NEO Community Bluepaper

NEO Persistable Classes 1.0 Deep Dive

An Efficient Object-Oriented Framework for C#.NEO Smart Contract Development

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NEO smart economy

What is a Bluepaper?

- From: Blue Papers – Writing Technical Specifications
  http://www.genuinewriting.com/blue_paper.html

  *The term "blue paper" is a currently seldom used phrase that is slowly catching on around the world. First used in Germany, the term is used as a means of distinguishing between policy and procedure papers (white papers) and those **papers outlining only technical specifications and descriptions of new technologies or particular pieces of equipment**.*

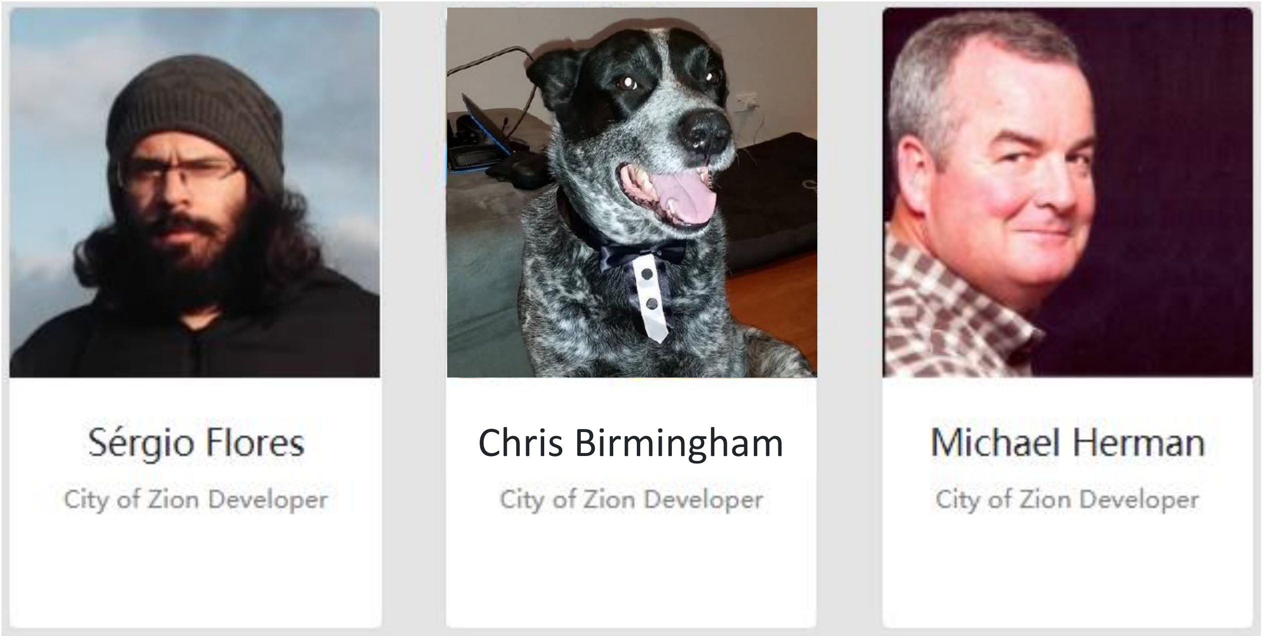
- What is a NEO Community Bluepaper?

  It is a bluepaper written by anyone who is passionate about the NEO Blockchain platform. They can be unsponsored; or sponsored by someone else or an organization (e.g. an employer).

- The NEO Persistable Classes 1.0 Deep Dive is an unsponsored bluepaper.

Shout-outs

- NEO Developer Tool Suite - CoZ Developers
  - @relfos – neo-debugger
  - @birmas – neo-gui-developer
  - @mwherman2000 – event log enhancements



Agenda

1. Purpose
2. Scenario
3. Problem
4. Analysis
5. Options
6. Code Solution
7. Test Results
8. Roadmap
9. Summary
10. Appendix A - NEO Blockchain Architecture Reference Model (ARM)

Checkout *Structuring Small Powerful Documents* at https://hyperonomy.com/2017/04/09/structuring-small-powerful-documents/

0. Key Definitions

- NPC
  - NEO Persistable Class Framework
- NeoVersionedAppUser (VAU)
  - NEO Versioned App User objects used to create NeoStorageKeys
- NeoStorageKeys (NSK)
  - NEO Storage Keys used to implement NPC Level 4 Collectible NPC classes
- NEO-KONG
  - NEO Key-Object Notation for Geeks is a specification used to implement NSKs
- C#.MS
  - Version of C# supported natively by the C# compiler in Visual Studio 2017 (C# 6.0)
- C#.NEO
  - The label for the implicit (undocumented) definition what is supported by the transcompiler and the NEO VM
  - Subset of C#.MS supported by the NEO neon.exe transcompiler (as of January 2018)
- C#.NPC
  - Explicit definition of the subset of C#.MS that is supported by the NEO transcompiler for .NET (neon.exe) that supports NPC's best practice recommendations for object-oriented development.

1. Purpose

- The purpose of this presentation is to explain the key drivers for the NEO Persistable Class Framework 1.0 (NPC) as well as a range of design and implementation details including:
  - A fairly complete description of C#.NEO, the subset of C#.MS (C# 6.0) supported by neon.exe, the C#.MS MSIL to NEO byte code transcompiler
  - Strategies and options for supporting the object programming capabilities found in C#.MS but not supported in C#.NEO
  - Basic guidance to smart contract development using C#.NPC
  - NPCdApp, the initial reference implementation for the NEO Persistable Class Framework

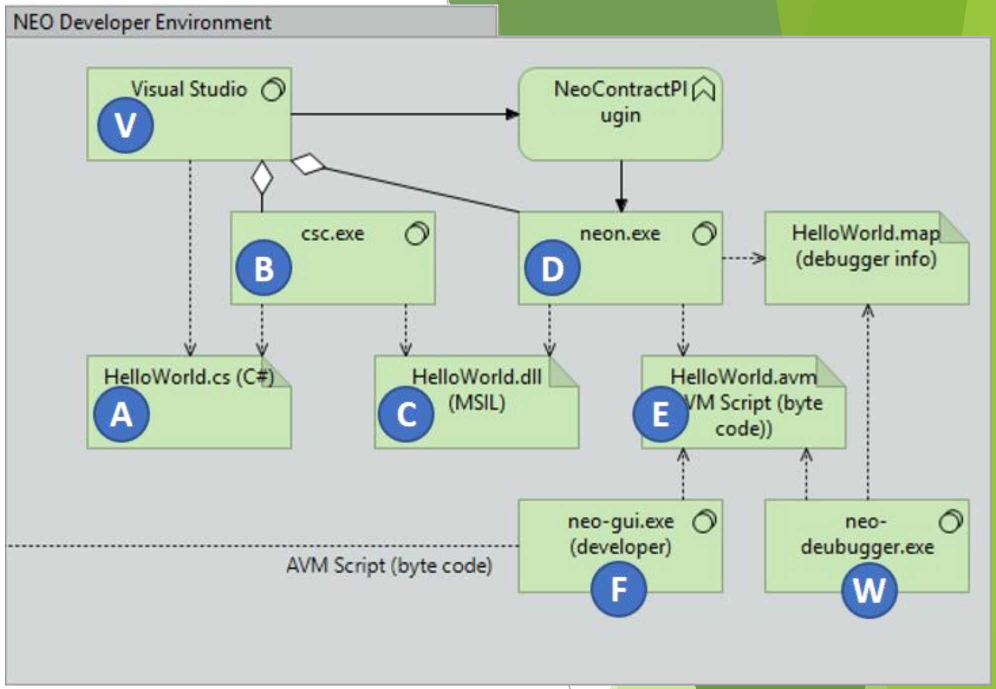
- Inspiration (NPC Level 0)
  - StructExample example https://github.com/neo-project/examples-csharp/blob/master/StructExample/StructExample.cs

2. Scenario

2. Scenario

- Developers on the NEO Blockchain platform have a variety of languages, tools, privatenet and testnet environments as well other technology options to consider for developing smart contracts
- Language options include:
  - C#.NEO
  - Python
  - Java
  - and others
- As a scenario, this document specifically targets C#.NEO smart contract development using Visual Studio 2017

2. Scenario (con't)



The diagram depicts a typical NEO development environment.

- A Developers develop their smart contract's code using their favorite IDE and high-level programming language (HLL) (e.g. C#.MS)
- C The IDE's integrated compiler compiles the HLL source into intermediate code (IL) (e.g. Microsoft Intermediate Language)
- E A transcompiler then translates the IL into byte code that is executable by the NEO VM (e.g. NEO VM byte code script files)
- W A debugger may be used to execute the VM byte code script off-chain using a VM emulator
- F An on-chain deployment and testing tool may be used to further test and validate the smart contract's implementation

- Reference: NEO Blockchain Architecture Reference Model (ARM) for .NET Developers https://github.com/mwherman2000/neo-charm

2. Scenario (con’t)

- The NEO Development environment gains incredible value from leveraging the Microsoft .NET compiler stack but there is a significant challenge with this approach:
  - Visual Studio doesn't know anything the instruction set that the NEO VM supports
  - The C#.MS compiler implements the full C# 6.0 specification and knows how to generate MSIL (MS Intermediate Language) code (DLL assembly files) for the full C#.MS language
  - On the other hand, the C#.NEO compiler (neon.exe) only supports a subset of the MSIL patterns generated by the MS compiler.
  - neon.exe reads MSIL files and transcompiles the logic into NEO byte code script files (.AVM files) and generates an error when an unsupported MSIL pattern is encountered
- I call this subset of C#.MS that is ultimately supported in the NEO VM: C#.NEO
  - What are the supported patterns of MSIL that neon.exe supports?
  - What are the good/better/best patterns to use?
  - How do you work around what is important but not supported in C#.NEO?

3. Problem

3. Problem

- Given that the subset of C#.MS that is supported by neon.exe (and the NEO VM) is not documented, how to we proceed to exploit the capabilities of C#.NEO?
  - What are the supported patterns of MSIL that neon.exe supports?
  - What are the good/better/best patterns to use?
  - How do you work around what is important but not supported in C#.NEO?
- How do we use C#.NEO for sophisticated object-oriented development?
- How do we support C# classes that are nothing more elaborate than C++/C## structs?

```
public class Point /* Level 0 */
{
    private BigInteger _x;
    private BigInteger _y;
}
```

4. Analysis

Sidebar: How is programming the NEO VM like learning to fly a flight simulator?

- As an analogy, learning to program the NEO VM is like learning to fly a flight simulator.
- A NEO smart contract running in the NEO VM is like the pilot in control of the flight simulator.
- The smart contract is performing various calculations and calling various virtual machine APIs to accomplish the smart contract's purpose and goals.
- In response to these API calls, the VM is interacting with its various subsystems (just like the flight simulator).
- https://github.com/mwherman2000/neo-charm/blob/master/README.md

4. Analysis

- What works in C#.NEO? What doesn't? What are the (good) workarounds?

