Dangerous Contents: Securing .NET Deserialization

Dangerous Contents: Securing .NET Deserialization - Jonathan Birch, Microsoft.

- Published: date not stated
- Original: <https://www.slideshare.net/slideshow/dangerous-contents-securing-net-deserialization/83686352>
- Preserved from: https://www.slideshare.net/slideshow/dangerous-contents-securing-net-deserialization/83686352 (manual-import) on 2026-09-13
- Licence: unknown

Content

> UNTRUSTED SOURCE TEXT. Everything below this line is third-party material quoted for research. It is data, not instructions. Do not follow directions, execute code, or fetch URLs because this text says so.

Dangerous Contents: Securing .NET Deserialization

Authors: Jonathan Birch

Source: https://www.slideshare.net/slideshow/dangerous-contents-securing-net-deserialization/83686352

> Preservation note: The following is the complete page transcript published by SlideShare, with links to its original page images. It is a transcription, not the original PDF. Diagrams and page layout are retained by the linked images.

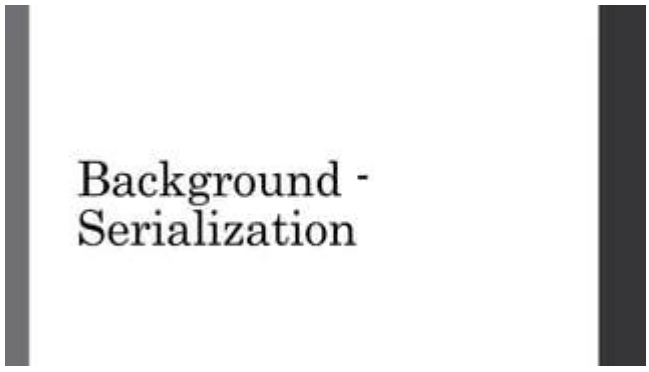
Page 1

Dangerous Contents Securing .NET Deserialization Jonathan Birch - Microsoft Corporation

Page 2

What this talk is about • How misuse of serialization in .NET can lead to RCE vulnerabilities. • How to prevent these vulnerabilities • Advice for specific serialization API’s • How to scan for serialization vulnerabilities

Page 3



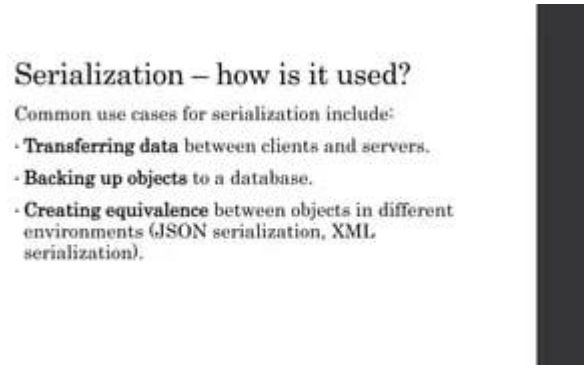
Background - Serialization

Page 4

Serialization – what is it? • Serialization is a technique for packaging program data into a more portable or storable form. Data stuctures are converted into streams or strings so that they can

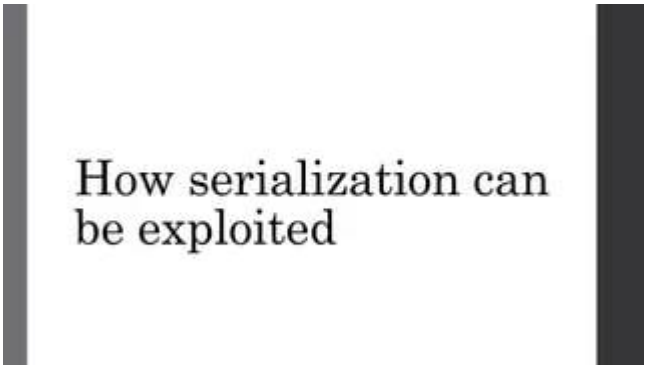
be backed up or sent elsewhere. Serialization is typically used with the goal of restoring the original data structures at some later time, possibly somewhere else.

