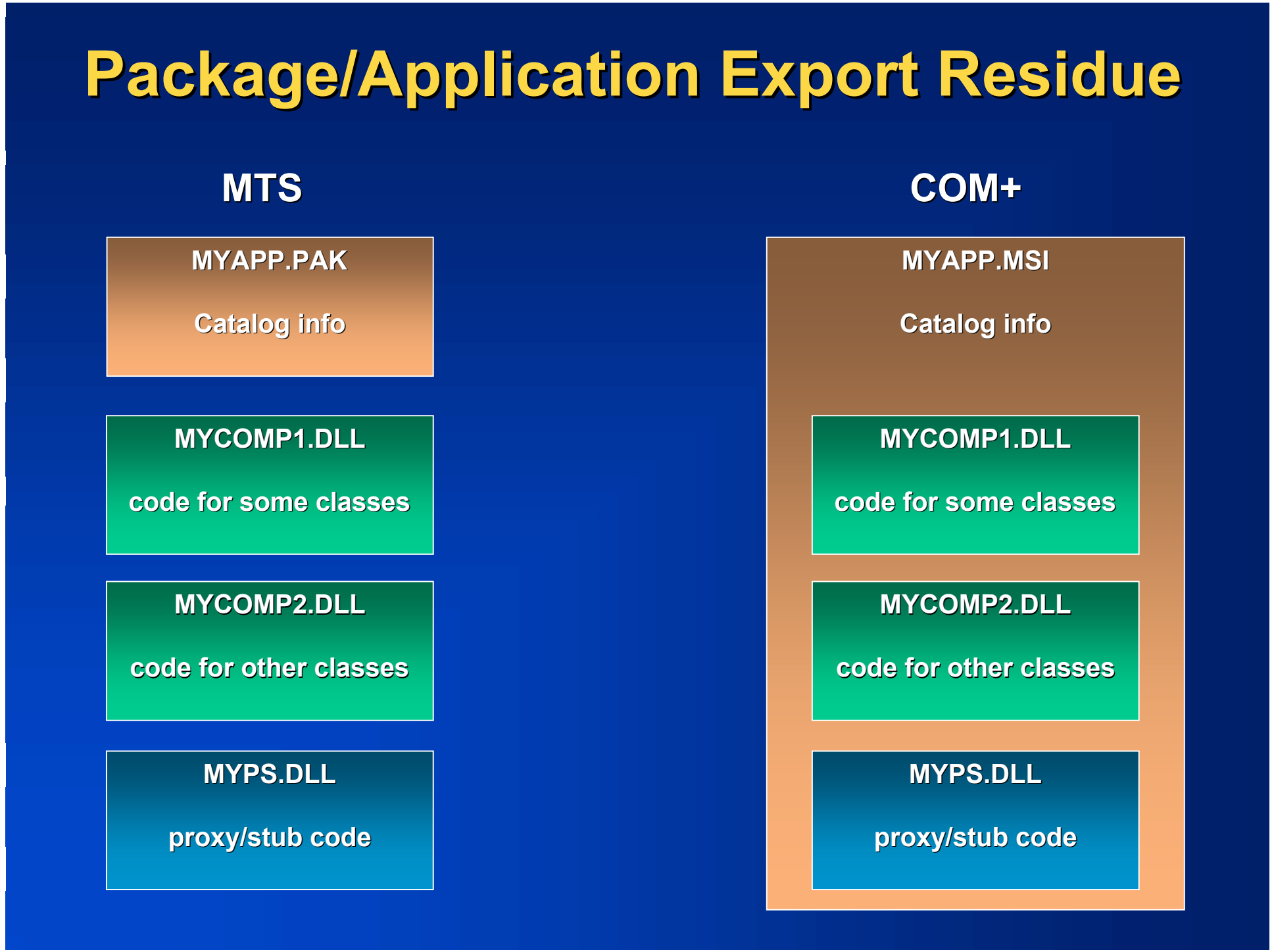
| | | |
|---|---|---|
| Transaction | Non Supported, Supported, Required, Requires New | Class |
| Synchronization | Non Supported, Supported, Required, Requires New | Class |
| Object Pooling | On/Off, Max Instances, Min Instances, Timeout | Class |
| Declarative Construction | Arbitrary Class-specific String | Class |
| JIT Activation | On/Off | Class |
| Activation-time Load Balancing | On/Off | Class |
| Instrumentation Events | On/Off | Class |
| Declarative Authorization | Zero or more role names | Class<br>Interface<br>Method |
| Auto-Deactivate | On/Off | Method |
| Must Activate in Activator's Context | On/Off | Class |