C#.MS	C#.NEO	C#.NPC
Class constructor (parameterless)	Supported: field layout only	`public static Point New()` class method `private static _Initialize(p)` class method
Class constructor (with parameters)	Not supported: ignored	`public static Point New(x,y)` class method
Class constructor logic	Not supported: ignored	`public static bool Foobar(p,a,b)` class methods
Properties (`get()/set()`)	Not supported	`public static SetX/GetX/Set()` class methods
`null` valued variables	Not supported	`EntityState _state; //` system field `public static bool IsNull(p)`
Floating-point data types	Not supported	Native Storage datatypes: `string, byte[], BigInteger` Limited datatypes: `int/Int32`
Integer data types (`int/Int32`)	Partially support	
`switch` statements	Not predictable	Use `if-then-else if-then-else if-…`

4. Analysis (con't)

C#.MS	C#.NEO	C#.NPC
Declare fixed size `byte[100]`	Not supported	Use byte[].Concat(byte[])
Assignment to element of `byte[]` array: `a[i] = 0x12;`	Not supported	Use byte[].Concat(byte[])
`0x0123456789abcdef.ToString()`	Not supported	`Neo.SmartContract.Framework.Helper.AsString(byte[])`
`((BigInteger)0x0123456789abcdef).ToString()`	Not supported	
`((BigInteger)0x0123456789abcdef).ToByteArray().ToString()`	Not supported	`((BigInteger)0x0123456789abcdef).AsByteArray().AsString()`
`enum` enumerations at `int`'s (internally)	Supported	`int/Int32` are supported but not native C#.NEO Storage datatypes NOTE: Be prepared to do lots of type coercions

4. Analysis (con't)

```
namespace Neo.SmartContract.Framework
{
    public static class Helper
    {
        ...public static BigInteger AsBigInteger(this byte[] source);
        ...public static byte[] AsByteArray(this BigInteger source);
        ...public static byte[] AsByteArray(this string source);
        ...public static string AsString(this byte[] source);
        ...public static byte[] Concat(this byte[] first, byte[] second);
        ...public static byte[] HexToBytes(this string hex);
        ...public static byte[] Range(this byte[] source, int index, int count);
        ...public static byte[] Take(this byte[] source, int count);
        ...public static Delegate ToDelegate(this byte[] source);
        ...public static byte[] ToScriptHash(this string address);
    }
}
```

4. Analysis (con’t)

```
namespace Neo.SmartContract.Framework.Services.Neo
{
    public static class Storage
    {
        public static StorageContext CurrentContext { get; }

        ...public static void Delete(StorageContext context, byte[] key);
        ...public static void Delete(StorageContext context, string key);
        ...public static byte[] Get(StorageContext context, byte[] key);
        ...public static byte[] Get(StorageContext context, string key);
        ...public static void Put(StorageContext context, byte[] key, byte[] value);
        ...public static void Put(StorageContext context, byte[] key, BigInteger value);
        ...public static void Put(StorageContext context, byte[] key, string value);
        ...public static void Put(StorageContext context, string key, byte[] value);
        ...public static void Put(StorageContext context, string key, BigInteger value);
        ...public static void Put(StorageContext context, string key, string value);
    }
}
```

4. Analysis (con’t)

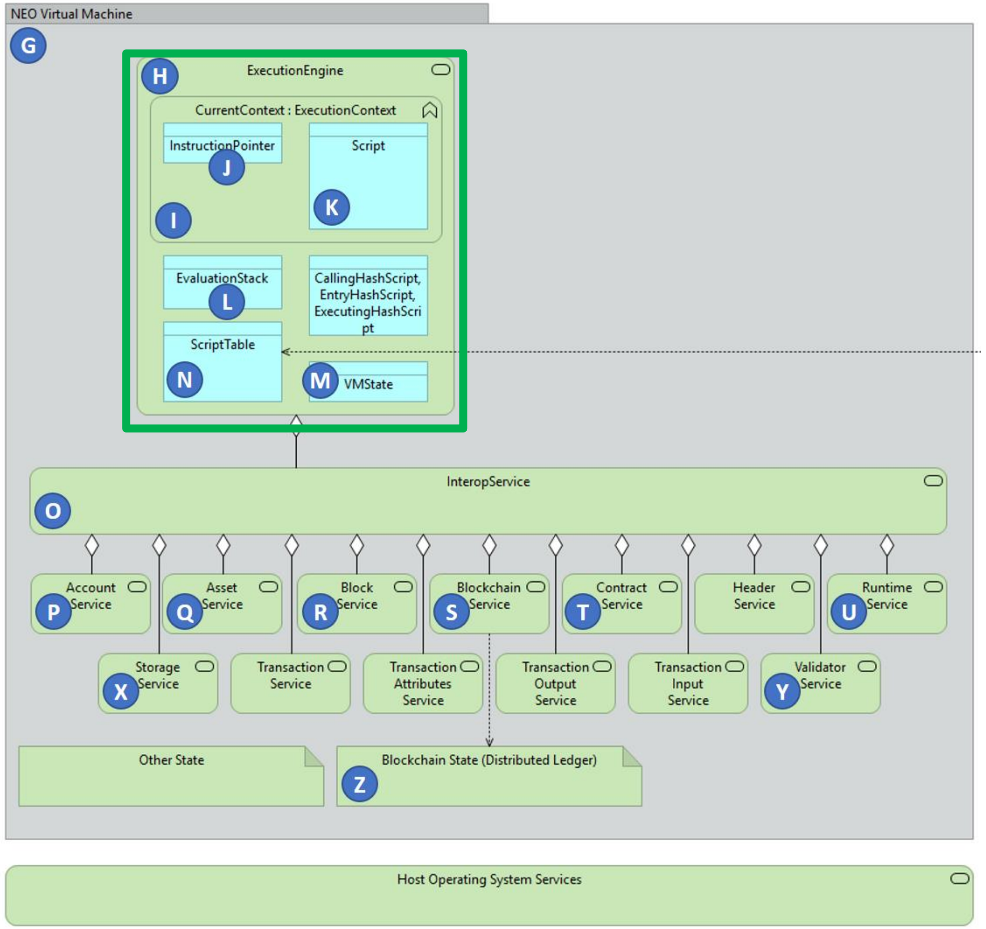
NEO Account Addresses, Keys and Key Lengths

Description	Length (byte[]/HexString)	Examples (Bold Lengths)
WIF1	(**52**/104)	L3f7C21q4Mu5FzZsDuCMeHqwJ1apHYCrwzU2821p1opaM43BAMKo
WIF1Address	(**34**/68)	AcCHoikUq9cP6SMESHufCEMwADJNcTwnAv
WIF1PublicKeyHex	(33/**66**)	02c44534465c8b21f659eba5708e69edae1ddd6f8cd63004095f8e39493cf54e82
WIF1PrivateKeyHex	(32/**64**)	c016e1c8a193cc1a28a15464106b91b52727547a3a36f40a8bfebd9933d1963c
WIF1AddressScriptHash	(20/**40**)	e000aa6a0ab08af8aa78b19d481e5b5c40d8be0e
	= WIF1Address.AsScriptHash();	
WIF2	(**52**/104)	KxDgvEKzgSBPPfuVfw67oPQBSjidEiqTHURKSDL1R7yGaGYAeYnr
WIF2Address	(**34**/68)	AK2nJJpJr6o664CWJKi1QRXjqeic2zRp8y
WIF2PublicKeyHex	(33/**66**)	031a6c6fbbdf02ca351745fa86b9ba5a9452d785ac4f7fc2b7548ca2a46c4fcf4a
WIF2PrivateKeyHex	(32/**64**)	1dd37fba80fec4e6a6f13fd708d8dcb3b29def768017052f6c930fa1c5d90bbb
WIF2AddressScriptHash	(20/**40**)	23ba2703c53263e8d6e522dc32203339dcd8eee9
	= WIF2Address.AsScriptHash();	

TxID, AssetID	(32/**64**)	687b68a1159429dc558e4fc7590e391d52f1ef79a12922f941daa37c00334ec5

Sidebar: NEO Virtual Machine

https://github.com/mwherman2000/neo-charm/blob/master/README.md



- This Analysis section has dug relatively deep in terms of analysing the core ExecutionEngine in the NEO VM from a C# development perspective.
- It has started to create a definition of C#.NPC as an explicit definition of the subset of C#.MS that is supported by the NEO transcompiler for .NET (neon.exe) **and** follows recommended and documented best practices.
- (C#.NEO remains as the label for the implicit (undocumented) definition what is supported by the transcompiler and the NEO VM).

5. Options

5. Options

Model every C# Class as an C#.NPC Class

- Fields
  - Only `string, byte[],` or `BigInteger` data types
  - Especially if there is any chance of class being persisted
- Constructors
  - Every class has a private parameterless constructor that is never used
  - Every class has `public static T New()` and `public static T New(x,y)`
- All class methods modeled as `public static` methods
  - Entity passed as the first parameter (except `Log()` and `LogExt()` methods)
- `null` valued variables
  - Start adding "system" fields to each class: `private EntityType _state;`
  - `public static` wrapper methods for all system fields (scoped `private`)
- Use `byte[]` whenever possible to minimize Storage as well as being the easiest to work from a supported runtime library perspective

5. Options (con't)

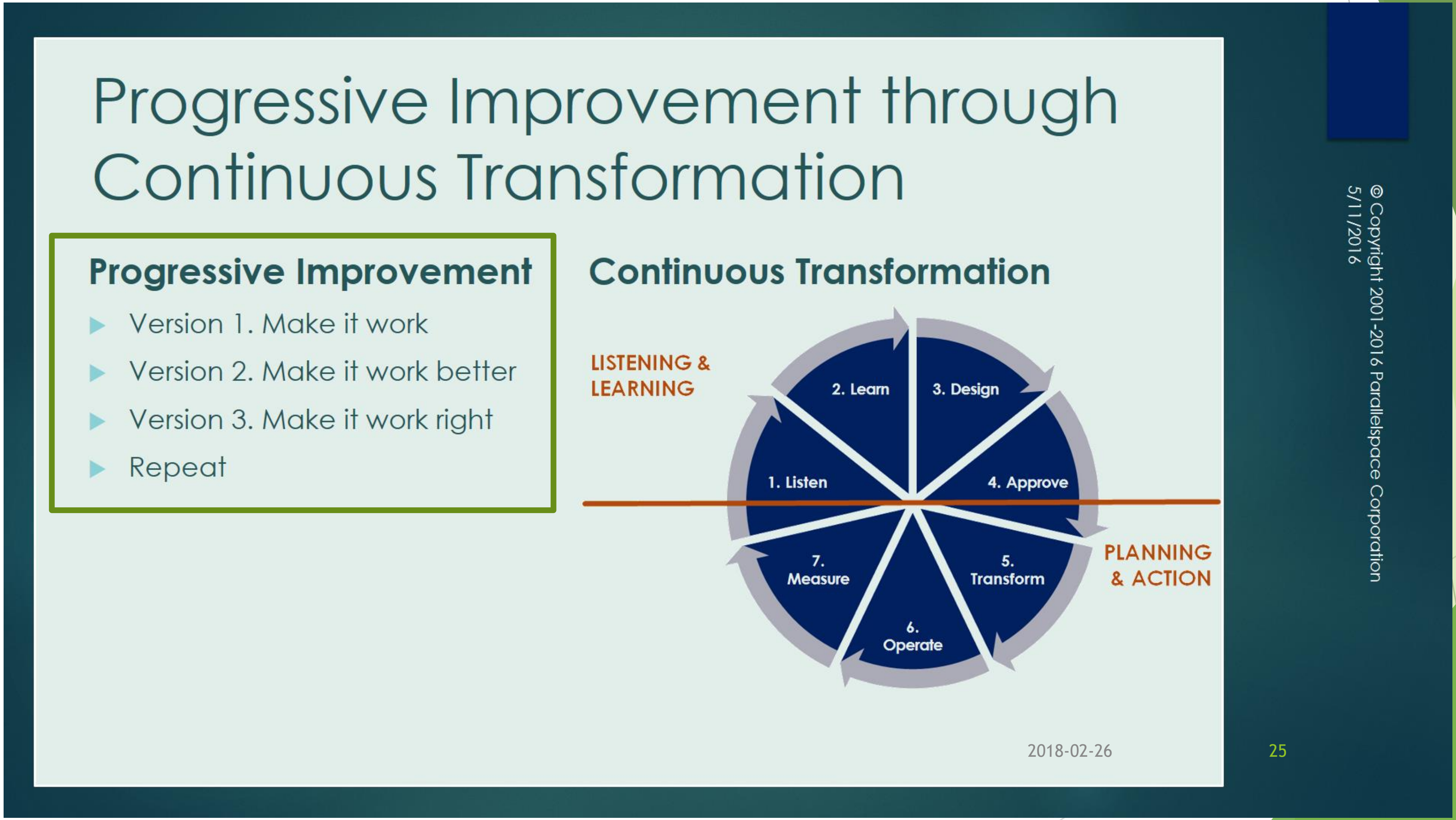
Model every C# Class as an C#.NPC Class with the following characteristics:

- All NPC have the same minimum set of default public static methods with the set of methods varying with the NPC Level being implemented for the class:
  - NPC Level 0 Basic
  - NPC Level 1 Managed
  - NPC Level 2 Persistable
  - NPC Level 3 Deletable (Bury/Tombstone)
  - NPC Level 4 Collectible
  - NPC Level 5 Extendible (Roadmap)
  - NPC Level 6 Authorized (Roadmap)
  - NPC Level 6 Optimized (Roadmap)
- NOTE: Primary driver for NPC Levels is minimizing code size by implementing only the Levels (and methods) required by the specific class

6. Solution

Sidebar: How we think about how we work?

https://hyperonomy.com/2016/05/09/how-do-we-think-about-how-we-work/



6. Solution

- NPC Level 0 Basic
- NPC Level 1 Managed
- NPC Level 2 Persistable
- NPC Level 3 Deletable (Bury/Tombstone)
- NPC Level 4 Collectible
- NPC Level 5 Extendible (Roadmap)
- NPC Level 6 Authorized (Roadmap)
- NPC Level 6 Optimized (Roadmap)

6. Solution – NPC Level 0 Basic

NPC Level 0 Basic - Point

```
public class Point /* Level 0 */
{
    public BigInteger x;
    public BigInteger y;
}
```

6. Solution – NPC Level 1 Managed

NPC Level 1 Managed – NeoTrace

```
public class NeoTrace /* Level *all* */
{
    public static void Trace(params object[] args)
    {
        Neo.SmartContract.Framework.Services.Neo.Runtime.Notify(args);
    }
}
```

NPC Level 1 Managed – NeoEntityModel

```
public static class NeoEntityModel /* Level 1 */
{
    public enum EntityState
    {
        NULL, INIT, SET
    }
    public static BigInteger AsBigInteger(this EntityState sta)
    {
        int istate = (int)sta;
        BigInteger bis = istate;
        return bis;
    }
    public static EntityState BytesToEntityState(byte[] bsta)
    {
        int ista = (int)bsta.AsBigInteger();
        NeoEntityModel.EntityState sta = (NeoEntityModel.EntityState)ista;
        return sta;
    }
}
```

NPC Level 1 Managed – Point

```
public class Point : NeoTrace /* Level 1 */
{
   private BigInteger _x;
   private BigInteger _y;
   private NeoEntityModel.EntityState _state;

   // Accessors
   public static void SetX(Point p, BigInteger value)
          { p._x = value; p._state = NeoEntityModel.EntityState.SET; }
   public static BigInteger GetX(Point p) { return p._x; }
   public static void SetY(Point p, BigInteger value)
          { p._y = value; p._state = NeoEntityModel.EntityState.SET; }
   public static BigInteger GetY(Point p) { return p._y; }
   public static void Set(Point p, BigInteger xvalue, BigInteger yvalue)
          { p._x = xvalue; p._y = yvalue; p._state = NeoEntityModel.EntityState.SET; }
```

NPC Level 1 Managed – Point (con’t)

```
// Factory methods
private Point()
{
}

private static Point _Initialize(Point p)
{
    p._x = 0;
    p._y = 0;
    p._state = NeoEntityModel.EntityState.NULL;
    LogExt("_Initialize(p).p", p);
    return p;
}
public static Point New()
{
    Point p = new Point();
    _Initialize(p);
    LogExt("New().p", p);
    return p;
}
```

NPC Level 1 Managed – Point (con't)

```
public static Point New(int x, int y)
{
    Point p = new Point();
    p._x = x;
    p._y = y;
    p._state = NeoEntityModel.EntityState.INIT;
    LogExt("New(x,y).p", p);
    return p;
}
public static Point Null()
{
    Point p = new Point();
    _Initialize(p);
    LogExt("Null().p", p);
    return p;
}
```

NPC Level 1 Managed – Point (con’t)

```
    // EntityState wrapper methods
    public static bool IsNull(Point p)
    {
        return (p._state == NeoEntityModel.EntityState.NULL);
    }

    // Log/trace methods
    public static void Log(string label, Point p)
    {
        NeoTrace.Trace(label, p._x, p._y);
    }
    public static void LogExt(string label, Point p)
    {
        NeoTrace.Trace(label, p._x, p._y, p._state);
    }
}
```

6. Solution – NPC Level 2 Persistable

NPC Level 2 Persistable - NeoEntityModel

```
public static class NeoEntityModel /* Level 2 Persistable */
{
    public enum EntityState
    {
        NULL, INIT, SET, PUTTED, GETTED, MISSING
    }

    public static BigInteger AsBigInteger(this EntityState state)
    {
        int istate = (int)state;
        BigInteger bis = istate;
        return bis;
    }
    public static EntityState BytesToEntityState(byte[] bsta)
    {
        int ista = (int)bsta.AsBigInteger();
        NeoEntityModel.EntityState sta = (NeoEntityModel.EntityState)ista;
        return sta;
    }
}
```

NPC Level 2 Persistable – Point

```
public class Point : NeoTrace /* Level 2 Persistable */
{
    private BigInteger _x;
    private BigInteger _y;
    private NeoEntityModel.EntityState _state;

    // Accessors
    public static void SetX(Point p, BigInteger value)
           { p._x = value; p._state = NeoEntityModel.EntityState.SET; }
    public static BigInteger GetX(Point p) { return p._x; }
    public static void SetY(Point p, BigInteger value)
           { p._y = value; p._state = NeoEntityModel.EntityState.SET; }
    public static BigInteger GetY(Point p) { return p._y; }
    public static void Set(Point p, BigInteger xvalue, BigInteger yvalue)
           { p._x = xvalue; p._y = yvalue; p._state = NeoEntityModel.EntityState.SET; }
```

NPC Level 2 Persistable – Point (con't)

```
// Class name and property names
private const string _className = "Point";
private const string _sX = "X";
private const string _sY = "Y";
private const string _sSTA = "_STA";
private const string _sEXT = "_EXT";
private static readonly byte[] _bX = Helper.AsByteArray(_sX);
private static readonly byte[] _bY = Helper.AsByteArray(_sY);
private static readonly byte[] _bSTA = Helper.AsByteArray(_sSTA);
private static readonly byte[] _bEXT = Helper.AsByteArray(_sEXT);

// Internal fields
private const string _classKeyTag = "/#" + _className + ".";
private static readonly byte[] _bclassKeyTag = Helper.AsByteArray(_classKeyTag);
```

NPC Level 2 Persistable – Point (con’t)

```
// Factory methods
private Point()
{
}
private static Point _Initialize(Point p)
{
    p._x = 0; p._y = 0;
    p._state = NeoEntityModel.EntityState.NULL;
    LogExt("_Initialize(p).p", p);
    return p;
}
public static Point New()
{
       Point p = new Point();
    _Initialize(p);
    LogExt("New().p", p);
    return p;
}
```

NPC Level 2 Persistable – Point (con’t)

```
public static Point New(int x, int y)
{
    Point p = new Point();
    p._x = x; p._y = y;
    p._state = NeoEntityModel.EntityState.INIT;
    LogExt("New(x,y).p", p);
    return p;
}
public static Point Null()
{
    Point p = new Point();
    _Initialize(p);
    LogExt("Null().p", p);
  return p;
}
```

NPC Level 2 Persistable – Point (con't)

```
// EntityState wrapper methods
public static bool IsNull(Point p)
{
    return (p._state == NeoEntityModel.EntityState.NULL);
}

// Log/trace methods
public static void Log(string label, Point p)
{
    NeoTrace.Trace(label, p._x, p._y);
}
public static void LogExt(string label, Point p)
{
    NeoTrace.Trace(label, p._x, p._y, p._state);
}
```

NPC Level 2 Persistable – Point (con’t)

```
// Persistable methods
public static bool IsMissing(Point p)
{
    return (p._state == NeoEntityModel.EntityState.MISSING);
}

public static Point Missing()
{
    Point p = new Point();
    p._x = 0; p._y = 0;
    p._state = NeoEntityModel.EntityState.MISSING;
    LogExt("Missing().p", p);
    return p;
}
```

NPC Level 2 Persistable – Point (con’t)

```
public static bool Put(Point p, byte[] key)
{
    if (key.Length == 0) return false;
    Neo.SmartContract.Framework.Services.Neo.StorageContext ctx =
            Neo.SmartContract.Framework.Services.Neo.Storage.CurrentContext;
    byte[] _bkeyTag = Helper.Concat(key, _bclassKeyTag);

    p._state = NeoEntityModel.EntityState.PUTTED;
    Neo.SmartContract.Framework.Services.Neo.Storage.Put(ctx,
            Helper.Concat(_bkeyTag, _bSTA), p._state.AsBigInteger());
    Neo.SmartContract.Framework.Services.Neo.Storage.Put(ctx,
            Helper.Concat(_bkeyTag, _bX), p._x);
    Neo.SmartContract.Framework.Services.Neo.Storage.Put(ctx,
            Helper.Concat(_bkeyTag, _bY), p._y);
    LogExt("Put(bkey).p", p);
    return true;
}
```

NPC Level 2 Persistable – Point (con’t)

```
public static Point Get(byte[] key)
{
    if (key.Length == 0) return Null();
    Neo.SmartContract.Framework.Services.Neo.StorageContext ctx =
        Neo.SmartContract.Framework.Services.Neo.Storage.CurrentContext;
    byte[] _bkeyTag = Helper.Concat(key, _bclassKeyTag);
    Point p;
    byte[] bsta = Neo.SmartContract.Framework.Services.Neo.Storage.Get(ctx, Helper.Concat(_bkeyTag, _bSTA));
    NeoTrace.Trace("Get(kb).bs", bsta.Length, bsta);
    if (bsta.Length == 0)
    {
        p = Point.Missing();
    }
    else // not MISSING
    {
        byte[] bext = Neo.SmartContract.Framework.Services.Neo.Storage.Get(ctx, Helper.Concat(_bkeyTag, _bEXT));
        int ista = (int)bsta.AsBigInteger();
        NeoEntityModel.EntityState sta = (NeoEntityModel.EntityState)ista;
        p = new Point();
        BigInteger x = Neo.SmartContract.Framework.Services.Neo.Storage.Get(ctx,
                       Helper.Concat(_bkeyTag, _bX)).AsBigInteger();
        BigInteger y = Neo.SmartContract.Framework.Services.Neo.Storage.Get(ctx,
                       Helper.Concat(_bkeyTag, _bY)).AsBigInteger();
        p._x = x; p._y = y; p._state = sta;
        p._state = NeoEntityModel.EntityState.GETTED; /* OVERRIDE */
    }
    LogExt("Get(kb).p", p);
    return p;
}
```