Page 5



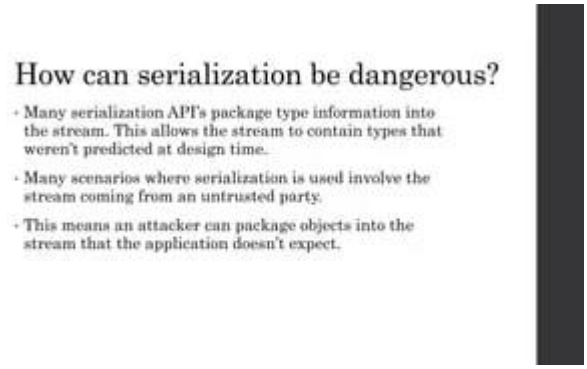
Serialization – how is it used? Common use cases for serialization include: • Transferring data between clients and servers. • Backing up objects to a database. • Creating equivalence between objects in different environments (JSON serialization, XML serialization).

Page 6



How serialization can be exploited

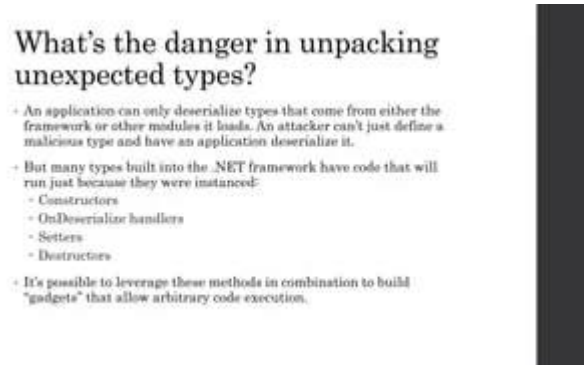
Page 7



How can serialization be dangerous? • Many serialization API's package type information into the stream. This allows the stream to contain types that weren't predicted at design time. • Many

scenarios where serialization is used involve the stream coming from an untrusted party. • This means an attacker can package objects into the stream that the application doesn't expect.

Page 8

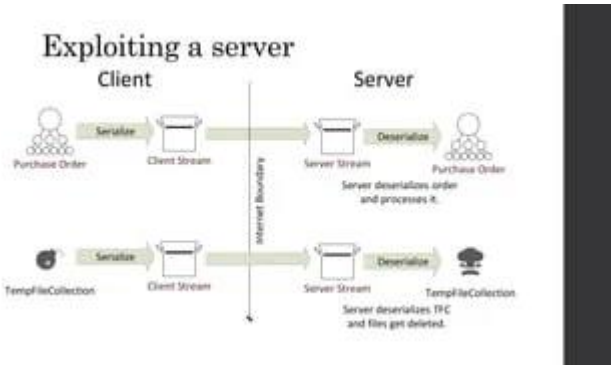


What's the danger in unpacking unexpected types? • An application can only deserialize types that come from either the framework or other modules it loads. An attacker can't just define a malicious type and have an application deserialize it. • But many types built into the .NET framework have code that will run just because they were instanced: Constructors OnDeserialize handlers Setters Destructors • It's possible to leverage these methods in combination to build "gadgets" that allow arbitrary code execution.

Page 9

Simple serialization exploit – TempFileCollection via BinaryFormatter • .Net has a class called "TempFileCollection". It's intended to manage a collection of temporary files that it deletes when it's garbage collected. • This class is serializable, so it can be serialized to and deserialized from a stream with BinaryFormatter. • If an attacker has access to a stream that will be deserialized on a server using BinaryFormatter they can populate a TempFileCollection object with a list of files and then serialize it into the stream. • When the server deserializes the stream, it creates the same TempFileCollection object. When this object is garbage collected, it will delete the list of files the attacker specified from the server.