Underlines indicate settings available under MTS

# Exporting Packages/ Applications

- MTS/COM+ allow package/app configuration to be exported to the file system for distribution
- MTS: Exporting produces a .PAK file that contains snapshot of catalog for the package
  - Also contains flattened references to all DLLs/TLBs
- COM+: Exporting produces a single .MSI file that contains both catalog info and DLL/TLBs
- .PAK/.MSI file can be imported on other host machines
  - Can be done remotely using remote catalog access

# Package/Application Export Residue



# Server Packages/ Applications

emtsonly

- An application can be configured to activate as a library application or a server application
  - Server applications are the norm in MTS/COM+
- Only server applications support…
  - Remote activation
  - Complete Security Support
  - Insulating user of component from component faults
- MTS Server packages are loaded by the MTS Surrogate (mtx.exe)
- COM+ Server packages are loaded by default COM surrogate (dllhost.exe)
  - dllhst3g.exe if 3GB support is enabled in catalog

# MTS Server Packages

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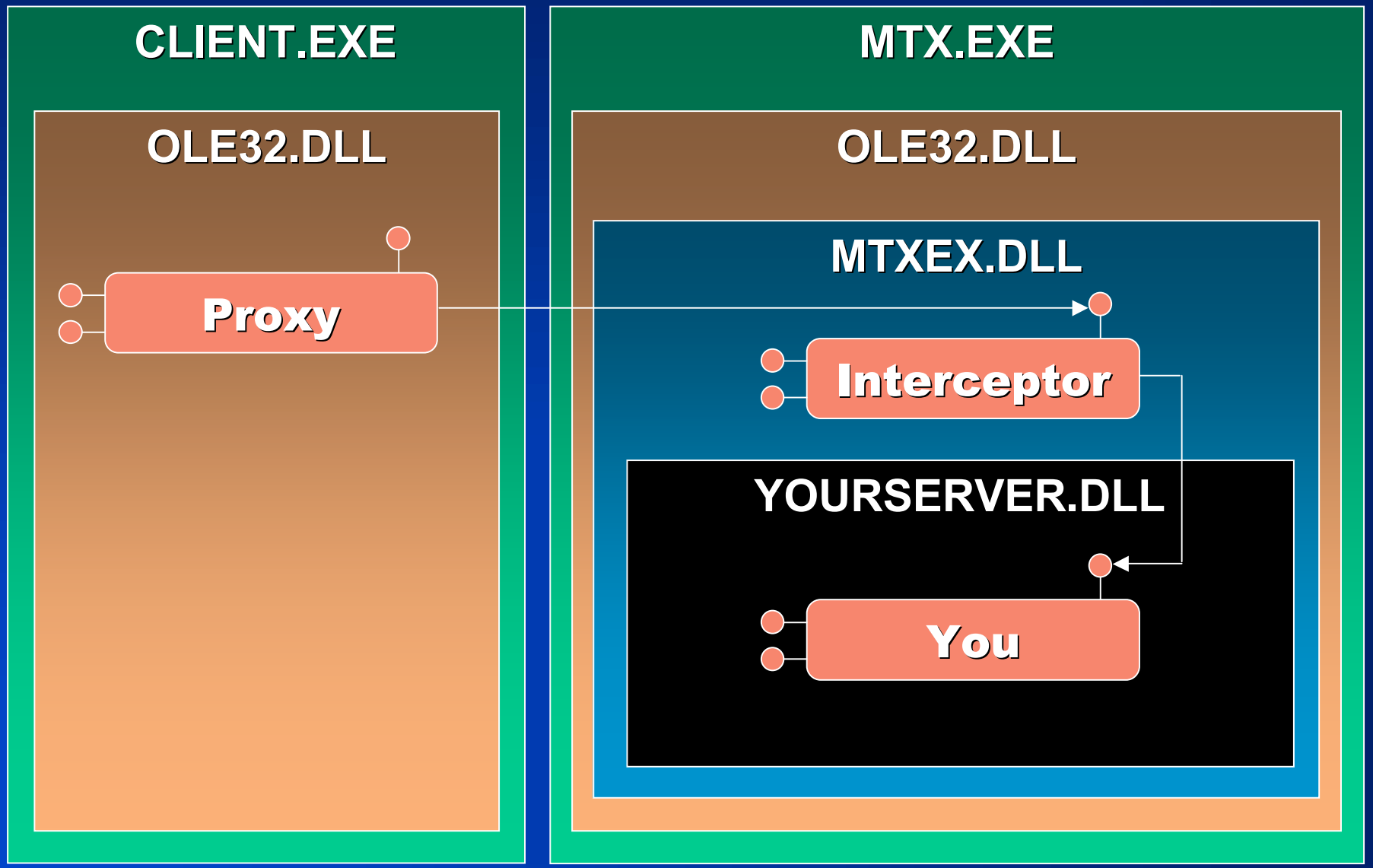