NPC Level 2 Persistable – Point (con’t)

```
public static Point Get(byte[] key)
{
    if (key.Length == 0) return Null();
    Neo.SmartContract.Framework.Services.Neo.StorageContext ctx =
        Neo.SmartContract.Framework.Services.Neo.Storage.CurrentContext;
    byte[] _bkeyTag = Helper.Concat(key, _bclassKeyTag);
    Point p;
    byte[] bsta = Neo.SmartContract.Framework.Services.Neo.Storage.Get(ctx, Helper.Concat(_bkeyTag, _bSTA));
    NeoTrace.Trace("Get(kb).bs", bsta.Length, bsta);
    if (bsta.Length == 0)
    {
        p = Point.Missing();
    }
    else // not MISSING
    {
        byte[] bext = Neo.SmartContract.Framework.Services.Neo.Storage.Get(ctx, Helper.Concat(_bkeyTag, _bEXT));
        int ista = (int)bsta.AsBigInteger();
        NeoEntityModel.EntityState sta = (NeoEntityModel.EntityState)ista;
        p = new Point();
        BigInteger x = Neo.SmartContract.Framework.Services.Neo.Storage.Get(ctx,
                           Helper.Concat(_bkeyTag, _bX)).AsBigInteger();
        BigInteger y = Neo.SmartContract.Framework.Services.Neo.Storage.Get(ctx,
                           Helper.Concat(_bkeyTag, _bY)).AsBigInteger();
        p._x = x; p._y = y; p._state = sta;
        p._state = NeoEntityModel.EntityState.GETTED; /* OVERRIDE */
    }
    LogExt("Get(kb).p", p);
    return p;
}
```

6. Solution – NPC Level 3 Deletable

NPC Level 3 Deletable - NeoEntityModel

```
public static class NeoEntityModel /* Level 3 Deletable */
{
    public enum EntityState
    {
        NULL, INIT, SET, PUTTED, GETTED, MISSING, TOMBSTONED
    }

    public static BigInteger AsBigInteger(this EntityState state)
    {
        int istate = (int)state;
        BigInteger bis = istate;
        return bis;
    }
    public static EntityState BytesToEntityState(byte[] bsta)
    {
        int ista = (int)bsta.AsBigInteger();
        NeoEntityModel.EntityState sta = (NeoEntityModel.EntityState)ista;
        return sta;
    }
}
```

NPC Level 3 Deletable – Point (con't)

```
...
    // Deletable methods
    public static bool IsBuried(Point p)
    {
        return (p._state == NeoEntityModel.EntityState.TOMBSTONED);
    }

    public static Point Tombstone()
    {
        Point p = new Point();
        p._x = 0;
        p._y = 0;
        p._state = NeoEntityModel.EntityState.TOMBSTONED;
        LogExt("Tombstone().p", p);
        return p;
    }
...
```

NPC Level 3 Deletable – Point (con't)

```
...
    public static Point Bury(byte[] key)
    {
       if (key.Length == 0) return Null();

       Neo.SmartContract.Framework.Services.Neo.StorageContext ctx =
                    Neo.SmartContract.Framework.Services.Neo.Storage.CurrentContext;
       byte[] _bkeyTag = Helper.Concat(key, _bclassKeyTag);

       Point p;
       byte[] bsta = Neo.SmartContract.Framework.Services.Neo.Storage.Get(ctx, Helper.Concat(_bkeyTag, _bSTA));
       NeoTrace.Trace("Bury(kb).bs", bsta.Length, bsta);
       if (bsta.Length == 0)
       {
           p = Point.Missing();
       }
       else // not MISSING - bury it
       {
           p = Point.Tombstone();
           Neo.SmartContract.Framework.Services.Neo.Storage.Put(ctx,
                    Helper.Concat(_bkeyTag, _bSTA), p._state.AsBigInteger());
           Neo.SmartContract.Framework.Services.Neo.Storage.Put(ctx, Helper.Concat(_bkeyTag, _bX), p._x);
           Neo.SmartContract.Framework.Services.Neo.Storage.Put(ctx, Helper.Concat(_bkeyTag, _bY), p._y);
       }
       LogExt("Bury(kb).p", p);
       return p; // return Point p to signal if key is Missing or bad key
    }
...
```

6. Solution – NPC Level 4 Collectible

NPC Level 4 Collectible - NeoEntityModel

```
public static class NeoEntityModel /* Level 4 Collectible */
{
    public enum EntityState
    {
        NULL, INIT, SET, PUTTED, GETTED, MISSING, TOMBSTONED, NOTAUTHORIZED /* Future */
    }
    public static BigInteger AsBigInteger(this EntityState state)
    {
        int istate = (int)state;
        BigInteger bis = istate;
        return bis;
    }
    public static EntityState BytesToEntityState(byte[] bsta)
    {
        int ista = (int)bsta.AsBigInteger();
        NeoEntityModel.EntityState sta = (NeoEntityModel.EntityState)ista;
        return sta;
    }
    public static readonly byte[] NullScriptHash = "".ToScriptHash();
    public static readonly byte[] NullByteArray = "".AsByteArray();
```

NPC Level 4 Collectible - NeoVersionedAppUser

```
public class NeoVersionedAppUser
{
    private byte[] _app;
    private int _major;
    private int _minor;
    private int _build;
    private byte[] _userScriptHash;
    private NeoEntityModel.EntityState _state;
```

NPC Level 4 Collectible - NeoVersionedAppUser

```
public static void SetAppName(NeoVersionedAppUser vau, byte[] value)
                          { vau._app = value; vau._state = NeoEntityModel.EntityState.SET; }
public static byte[] GetAppNameAsByteArray(NeoVersionedAppUser vau) { return vau._app; }
public static void SetAppName(NeoVersionedAppUser vau, string value)
                     { vau._app = value.AsByteArray(); vau._state = NeoEntityModel.EntityState.SET; }
public static string GetAppNameAsString(NeoVersionedAppUser vau) { return vau._app.AsString(); }
public static void SetMajor(NeoVersionedAppUser vau, int value)
                     { vau._major = value; vau._state = NeoEntityModel.EntityState.SET; }
public static int GetMajor(NeoVersionedAppUser vau) { return vau._major; }
public static void SetMinor(NeoVersionedAppUser vau, int value)
                     { vau._minor = value; vau._state = NeoEntityModel.EntityState.SET; }
public static int GetMinor(NeoVersionedAppUser vau) { return vau._minor; }
public static void SetBuild(NeoVersionedAppUser vau, int value)
                     { vau._build = value; vau._state = NeoEntityModel.EntityState.SET; }
public static int GetBuild(NeoVersionedAppUser vau) { return vau._build; }
public static void SetUserScriptHash(NeoVersionedAppUser vau, byte[] value)
                     { vau._userScriptHash = value; vau._state = NeoEntityModel.EntityState.SET; }
public static byte[] GetUserScriptHash(NeoVersionedAppUser vau) { return vau._userScriptHash; }
public static void Set(NeoVersionedAppUser vau, byte[] app, int major, int minor, int build, byte[] userScriptHash)
{
    vau._app = app; vau._major = major; vau._minor = minor; vau._build = build;
    vau._userScriptHash = userScriptHash; vau._state = NeoEntityModel.EntityState.SET;
}
public static void Set(NeoVersionedAppUser vau, string app, int major, int minor, int build, byte[] userScriptHash)
{
    vau._app = app.AsByteArray(); vau._major = major; vau._minor = minor; vau._build = build;
    vau._userScriptHash = userScriptHash; vau._state = NeoEntityModel.EntityState.SET;
}
```

NPC Level 4 Collectible - NeoStorageKey

```
public class NeoStorageKey
{
    private byte[] _app;
    private int _major;
    private int _minor;
    private int _build;
    private byte[] _userScriptHash;
    private byte[] _className;
    private int _index;
    private string _fieldName;
    private NeoEntityModel.EntityState _state;
```

NPC Level 4 Collectible - NeoStorageKey (con't)

```
public static NeoStorageKey New(NeoVersionedAppUser vau, byte[] className)
{
    if (NeoVersionedAppUser.IsNull(vau))
    {
        return NeoStorageKey.Null();
    }

    NeoStorageKey nsk = new NeoStorageKey();
    nsk._app = NeoVersionedAppUser.GetAppNameAsByteArray(vau);
    nsk._major = NeoVersionedAppUser.GetMajor(vau);
    nsk._minor = NeoVersionedAppUser.GetMinor(vau);
    nsk._build = NeoVersionedAppUser.GetBuild(vau);
    nsk._userScriptHash = NeoVersionedAppUser.GetUserScriptHash(vau);
    nsk._className = className;
    nsk._index = 0;
    nsk._fieldName = "";
    nsk._state = NeoEntityModel.EntityState.INIT;
    LogExt("New(vau,bc)", nsk);
    return nsk;
}
```

NPC Level 4 Collectible - NeoStorageKey (con't)

```
private static readonly byte[] _bLeftBrace = "{".AsByteArray();
private static readonly byte[] _bRightBrace = "}".AsByteArray();
private static readonly byte[] _bColon = ":".AsByteArray();
private static readonly byte[] _bEquals = "=".AsByteArray();
private static readonly byte[] _bSemiColon = ";".AsByteArray();
private static readonly byte[] _ba = "a".AsByteArray(); // App name
private static readonly byte[] _bM = "M".AsByteArray(); // App major version
private static readonly byte[] _bm = "m".AsByteArray(); // App minor version
private static readonly byte[] _bb = "b".AsByteArray(); // App build number
private static readonly byte[] _bu = "u".AsByteArray(); // User script hash
private static readonly byte[] _bc = "c".AsByteArray(); // Class name
private static readonly byte[] _bi = "i".AsByteArray(); // Index value
private static readonly byte[] _bf = "f".AsByteArray(); // Field name

private static readonly byte[] _bStringType =
                               { (byte)Neo.SmartContract.ContractParameterType.String };
private static readonly byte[] _bBigIntegerType =
                               { (byte)Neo.SmartContract.ContractParameterType.Integer };
private static readonly byte[] _bUserScriptHashType =
                               { (byte)Neo.SmartContract.ContractParameterType.ByteArray };
```

NPC Level 4 Collectible - NeoStorageKey (con't)

```
public static byte[] StorageKey(NeoStorageKey nsk, int index, byte[] fieldName)
{
    LogExt("StorageKey(nsk,i,fb).nsk", nsk);
    byte[] bkey = Helper.Concat(_bLeftBrace, _ba).Concat(_bColon).Concat(_bStringType)
                .Concat(_bEquals).Concat(nsk._app).Concat(_bSemiColon);
    bkey = Helper.Concat(bkey, _bM).Concat(_bColon).Concat(_bBigIntegerType)
                .Concat(_bEquals).Concat(((BigInteger)(nsk._major)).AsByteArray()).Concat(_bSemiColon);
    bkey = Helper.Concat(bkey, _bm).Concat(_bColon).Concat(_bBigIntegerType)
                .Concat(_bEquals).Concat(((BigInteger)(nsk._minor)).AsByteArray()).Concat(_bSemiColon);
    bkey = Helper.Concat(bkey, _bb).Concat(_bColon).Concat(_bBigIntegerType)
                .Concat(_bEquals).Concat(((BigInteger)(nsk._build)).AsByteArray()).Concat(_bSemiColon);
   bkey = Helper.Concat(bkey, _bu).Concat(_bColon).Concat(_bUserScriptHashType)
                .Concat(_bEquals).Concat(nsk._userScriptHash).Concat(_bSemiColon);
    bkey = Helper.Concat(bkey, _bc).Concat(_bColon).Concat(_bStringType)
                .Concat(_bEquals).Concat(nsk._className).Concat(_bSemiColon);

    bkey = Helper.Concat(bkey, _bi).Concat(_bColon).Concat(_bBigIntegerType)
                .Concat(_bEquals).Concat(((BigInteger)(index)).AsByteArray()).Concat(_bSemiColon);
    bkey = Helper.Concat(bkey, _bf).Concat(_bColon).Concat(_bStringType)
                .Concat(_bEquals).Concat(fieldName).Concat(_bSemiColon);
    bkey = Helper.Concat(bkey, _bRightBrace);
    NeoTrace.Trace("StorageKey(nsk).bkey$BSK", bkey);
    return bkey;
}
```