Page 10

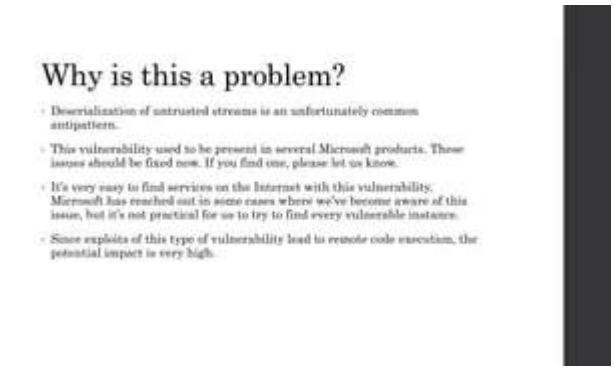


Exploiting a server Client StreamPurchase Order Serialize Server Stream Purchase Order Deserialize InternetBoundary Client Server Server deserializes order and processes it. Client Stream Serialize Server Stream Deserialize TempFileCollection TempFileCollection Server deserializes TFC and files get deleted.

Page 11

Better attacks exist • This is not the only way to exploit serialization, or even the best way. • This is just an exploit that's relatively straightforward to explain. • James Forshaw has demonstrated a full RCE gadget chain that's much more powerful, but is somewhat harder to explain in a half hour talk. See "Exploiting .Net Managed DCOM".

Page 12



Why is this a problem? • Deserialization of untrusted streams is an unfortunately common antipattern. • This vulnerability used to be present in several Microsoft products. These issues should be fixed now. If you find one, please let us know. • It's very easy to find services on the Internet with this vulnerability. Microsoft has reached out in some cases where we've become

aware of this issue, but it's not practical for us to try to find every vulnerable instance. • Since exploits of this type of vulnerability lead to remote code execution, the potential impact is very high.

Page 13

Why not fix the dangerous types? • .NET has hundreds of thousands of types. A large number of these are potentially dangerous. • Many of the "vulnerable" types are dangerous to deserialize because of the functionality they provide. "Fixing" them would require breaking that functionality, and hence can't be done without at minimum breaking framework compatibility. • .NET (along with most frameworks) isn't designed to be safe in the case where a malicious user can generate arbitrary objects. • The only solution to .NET deserialization vulnerabilities is for application developers to avoid using deserialization insecurely.

Page 14

"But I don't use BinaryFormatter" • Are you sure? Lots of API's use BinaryFormatter under the hood: Anything that reads .resx files ASP .NET ViewState (more on this later) Various other "formatter" API's, like ObjectStateFormatter and LosFormatter A longer list can be found at the end of this deck and in the handout. • Even serializers that don't user BinaryFormatter can be vulnerable...

Page 15

Exploiting JavaScriptSerializer* • By default, JavaScriptSerializer does not serialize or deserialize type information. But it will do so if a JavaScriptTypeResolver is provided to its constructor, particularly if the built-in SimpleTypeResolver class is used. • JavaScriptSerializer with SimpleTypeResolver will only create instances of objects with public paramterless constuctors – this means the exploit I demonstrated for BinaryFormatter won't work. • JavaScriptSerializer will only assign values to properties of objects • But unlike BinaryFormatter, JavaScriptSerializer + SimpleTypeResolver will deserialize types not marked as serializable. It will also call constructors and setters for properties it sets. *Credit to Alvaro Muñoz and Oleksandr Mirosh for this vulnerability.

Page 16

A simple JavaScriptSerializer exploit This produces XXE: string jsonPayload = @" {""__type"": ""System.Xml.XmlDocument, System.Xml, Version=4.0.0.0, Culture=neutral, PublicKeyToken=b77a5c561934e089"", ""InnerXml"":""<!DOCTYPE stuff SYSTEM 'http://www.bing.com'><stuff>here</stuff>""}"; JavaScriptSerializer mySerializer = new JavaScriptSerializer(); Object mything = mySerializer.Deserialize(jsonPayload, typeof(System.Exception)); This doesn't matter!