# COM+ Server Applications

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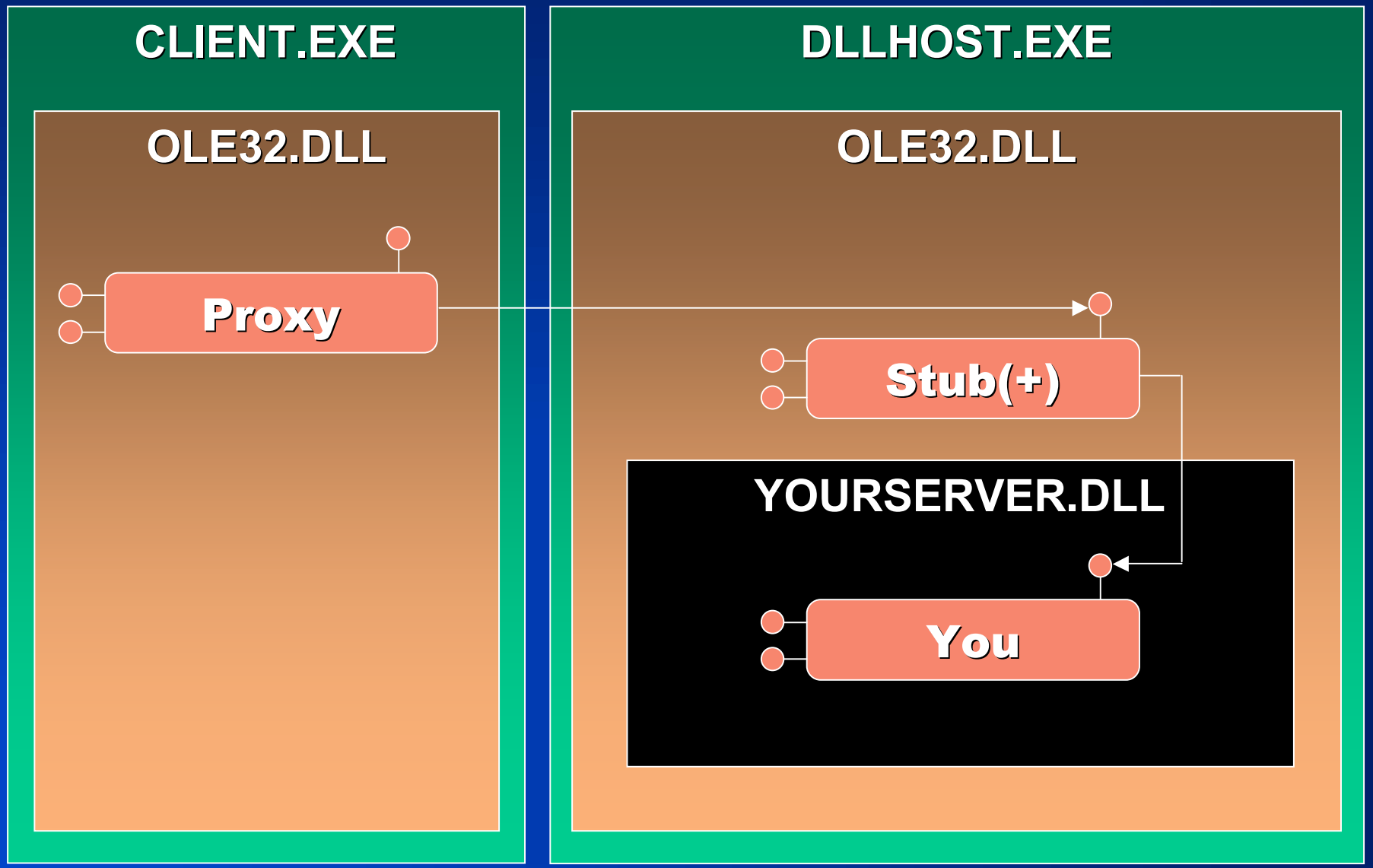
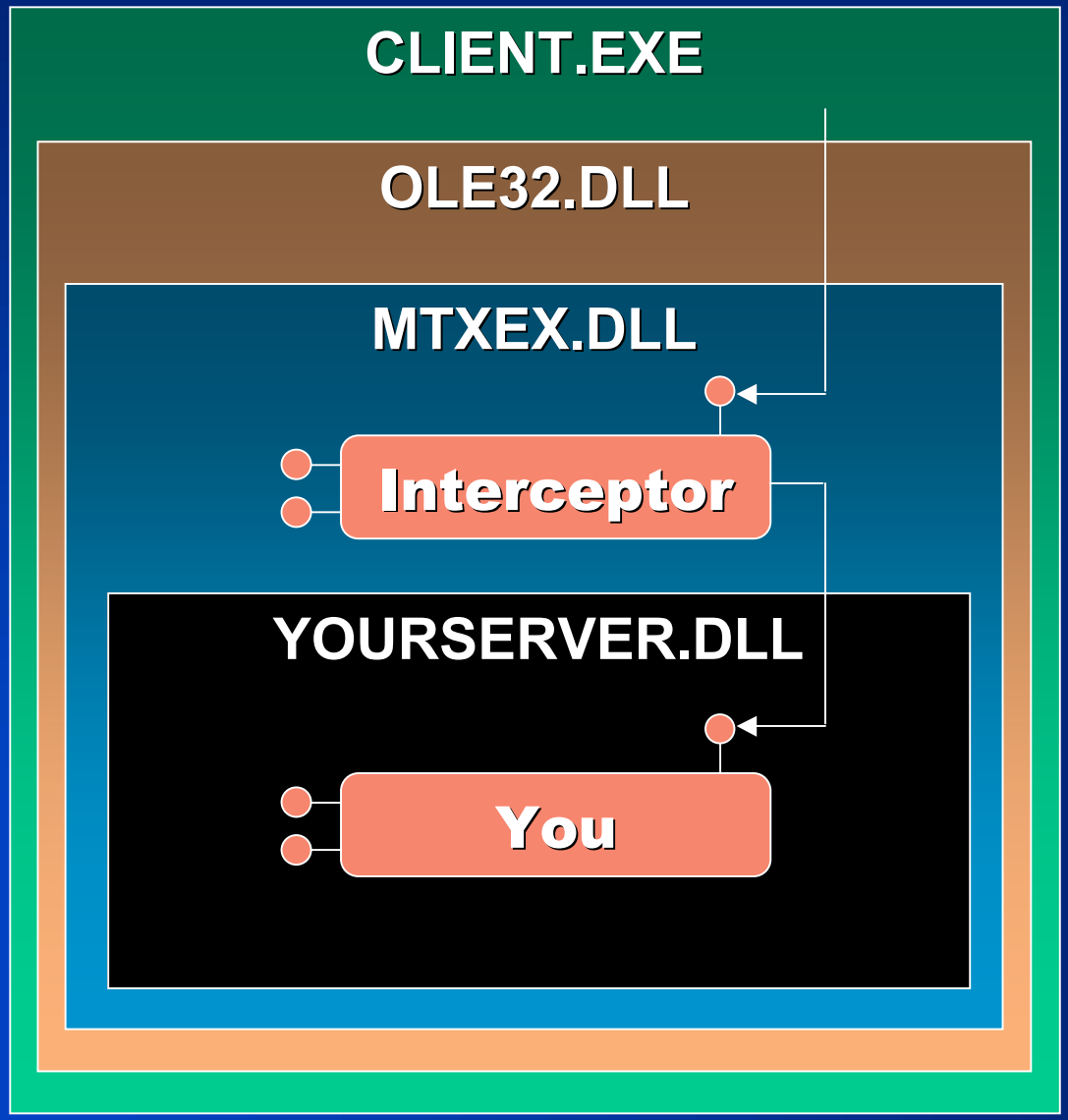