NPC Level 4 Collectible - Point

```
public static Point BuryElement(NeoVersionedAppUser vau, int index)
{
    if (NeoVersionedAppUser.IsNull(vau)) return Point.Null();

    Neo.SmartContract.Framework.Services.Neo.StorageContext ctx =
                            Neo.SmartContract.Framework.Services.Neo.Storage.CurrentContext;
    NeoStorageKey nsk = NeoStorageKey.New(vau, "Point");
    byte[] bkey;
    Point p;
    byte[] bsta = Neo.SmartContract.Framework.Services.Neo.Storage.Get(ctx, NeoStorageKey.StorageKey(nsk, index, _bSTA));
    NeoTrace.Trace("Bury(vau,index).bs", bsta.Length, bsta);
    if (bsta.Length == 0)
    {
        p = Point.Missing();
    }
    else // not MISSING - bury it
    {
        p = Point.Tombstone();
        Neo.SmartContract.Framework.Services.Neo.Storage.Put(ctx, NeoStorageKey.StorageKey(nsk, index, _bSTA),
                                                              p._state.AsBigInteger());
        Neo.SmartContract.Framework.Services.Neo.Storage.Put(ctx, NeoStorageKey.StorageKey(nsk, index, _bEXT),
                                                              p._extension);
        Neo.SmartContract.Framework.Services.Neo.Storage.Put(ctx, NeoStorageKey.StorageKey(nsk, index, _bX), p._x);
        Neo.SmartContract.Framework.Services.Neo.Storage.Put(ctx, NeoStorageKey.StorageKey(nsk, index, _bY), p._y);
    }
    LogExt("Bury(vau,i).p", p);
    return p;
}
```

7. Test Results

7. Test Results

- `Test1()`
  - Dump miscellaneous variables to the log
- `Test2()`
  - NPC Level 1 test cases: Create 3 Points and a line. Add two Points. Log the results.
- `Test3()`
  - NPC Level 2/3 test cases: Create 3 Points and test NPC Level 3 entity persistence. Log the results.
- `Test4()`
  - NPC Level 2/3 test cases: Test IsNull(), IsMissing() and IsExtended(). Log the results.
- `Test5()`
  - NPC Level 4 test cases: Test NeoStorageKeys. Log the results.
- `Test6()`
  - NPC Level 4 test cases: Test NeoStorageKeys. Log the results

Test1() - Code

```
public static string test1(object[] args)
{
    string msg = "success";

    NeoTrace.Trace("NullHash", NeoEntityModel.NullScriptHash);

    NeoTrace.Trace("NeoEntityModel.EntityState...");
    NeoEntityModel.EntityState state1 = NeoEntityModel.EntityState.MISSING;
    NeoTrace.Trace("state", state1);
    int istate = (int)state1;
    NeoTrace.Trace("state1", state1);

    BigInteger bis = state1.AsBigInteger();
    NeoTrace.Trace("bis", bis);

    byte[] bsta = { 0x4 };
    NeoTrace.Trace("bsta", bsta);
    NeoEntityModel.EntityState state2 = NeoEntityModel.BytesToEntityState(bsta);
    NeoTrace.Trace("state2", state2);

    return msg;
}
```

Test1() - neo-gui Event Log

neo-gui - ChainDockerPrivateNet2

Wallet Transaction Advanced Help

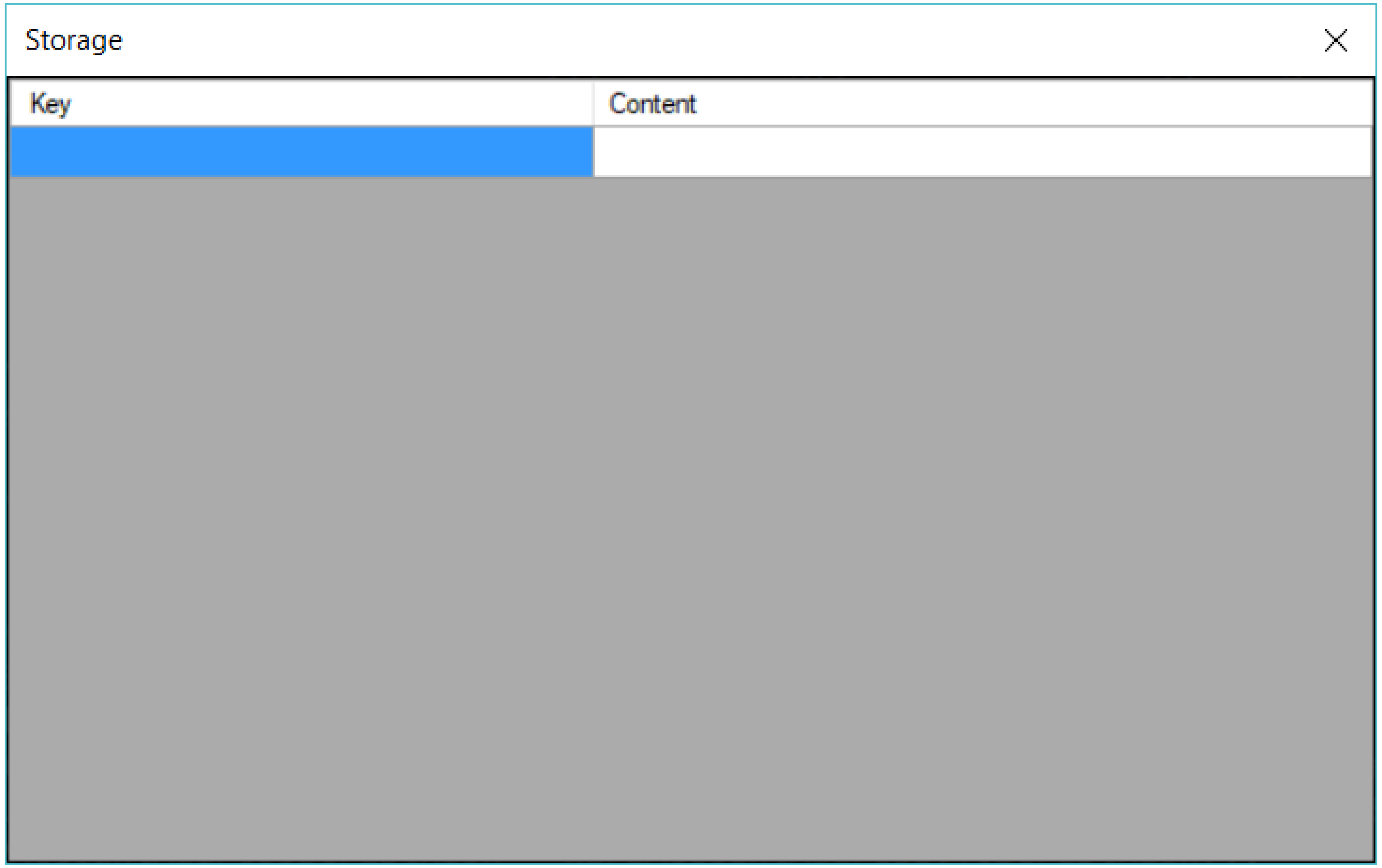
Account Asset Transaction History Event Log

Time	Block	Script Hash	Name	Type	Message
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	==
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	NPCdApp - NEO Persistable Class (NPC) Framework
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	NPCdApp - Version 0.1 Reference Implementation
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	--
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	operation / (STR5) 7465737431 'test1' /
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	==
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	NullHash / (BIN0) [binary]
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	NeoEntityModel.EntityState...
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	state / (BINT1) 5
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	state1 / (BINT1) 5
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	bis / (BINT1) 5
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	bsta / (STR1) 04 '□'
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	state2 / (STR1) 04 '□'
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	--
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	==
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	NPCdApp - NEO Persistable Class (NPC) Framework
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	NPCdApp - Version 0.1 Reference Implementation
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	--
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	operation / (STR5) 7465737431 'test1' /
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	==
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	NullHash / (BIN0) [binary]
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	NeoEntityModel.EntityState...
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	state / (BINT1) 5
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	state1 / (BINT1) 5
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	bis / (BINT1) 5
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	bsta / (STR1) 04 '□'
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	state2 / (STR1) 04 '□'
2018-02-2...	993	0x7074acf3f06dd3...	a	Notify	--

Height: 997/997/997 Connected: 3

Waiting for next block:

Test1() – neo-debugger Storage Viewer



Test2() - Code

```
public static string test2(object[] args)
{
    string msg = "success";

    NeoTrace.Trace("Make P0...");
    Point p0 = Point.New();
    Point.Log("p0", p0);
    Point.SetX(p0, 7);
    Point.SetY(p0, 8);
    Point.Log("p0", p0);
    Point.Set(p0, 9, 10);
    Point.Log("p0", p0);

    NeoTrace.Trace("Make P1...");
    Point p1 = Point.New();
    Point.Set(p1, 2, 4);
    Point.Log("p1", p1);

    NeoTrace.Trace("Make P2...");
    Point p2 = Point.New();
    Point.Set(p2, 15, 16);
    Point.Log("p2", p2);

    NeoTrace.Trace("Make line1...");
    Point[] line1 = new[]
    {
        p1, p2
    };
    NeoTrace.Trace("line1", line1, p1, p2); // TODO: neo-gui doesn't understand this: line1

    NeoTrace.Trace("Add 2 points...");
    Point p3 = Add(line1[0], line1[1]);
    Point.Log("p3", p3);

    return msg;
}
```