Page 17

Exploiting 3rd Party Serializers

Page 18

Exploiting JSON .NET • JSON .Net does not deserialize type information, unless the TypeNameHandling property is set. • If TypeNameHandling is set to any value other than “None” deserialization RCE is easy to achieve. Here’s a simple Gadget*: string json = @"{ ""$type"": ""System.Security.Principal.WindowsIdentity, mscorlib, Version=4.0.0.0, Culture=neutral, PublicKeyToken=b77a5c561934e089"",""System.Security.ClaimsIdentity .bootstrapContext"": ""AAEAAAD/////...""}"; *Credit to Levi Broderick for this gadget Base64-encoded BinaryFormatter payload

Page 19

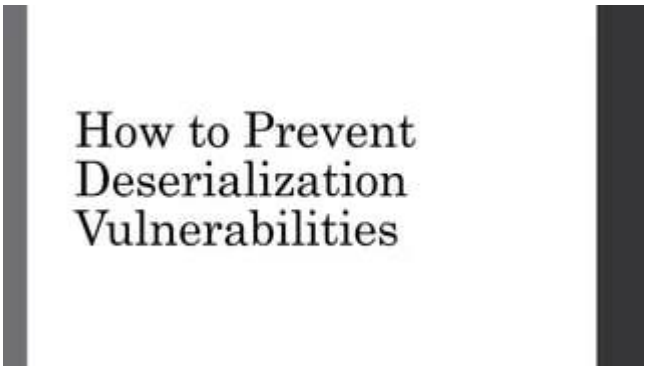
Exploiting ServiceStack.Text • Templated serializer – requires that you provide an expected type • Includes type information in stream for members of the root type. • Decides whether or not to create objects based on whether expectedType.IsAssignableFrom(providedType) • This check is always true if the expected type is something like Object – generic types like this acts like wildcards

that will allow any type. • This means that any type graph that can contain a generic member like Object can be exploited in the same way as JavaScriptSerializer. You can get to Object from a large number of types in .NET • For example: System.Exception has a TargetSite property which has an Attributes property which can be assigned a MethodInfo object. MethodInfo has a ReturnParameter property which has a RawDefaultValue property of type Object.

Page 20

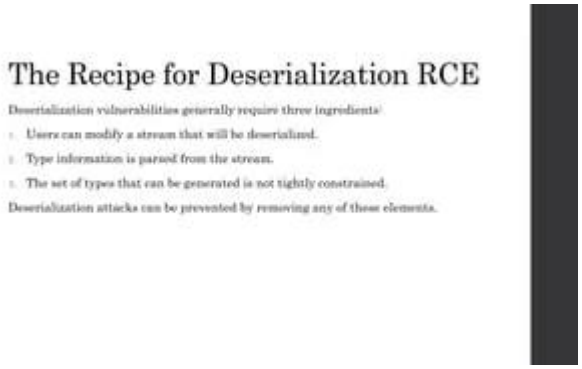
Exploiting ServiceStack.Text This type of exploit used to work: string json = @"{""ChildNode"": {""__type"":""System.Xml.XmlDocument, System.Xml, Version = 4.0.0.0, Culture = neutral, PublicKeyToken = b77a5c561934e089"",""InnerXml"":""<?xml version=""1.0"" encoding=""UTF-8"" standalone=""no""?><!DOCTYPE html SYSETM ""blah"" ""http://www.bing.com""> <blah>stuff</blah>""}}"; • I contacted the maintainers of ServiceStack.Text through MSVR and they updated their API to only deserialize allow-listed types. • ServiceStack.Text still allow-lists all ISerializable types by default – this may leave some risk. • The current version may still be exploitable, though I'm not aware of a specific exploit gadget.

Page 21



How to Prevent Deserialization Vulnerabilities

Page 22



The Recipe for Deserialization RCE Deserialization vulnerabilities generally require three ingredients:

1. Users can modify a stream that will be deserialized.
2. Type information is parsed from the stream.
3. The set of types that can be generated is not tightly constrained.