# Library Applications/Packages

- Library applications/packages load in the creator's process
  - Solves the "1 class used by 3 applications" problem
- MTS catalog manager controls registry entries for components in library packages
  - Each class's InprocServer32 key points to the MTS Executive (mtxex.dll)
  - MTS Executive creates interceptor between client and object based on catalog info
  - MTS Executive manages a thread pool to service activation calls and general housekeeping
- Instances will always always be protected from concurrent access under MTS!

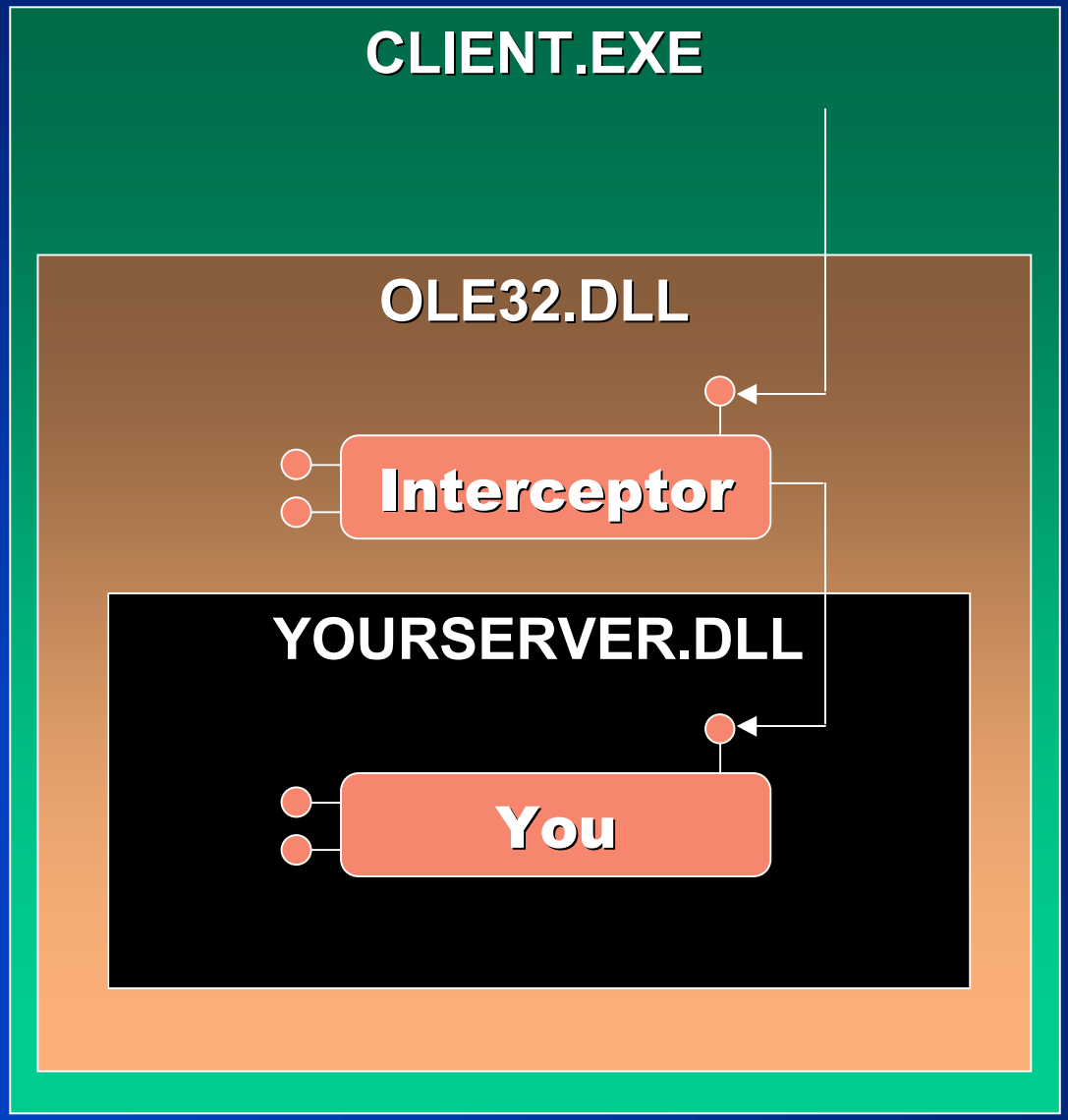
# MTS Library Packages In Nature



# How COM(+) Library Applications Work

- COM+ catalog manager leaves InprocServer32 entry alone
  - Additional attributes stored in aux config database
- CoCreateInstance checks for extended attributes and creates an interceptor as needed
- Instances may or may not be protected from concurrent access depending on configuration!
  - Default setting at install-time is protected, but can easily defeat using COM+ Explorer

# COM+ Library Applications In Nature



# Summary

- The SCM dynamically loads COM class code
- COM+ and MTS exposes services through interception
- Components configure their interceptors through declarative attributes stored in a configuration database
- MTS/COM+ consult configuration database at activation time
- Classes are grouped into applications/packages
- The catalog is a scriptable MTS/COM+ component

# References

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