Test2() - neo-gui Event Log

neo-gui - ChainDockerPrivateNet2

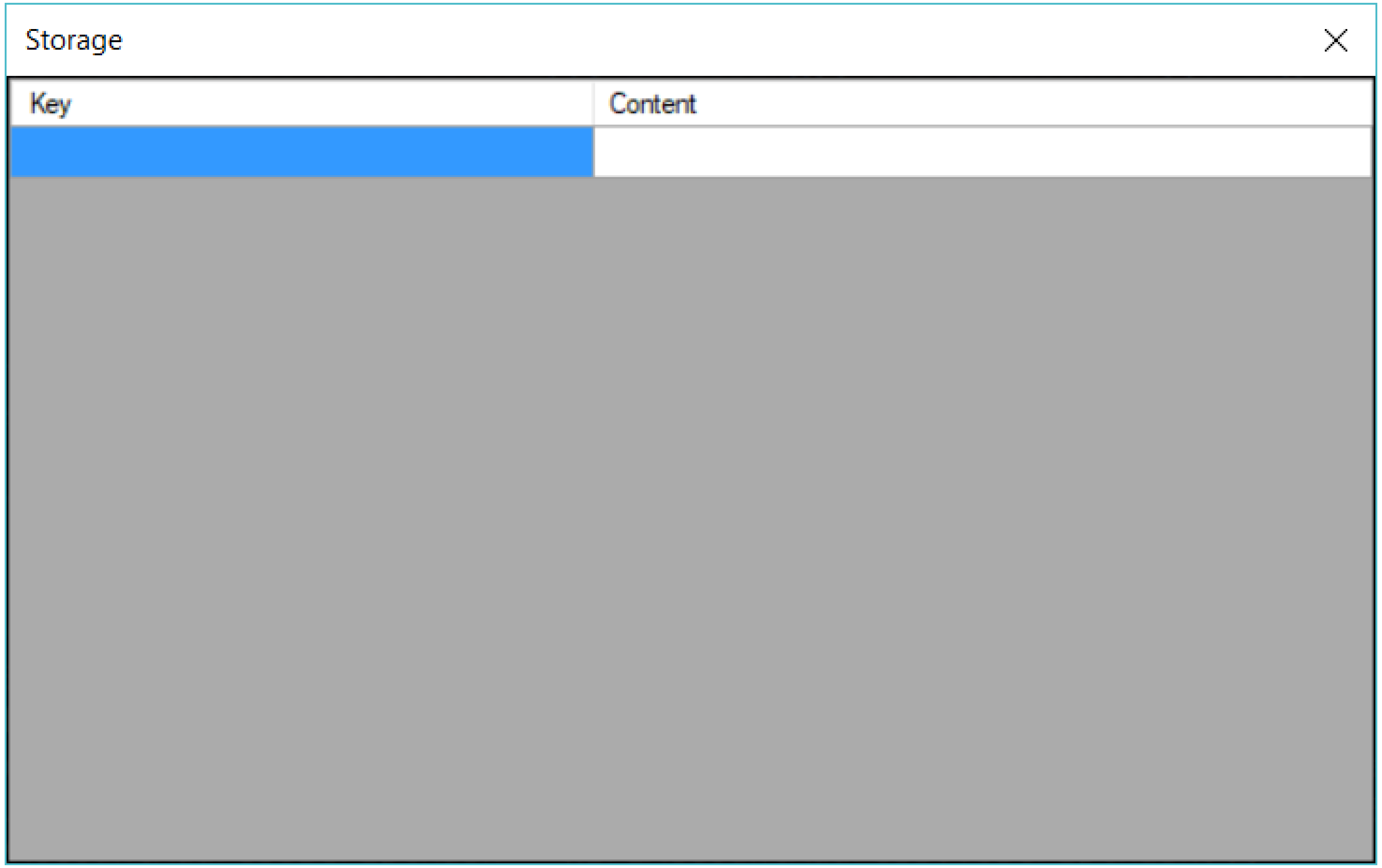
Wallet Transaction Advanced Help

Account Asset Transaction History Event Log

Time	Block	Script Hash	Name	Type	Message
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	line1 / / /
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	Add 2 points...
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	_Initialize(p).p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	New().p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	p3 / (BINT2) 17 / (BINT2) 20
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	--
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	==
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	NPCdApp - NEO Persistable Class (NPC) Framework
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	NPCdApp - Version 0.1 Reference Implementation
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	--
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	operation / (STR5) 7465737432 'test2' /
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	==
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	Make P0...
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	_Initialize(p).p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	New().p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	p0 / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	p0 / (BINT1) 7 / (BINT1) 8
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	p0 / (BINT1) 9 / (BINT2) 10
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	Make P1...
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	_Initialize(p).p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	New().p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	p1 / (BINT1) 2 / (BINT1) 4
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	Make P2...
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	_Initialize(p).p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	New().p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	p2 / (BINT2) 15 / (BINT2) 16
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	Make line1...
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	line1 / / /
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	Add 2 points...
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	_Initialize(p).p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	New().p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	p3 / (BINT2) 17 / (BINT2) 20
2018-02-2...	1002	0x7074acf3f06dd3...	a	Notify	--

Height: 1003/1003/1003 Connected: 2 Waiting for next block:

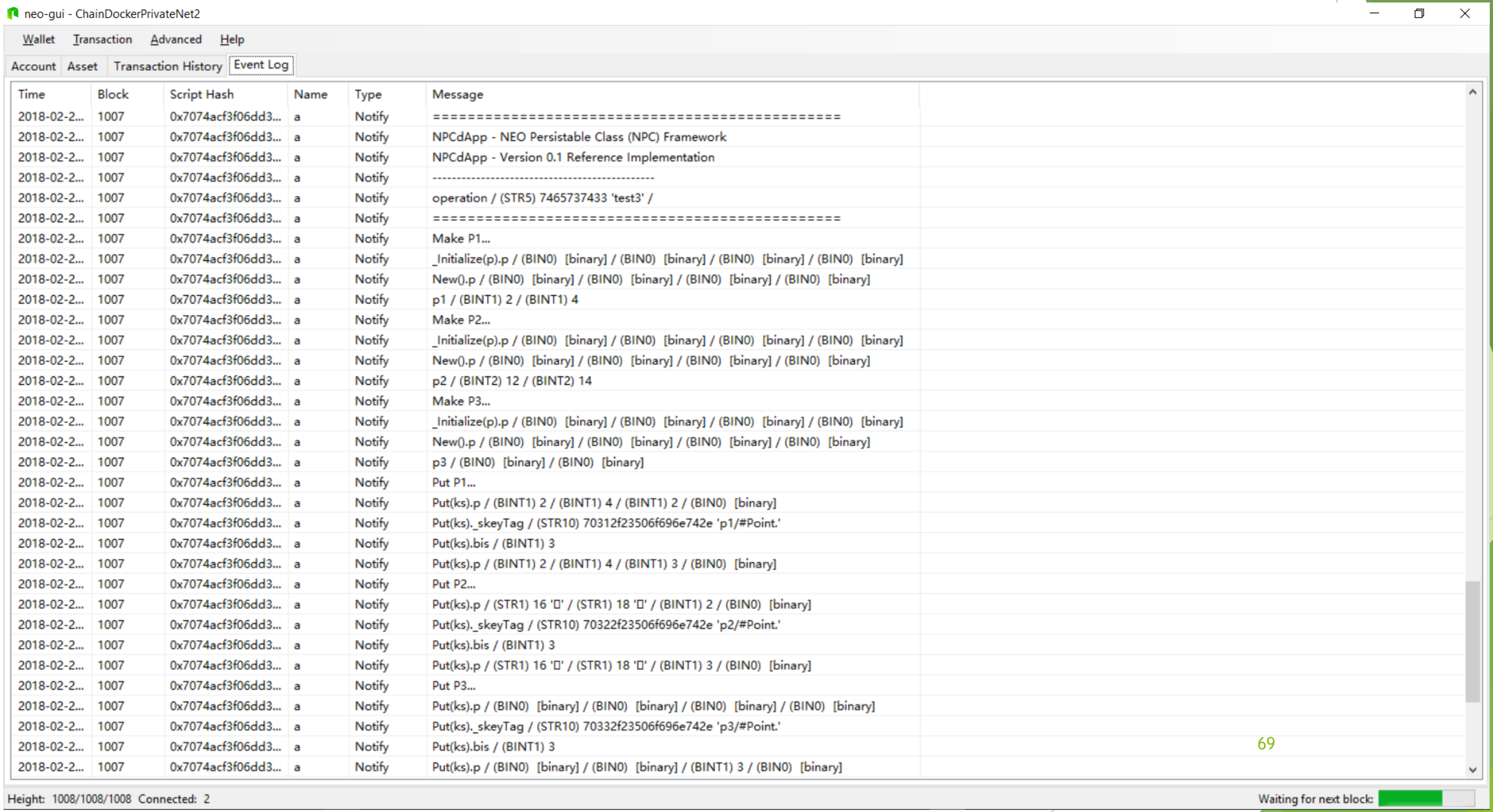
Test2() – neo-debugger Storage Viewer



Test3() - Code

```
public static string test3(object[] args)
{
    string msg = "success";

    NeoTrace.Trace("Make P1...");
    Point p1 = Point.New();
    Point.Set(p1, 2, 4);
    Point.Log("p1", p1);

    NeoTrace.Trace("Make P2...");
    Point p2 = Point.New();
    Point.Set(p2, 12, 14);
    Point.Log("p2", p2);

    NeoTrace.Trace("Make P3...");
    Point p3 = Point.New();
    Point.Set(p2, 22, 24);
    Point.Log("p3", p3);

    NeoTrace.Trace("Put P1...");
    Point.Put(p1, "p1");
    NeoTrace.Trace("Put P2...");
    Point.Put(p2, "p2");
    NeoTrace.Trace("Put P3...");
    Point.Put(p3, "p3");

    NeoTrace.Trace("Get P1...");
    Point p1get = Point.Get("p1");
    Point.Log("p1get", p1get);
    NeoTrace.Trace("Get P2...");
    Point p2get = Point.Get("p2");
    Point.Log("p2get", p2get);
    NeoTrace.Trace("Get P3...");
    Point p3get = Point.Get("p3");
    Point.Log("p3get", p3get);

    return msg;
}
```

Test3() – neo-gui Event Log



Time	Block	Script Hash	Name	Type	Message
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	==
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	NPCdApp - NEO Persistable Class (NPC) Framework
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	NPCdApp - Version 0.1 Reference Implementation
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	--
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	operation / (STR5) 7465737433 'test3' /
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	==
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	Make P1...
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	_Initialize(p).p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	New().p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	p1 / (BINT1) 2 / (BINT1) 4
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	Make P2...
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	_Initialize(p).p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	New().p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	p2 / (BINT2) 12 / (BINT2) 14
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	Make P3...
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	_Initialize(p).p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	New().p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	p3 / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	Put P1...
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	Put(ks).p / (BINT1) 2 / (BINT1) 4 / (BINT1) 2 / (BIN0) [binary]
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	Put(ks)._skeyTag / (STR10) 70312f23506f696e742e 'p1/#Point.'
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	Put(ks).bis / (BINT1) 3
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	Put(ks).p / (BINT1) 2 / (BINT1) 4 / (BINT1) 3 / (BIN0) [binary]
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	Put P2...
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	Put(ks).p / (STR1) 16 '□' / (STR1) 18 '□' / (BINT1) 2 / (BIN0) [binary]
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	Put(ks)._skeyTag / (STR10) 70322f23506f696e742e 'p2/#Point.'
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	Put(ks).bis / (BINT1) 3
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	Put(ks).p / (STR1) 16 '□' / (STR1) 18 '□' / (BINT1) 3 / (BIN0) [binary]
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	Put P3...
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	Put(ks).p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	Put(ks)._skeyTag / (STR10) 70332f23506f696e742e 'p3/#Point.'
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	Put(ks).bis / (BINT1) 3
2018-02-2...	1007	0x7074acf3f06dd3...	a	Notify	Put(ks).p / (BIN0) [binary] / (BIN0) [binary] / (BINT1) 3 / (BIN0) [binary]