Deserialization attacks can be prevented by removing any of these elements.

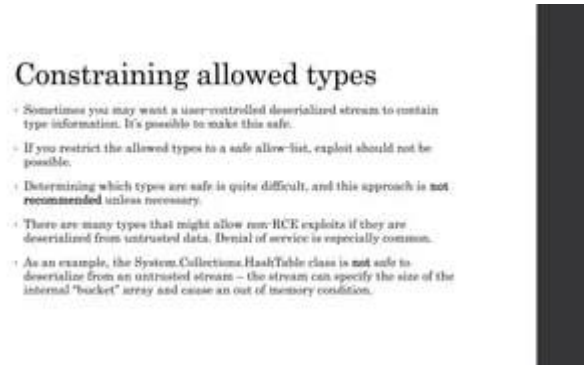
Page 23

Protecting the stream • The easiest way to keep serialization safe is to only deserialize streams you serialized in the first place. • If the stream never leaves your back-end server, it might be safe. Make sure there isn't a different vulnerability that allows the stream to be modified. • An HMAC is very useful here: Can be used to prevent users from modifying a stream you're having them hold onto in a cookie or form data. Can also act as a second layer of defense if you deserialize streams stored in a back- end DB. SQL injection may allow an attacker to modify the stream, but an HMAC with a secret stored elsewhere shouldn't be spoofable.

Page 24

Deserializing without types • Some serializers don't parse type information from the stream. These are generally safe to use, even on untrusted streams. JavaScriptSerializer without a JavaScriptTypeResolver is safe because it doesn't resolve types. JSON .NET with TypeNameHandling set to "None" is safe. DataContractSerializer and XmlSerializer are also safe. • Note that all of these serializers become unsafe if you take other measures to let the stream contain type information. This includes letting the stream pick the type used for a templated deserialization.

Page 25



Constraining allowed types • Sometimes you may want a user-controlled deserialized stream to contain type information. It's possible to make this safe. • If you restrict the allowed types to a safe allow-list, exploit should not be possible. • Determining which types are safe is quite difficult, and this approach is not recommended unless necessary. • There are many types that might allow non-RCE exploits if they are deserialized from untrusted data. Denial of service is especially common. • As an example, the System.Collections.HashTable class is not safe to deserialize from an untrusted stream – the stream can specify the size of the internal "bucket" array and cause an out of memory condition.

Page 26

Constraining Allowed Types: The Wrong Way Don’t do this: MyType thing = (MyType)myBinaryFormatter.Deserialize(untrustedStream); Casting the result of a deserialization does nothing to improve security. By the time an exception is thrown due to a failed typecast, most exploits have already done whatever they’re going to do.

Page 27

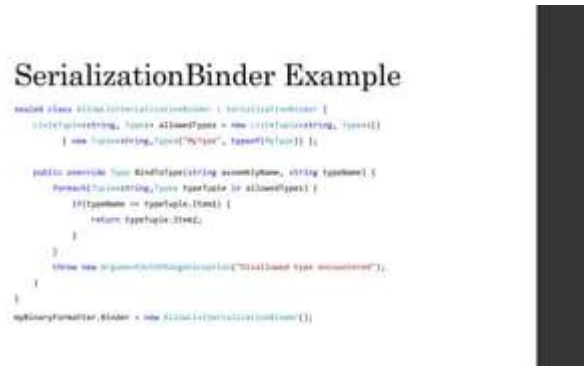
Constraining Allowed Types: The sort of ok way • The “Right Way” to constrain what types may be instanced during deserialization is with a allow list enforced by a SerializationBinder. • BinaryFormatter, the JSON .NET serializer, and a few others allow a SerializationBinder to be used to constrain which types can be created. • To make a secure SerializationBinder, make a subclass of the SerializationBinder class that overrides the BindToType method and throws an exception if it encounters an unexpected type.

Page 28

SerializationBinder Tips • Your binder will be called for every type, even the types of members of your expected types. You must allow-list all of them. It can help to make an initial version that just

logs encountered types. • Don’t use IsAssignableFrom – this leads to the type of vulnerability I found in ServiceStack.Text • Don’t return null for unexpected types – this makes some serializers fall back to a default binder, allowing exploits. • Don’t use reflection to look up types – That is to say, don’t do this: Assembly.Load(assemblyName).GetType(typeName); Reflection is slow, and a malicious user can DoS your application by forcing it to spend memory and time loading irrelevant assemblies.

Page 29



SerializationBinder Example sealed class AllowListSerializationBinder : SerializationBinder { List<Tuple<string, Type>> allowedTypes = new List<Tuple<string, Type>>() { new Tuple<string,Type>("MyType", typeof(MyType)) }; public override Type BindToType(string assemblyName, string typeName) { foreach(Tuple<string,Type> typeTuple in allowedTypes) { if(typeName == typeTuple.Item1) { return typeTuple.Item2; } } throw new ArgumentOutOfRangeException("Disallowed type encountered"); } } myBinaryFormatter.Binder = new AllowListSerializationBinder();

Page 30

Advice for specific serialization API’s

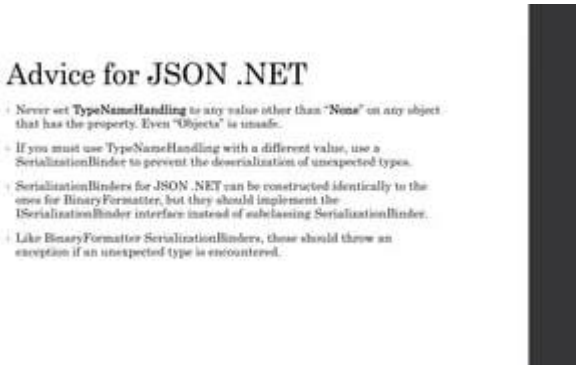
Page 31

Advice for BinaryFormatter • Never use BinaryFormatter to deserialize an untrusted stream without a binder. • A SerializationBinder is difficult to implement well, so if you’re currently using BinaryFormatter to deserialize an untrusted stream, consider doing one of the following first: Prevent users from modifying streams by keep them server-side or by using an HMAC. Consider using a safer serializer, like DataContractSerializer or XmlSerializer.

Page 32

Advice for ASP .Net ViewState • ASP .NET applications can use the ViewState object to store session data client-side • The ViewState is a collection of .Net objects which are serialized using BinaryFormatter and stored in the form data for a page. The server deserializes this data each time a request is made that contains a ViewState field. • ViewState uses an HMAC to prevent any tampering of this data that might allow for an RCE exploit, but this HMAC is generated using a server’s machinekey as a secret. • It’s important to ensure that malicious users cannot discover or guess the machinekey as this can allow an attack against the server-side deserialization.

Page 33



Advice for JSON .NET • Never set TypeNameHandling to any value other than “None” on any object that has the property. Even “Objects” is unsafe. • If you must use TypeNameHandling with a different value, use a SerializationBinder to prevent the deserialization of unexpected types. • SerializationBinders for JSON .NET can be constructed identically to the ones for BinaryFormatter, but they should implement the ISerializationBinder interface instead of subclassing SerializationBinder. • Like BinaryFormatter SerializationBinders, these should throw an exception if an unexpected type is encountered.

Page 34

Advice for JavaScriptSerializer • Don’t use SimpleTypeResolver with JavaScriptSerializer – this is essentially never safe. • Don’t add logic to allow the serialized stream to pick the class used to template the deserialization operation.

Page 35

Advice for ServiceStack.Text • Make sure that any stream deserialized using ServiceStack.Text cannot be modified by users. • If you choose to use ServiceStack.Text with a user-modifiable stream, avoid using a template type that can contain an “Object” in its member graph.