Test3() – neo-debugger Storage Viewer

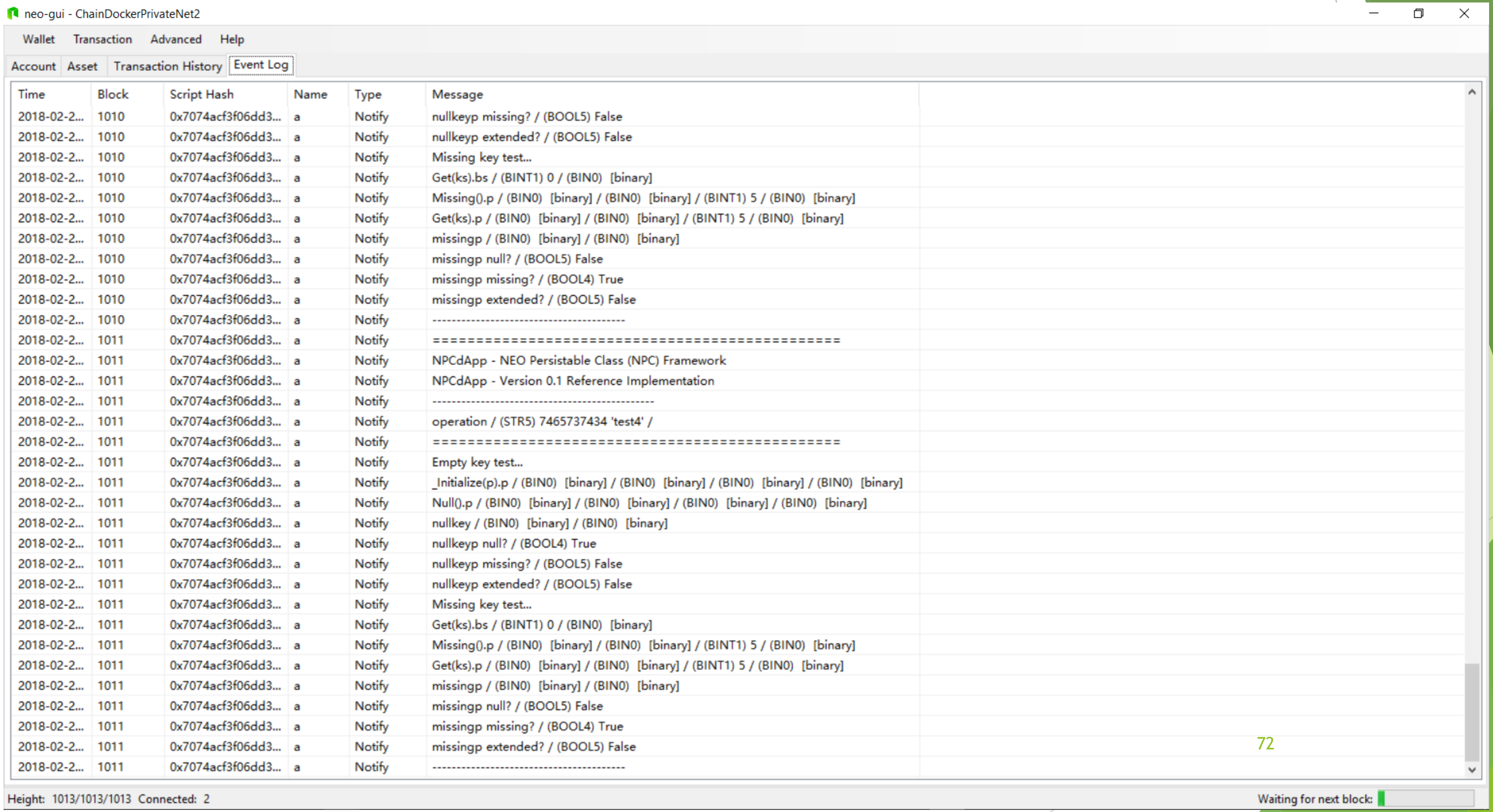
Storage

Key	Content
p1/#Point._STA	3
p1/#Point._EXT	
p1/#Point.X	2
p1/#Point.Y	4
p2/#Point._STA	3
p2/#Point._EXT	
p2/#Point.X	22
p2/#Point.Y	24
p3/#Point._STA	3
p3/#Point._EXT	
p3/#Point.X	
p3/#Point.Y	

Test4() - Code

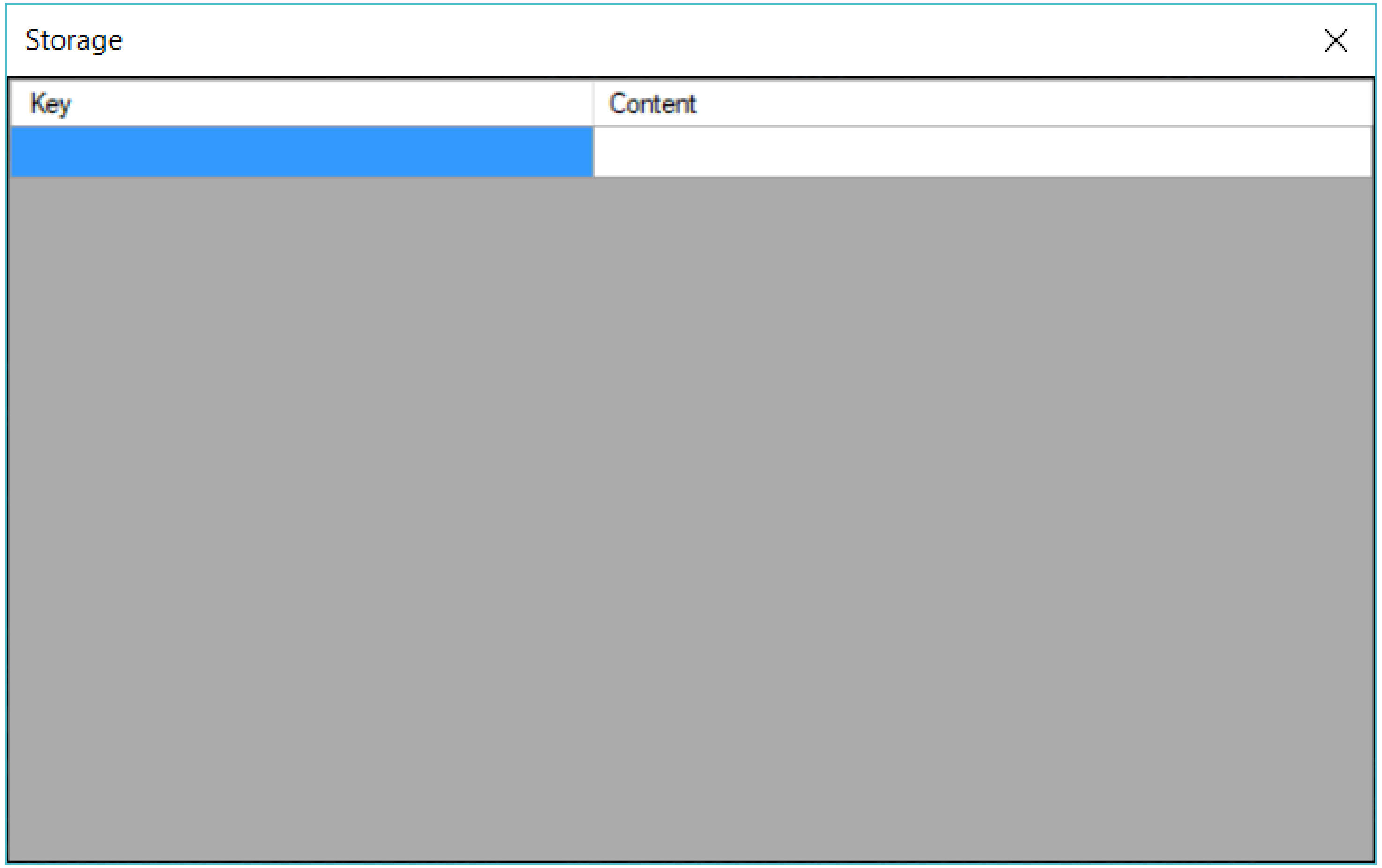
```
public static string test4(object[] args)
{
    string msg = "success";

    NeoTrace.Trace("Empty key test...");
    Point nullkeyp = Point.Get("");
    Point.Log("nullkey", nullkeyp);
    NeoTrace.Trace("nullkeyp null?", Point.IsNull(nullkeyp));
    NeoTrace.Trace("nullkeyp missing?", Point.IsMissing(nullkeyp));
    NeoTrace.Trace("nullkeyp extended?", Point.IsExtended(nullkeyp));

    NeoTrace.Trace("Missing key test...");
    Point missingp = Point.Get("missingp");
    Point.Log("missingp", missingp);
    NeoTrace.Trace("missingp null?", Point.IsNull(missingp));
    NeoTrace.Trace("missingp missing?", Point.IsMissing(missingp));
    NeoTrace.Trace("missingp extended?", Point.IsExtended(missingp));

    return msg;
}
```

Test4() – neo-gui Event Log



Time	Block	Script Hash	Name	Type	Message
2018-02-2...	1010	0x7074acf3f06dd3...	a	Notify	nullkeyp missing? / (BOOL5) False
2018-02-2...	1010	0x7074acf3f06dd3...	a	Notify	nullkeyp extended? / (BOOL5) False
2018-02-2...	1010	0x7074acf3f06dd3...	a	Notify	Missing key test...
2018-02-2...	1010	0x7074acf3f06dd3...	a	Notify	Get(ks).bs / (BINT1) 0 / (BIN0) [binary]
2018-02-2...	1010	0x7074acf3f06dd3...	a	Notify	Missing().p / (BIN0) [binary] / (BIN0) [binary] / (BINT1) 5 / (BIN0) [binary]
2018-02-2...	1010	0x7074acf3f06dd3...	a	Notify	Get(ks).p / (BIN0) [binary] / (BIN0) [binary] / (BINT1) 5 / (BIN0) [binary]
2018-02-2...	1010	0x7074acf3f06dd3...	a	Notify	missingp / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1010	0x7074acf3f06dd3...	a	Notify	missingp null? / (BOOL5) False
2018-02-2...	1010	0x7074acf3f06dd3...	a	Notify	missingp missing? / (BOOL4) True
2018-02-2...	1010	0x7074acf3f06dd3...	a	Notify	missingp extended? / (BOOL5) False
2018-02-2...	1010	0x7074acf3f06dd3...	a	Notify	--
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	===
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	NPCdApp - NEO Persistable Class (NPC) Framework
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	NPCdApp - Version 0.1 Reference Implementation
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	--
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	operation / (STR5) 7465737434 'test4' /
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	===
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	Empty key test...
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	_Initialize(p).p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	Null().p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	nullkey / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	nullkeyp null? / (BOOL4) True
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	nullkeyp missing? / (BOOL5) False
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	nullkeyp extended? / (BOOL5) False
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	Missing key test...
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	Get(ks).bs / (BINT1) 0 / (BIN0) [binary]
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	Missing().p / (BIN0) [binary] / (BIN0) [binary] / (BINT1) 5 / (BIN0) [binary]
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	Get(ks).p / (BIN0) [binary] / (BIN0) [binary] / (BINT1) 5 / (BIN0) [binary]
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	missingp / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	missingp null? / (BOOL5) False
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	missingp missing? / (BOOL4) True
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	missingp extended? / (BOOL5) False
2018-02-2...	1011	0x7074acf3f06dd3...	a	Notify	--

Test4() – neo-debugger Storage Viewer



Test5() - Code

```
public static string test5(object[] args)
{
    string msg = "success";

    NeoTrace.Trace("Test NeoStorageKeys...");
    Point p4 = Point.New();
    Point.Set(p4, 10, 20);
    Point.Log("p4", p4);

    string app = "FooBar";
    byte[] user = WIF2AccountAddressScriptHash;
    NeoVersionedAppUser vau = NeoVersionedAppUser.New(app, 1, 0, 2034, user);
    NeoVersionedAppUser.Log("test5.vau", vau);

    int index = 24;
    NeoTrace.Trace("index", index);
    Point.PutElement(p4, vau, index);
    index = 25;
    NeoTrace.Trace("index", index);
    Point.PutElement(p4, vau, index);

    index = 24;
    Point p4get = Point.GetElement(vau, index);
    Point.LogExt("p4get", p4get);

    Point p4bury1 = Point.BuryElement(vau, index);
    Point.LogExt("p4bury1", p4bury1);
    Point p4bury2 = Point.GetElement(vau, index);
    Point.LogExt("p4bury2", p4bury2);

    return msg;
}
```