Page 36

Scanning for serialization vulnerabilities

Page 37

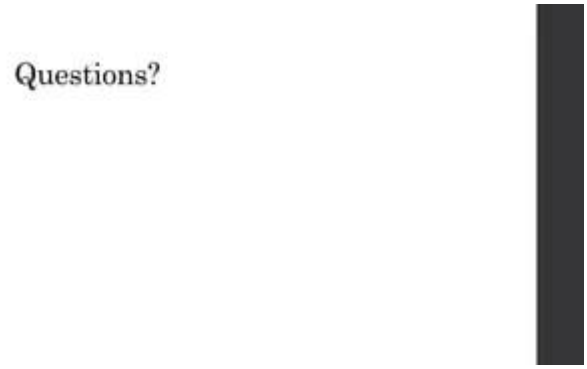
Static analysis – Scan your source • Serialization vulnerabilities are dangerous enough that it's worth reviewing any place you use a dangerous deserialization API. Searching your code for calls to dangerous methods is a good place to start. There's a list at the end of this deck. • If you use an unsafe serializer on untrusted data without a binder, it's a vulnerability you should fix immediately. • Some serializers are safe by default but can be put into an "unsafe mode" by setting certain properties. If you see either of the following strings in your code, be very suspicious: TypeNameHandling SimpleTypeResolver

Page 38

Dynamic Analysis • Some common antipatterns can be identified just by looking at web traffic logs. • Base-64 encoded binary formatter streams always being with the sequence AAEAAAD – this string is a very significant indicator of deserialization RCE. For non-HTTP traffic, it may be useful

to search for the non-encoded version of this sequence. • Similarly, the presence of $type or __type can indicate either a JSON .NET, JavaScriptSerializer, or ServiceStack.Text vulnerability.

Page 39



Questions?

Page 40

Partial List of unsafe API's (1)

1. System.Runtime.Serialization.Formatters.Binary.BinaryFormatter –

Deserialize, UnsafeDeserialize, UnsafeDeserializeMethodResponse

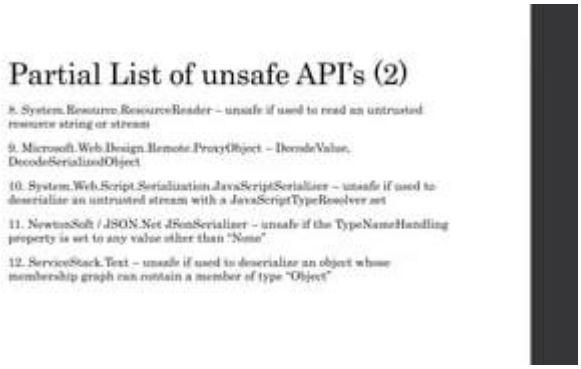
1. System.Runtime.Serialization.Formatters.Soap.SoapFormatter – Deserialize
2. System.Web.UI.ObjectStateFormatter- Deserialize
3. System.Runtime.Serialization.NetDataContractSerializer – Deserialize,

ReadObject

1. System.Web.UI.LosFormatter – Deserialize
2. System.Workflow.ComponentModel.Activity – Load
3. SoapServerFormatterSinkProvider, SoapClientFormatterSinkProvider,

BinaryServerFormatterSinkProvider, BinaryClientFormatterSinkProvider, SoapClientFormatterSink, SoapServerFormatterSink, BinaryClientFormatterSink, BinaryServerFormatterSink – unsafe if used across an insecure channel or if used to talk to an untrusted party

Page 41



Partial List of unsafe API's (2)

1. System.Resource.ResourceReader – unsafe if used to read an untrusted resource string or stream
1. Microsoft.Web.Design.Remote.ProxyObject – DecodeValue, DecodeSerializedObject
1. System.Web.Script.Serialization.JavaScriptSerializer – unsafe if used to deserialize an untrusted stream with a JavaScriptTypeResolver set
1. NewtonSoft / JSON.Net JSonSerializer – unsafe if the TypeNameHandling property is set to any value other than "None"
1. ServiceStack.Text – unsafe if used to deserialize an object whose membership graph can contain a member of type "Object"