Test5() – neo-gui Event Log

neo-gui - ChainDockerPrivateNet2

Wallet Transaction Advanced Help

Account Asset Transaction History Event Log

Time	Block	Script Hash	Name	Type	Message
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	==
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	NPCdApp - NEO Persistable Class (NPC) Framework
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	NPCdApp - Version 0.1 Reference Implementation
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	--
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	operation / (STR5) 7465737435 'test5' /
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	==
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	Test NeoStorageKeys...
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	_Initialize(p).p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	New().p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	p4 / (BINT2) 10 / (STR1) 14 '□'
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	New(a,m,m,b,u).vau / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (ADHASH20) 23ba2703c53263e8d6e522dc32203339dcd8eee9 [binary] / (BINT1) 1
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	test5.vau / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (ADHASH20) 23ba2703c53263e8d6e522dc32203339dcd8eee9 [binary]
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	index / (STR1) 18 '□'
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	New(vau,cs).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (ADHASH20) 23ba2703c
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk,i,fb).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (ADHASH20) 23b
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk).bkey$BSK / ($BSK80) {a:□=FooBar;M: =□;m: =;b: =?□;u:□=#?'□?2c???"?2 39????;c:□=Point;i: :□;f:□:_STA}
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk,i,fb).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (ADHASH20) 23b
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk).bkey$BSK / ($BSK80) {a:□=FooBar;M: =□;m: =;b: =?□;u:□=#?'□?2c???"?2 39????;c:□=Point;i: :□;f:□:_EXT}
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk,i,fb).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (ADHASH20) 23b
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk).bkey$BSK / ($BSK77) {a:□=FooBar;M: =□;m: =;b: =?□;u:□=#?'□?2c???"?2 39????;c:□=Point;i: :□;f:□:X}
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk,i,fb).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (ADHASH20) 23b
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk).bkey$BSK / ($BSK77) {a:□=FooBar;M: =□;m: =;b: =?□;u:□=#?'□?2c???"?2 39????;c:□=Point;i: :□;f:□:Y}
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	PutElement(vau,i).p / (BINT2) 10 / (STR1) 14 '□' / (BINT1) 3 / (BIN0) [binary]
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	index / (STR1) 19 '□'
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	New(vau,cs).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (ADHASH20) 23ba2703c
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk,i,fb).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (ADHASH20) 23b
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk).bkey$BSK / ($BSK80) {a:□=FooBar;M: =□;m: =;b: =?□;u:□=#?'□?2c???"?2 39????;c:□=Point;i: :□;f:□:_STA}
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk,i,fb).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (ADHASH20) 23b
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk).bkey$BSK / ($BSK80) {a:□=FooBar;M: =□;m: =;b: =?□;u:□=#?'□?2c???"?2 39????;c:□=Point;i: :□;f:□:_EXT}
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk,i,fb).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (ADHASH20) 23b
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk).bkey$BSK / ($BSK77) {a:□=FooBar;M: =□;m: =;b: =?□;u:□=#?'□?2c???"?2 39????;c:□=Point;i: :□;f:□:X}
2018-02-2...	1016	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk,i,fb).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (ADHASH20) 23b

Height: 1028/1028/1028 Connected: 2

Waiting for next block:

Test5() – neo-debugger Storage Viewer

Storage

Key	Content
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=24;c:7=_STA;}	6
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=24;c:7=_EXT;}	
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=24;c:7=X;}	
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=24;c:7=Y;}	
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=25;c:7=_STA;}	3
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=25;c:7=_EXT;}	
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=25;c:7=X;}	
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=25;c:7=Y;}	20

Test6() - Code

```
public static string test6(object[] args)
{
    string msg = "success";
    int maxIterations = 10;
    if (args.Length > 0)
    {
        maxIterations = (int)((byte[])args[0]).AsBigInteger();
        NeoTrace.Trace("maxIterations", maxIterations);
    }
    if (maxIterations <= 0) maxIterations = 10;
    if (maxIterations > 20) maxIterations = 10;
    NeoTrace.Trace("maxIterations", maxIterations);

    byte[] callingUserScriptHash = ExecutionEngine.CallingScriptHash;
    NeoTrace.Trace("callingUserScriptHash", callingUserScriptHash);
    byte[] entryUserScriptHash = ExecutionEngine.EntryScriptHash;
    NeoTrace.Trace("entryUserScriptHash", entryUserScriptHash);
    byte[] executingUserScriptHash = ExecutionEngine.ExecutingScriptHash;
    NeoTrace.Trace("executingUserScriptHash", executingUserScriptHash);
    byte[] invokingUserScriptHash = GetInvokingUserScriptHash();
    NeoTrace.Trace("invokingUserScriptHash", invokingUserScriptHash.Length, invokingUserScriptHash);
    if (invokingUserScriptHash.Length == 0) invokingUserScriptHash = WIF2AccountAddressScriptHash;
    NeoTrace.Trace("invokingUserScriptHash", invokingUserScriptHash);

    Point p4 = Point.New();
    Point.Set(p4, 10, 20);
    Point.Log("p4", p4);
```

Test6() - Code (con't)

```
    string app = "FooBar";
    NeoVersionedAppUser vau = NeoVersionedAppUser.New(app, 1, 0, 2034, invokingUserScriptHash);
    NeoVersionedAppUser.Log("test6.vau", vau);

    int iteration = 0;
    for (int index = 30; index < 40; index++)
    {
        NeoTrace.Trace("index", index);
        Point.Set(p4, index, -index);
        Point.PutElement(p4, vau, index);
        iteration++;
        if (iteration > maxIterations) break;
    }

    iteration = 0;
    for (int index = 30; index < 40; index++)
    {
        Point.Set(p4, index, -index);
        Point x = Point.GetElement(vau, index);
        Point.Log("loop.x", x);
        if (Point.GetX(p4) != index || Point.GetY(p4) != -index)
        {
            msg = ">>>>(x,y) are different";
            NeoTrace.Trace(msg);
            break;
        }
        iteration++;
        if (iteration > maxIterations) break;
    }

    return msg;
}
```

Test6() – neo-gui Event Log

neo-gui - ChainDockerPrivateNet2

Wallet Transaction Advanced Help

Account Asset Transaction History Event Log

Time	Block	Script Hash	Name	Type	Message
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	==
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	NPCdApp - NEO Persistable Class (NPC) Framework
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	NPCdApp - Version 0.1 Reference Implementation
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	--
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	operation / (STR5) 7465737436 'test6' /
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	==
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	maxIterations / (BINT1) 5
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	callingUserScriptHash / (ADHASH20) bc7eb0045b1cf6eb5310e156f4d36df0f3ac7470 [binary]
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	entryUserScriptHash / (ADHASH20) 4fe55ee9a25bf0c59f0116cee34fcdb6969aebb4 [binary]
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	executingUserScriptHash / (ADHASH20) bc7eb0045b1cf6eb5310e156f4d36df0f3ac7470 [binary]
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	invokingUserScriptHash / (BIN0) [binary]
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	_Initialize(p).p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	New().p / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary]
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	p4 / (BINT2) 10 / (STR1) 14 '□'
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	New(a,m,m,b,u).vau / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (BIN0) [binary] / (BINT1) 1
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	test6.vau / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (BIN0) [binary]
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	New(vau,cs).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BINT1
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk,i,fb).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] ,
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk).bkey$BSK / ($BSK60) {a:□=FooBar;M: =□;m: =;b: =?□;u:□=;c:□=Point;i: :;f:□:_STA}
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk,i,fb).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] ,
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk).bkey$BSK / ($BSK60) {a:□=FooBar;M: =□;m: =;b: =?□;u:□=;c:□=Point;i: :;f:□:_EXT}
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk,i,fb).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] ,
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk).bkey$BSK / ($BSK57) {a:□=FooBar;M: =□;m: =;b: =?□;u:□=;c:□=Point;i: :;f:□:X}
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk,i,fb).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] ,
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk).bkey$BSK / ($BSK57) {a:□=FooBar;M: =□;m: =;b: =?□;u:□=;c:□=Point;i: :;f:□:Y}
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	PutElement(vau,i).p / (STR1) 1e '' / (BINT3) -30 / (BINT1) 3 / (BIN0) [binary]
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	New(vau,cs).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] / (BINT1
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk,i,fb).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] ,
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk).bkey$BSK / ($BSK60) {a:□=FooBar;M: =□;m: =;b: =?□;u:□=;c:□=Point;i: :;f:□:_STA}
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk,i,fb).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] ,
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk).bkey$BSK / ($BSK60) {a:□=FooBar;M: =□;m: =;b: =?□;u:□=;c:□=Point;i: :;f:□:_EXT}
2018-02-2...	1021	0x7074acf3f06dd3...	a	Notify	StorageKey(nsk,i,fb).nsk / (STR6) 466f6f426172 'FooBar' / (BINT1) 1 / (BIN0) [binary] / (STR2) f207 '?□' / (STR5) 506f696e74 'Point' / (BIN0) [binary] / (BIN0) [binary] / (BIN0) [binary] ,

Height: 1023/1023/1023 Connected: 2

Waiting for next block:

Test6() – neo-debugger Storage Viewer

Storage

Key	Content
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=30;c:7=_STA;}	3
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=30;c:7=_EXT;}	
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=30;c:7=X;}	30
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=30;c:7=Y;}	?
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=31;c:7=_STA;}	3
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=31;c:7=_EXT;}	
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=31;c:7=X;}	31
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=31;c:7=Y;}	?
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=32;c:7=_STA;}	3
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=32;c:7=_EXT;}	
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=32;c:7=X;}	
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=32;c:7=Y;}	?
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=33;c:7=_STA;}	3
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=33;c:7=_EXT;}	
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=33;c:7=X;}	!
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=33;c:7=Y;}	?
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=34;c:7=_STA;}	3
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=34;c:7=_EXT;}	
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=34;c:7=X;}	"
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=34;c:7=Y;}	?
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=35;c:7=_STA;}	3
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=35;c:7=_EXT;}	
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=35;c:7=X;}	#
{a:7=FooBar;M:2=1;m:2=0;b:2=2034;u:5=23-BA-27-03-C5-32-63-E8-D6-E5-22-DC-32-20-33-39-DC-D8-EE-E9;c:7=Point;i:2=35;c:7=Y;}	?

8. Roadmap

8. Roadmap

- Automatic Code Generation
  - In NPC 1.0, Point() was handcoded for each NPC Level but with an eye to being automatically generated in the future
- Add support for Storage.Delete()
  - Simply overlooked in NPC 1.0
- Level 5 Extendible
  - Support entity extension capabilities for existing entities living in deployed smart contracts
- Level 6 Authorized
  - Support for to support authenticated and role-based authorization to entities you create (and others create)
- Level 7 Optimized
  - Key space optimizations starting with NeoStorageKey compression

Roadmap: Automatic Code Generation

- NPC Compiler (npcc.exe)
- Compile .cs file something like the following into a DLL
- Then pass the DLL plus NPC Level of persistence support you need to npcc.exe and a new expanded .cs file is created.

```
namespace NeoPesistenceClasses0
{
    public class Point /* Level 0 - Basic */
    {
        private BigInteger _x;
        private BigInteger _y;
    }
}
```

- Support for ___npcconfig class for imbedded npcc configuration parameters (e.g. NPC Level)
- Investigate support for partial classes in C#.NEO/C#.NPC

9. Summary

Sidebar: What is this a picture of? https://www.linkedin.com/groups/50758/50758-6372830537052155904

- It’s an architecture for a global NEO blockchain app
- ...the spoons represent Actors in the real world who in turn have personas (Business (and non-Business) Roles).
- The black phone and the red thing are apps (with smart contracts) - deployed on and consumers (Accessing) of the NEO blockchain (Application Software/Functions).
- The Lucite thing is an authenticated identity (Actor) for the Actor spoon on the far side of the table.
- The Sweet'n Low packets are his/her personas (Business/non-Business Roles).

9. Summary

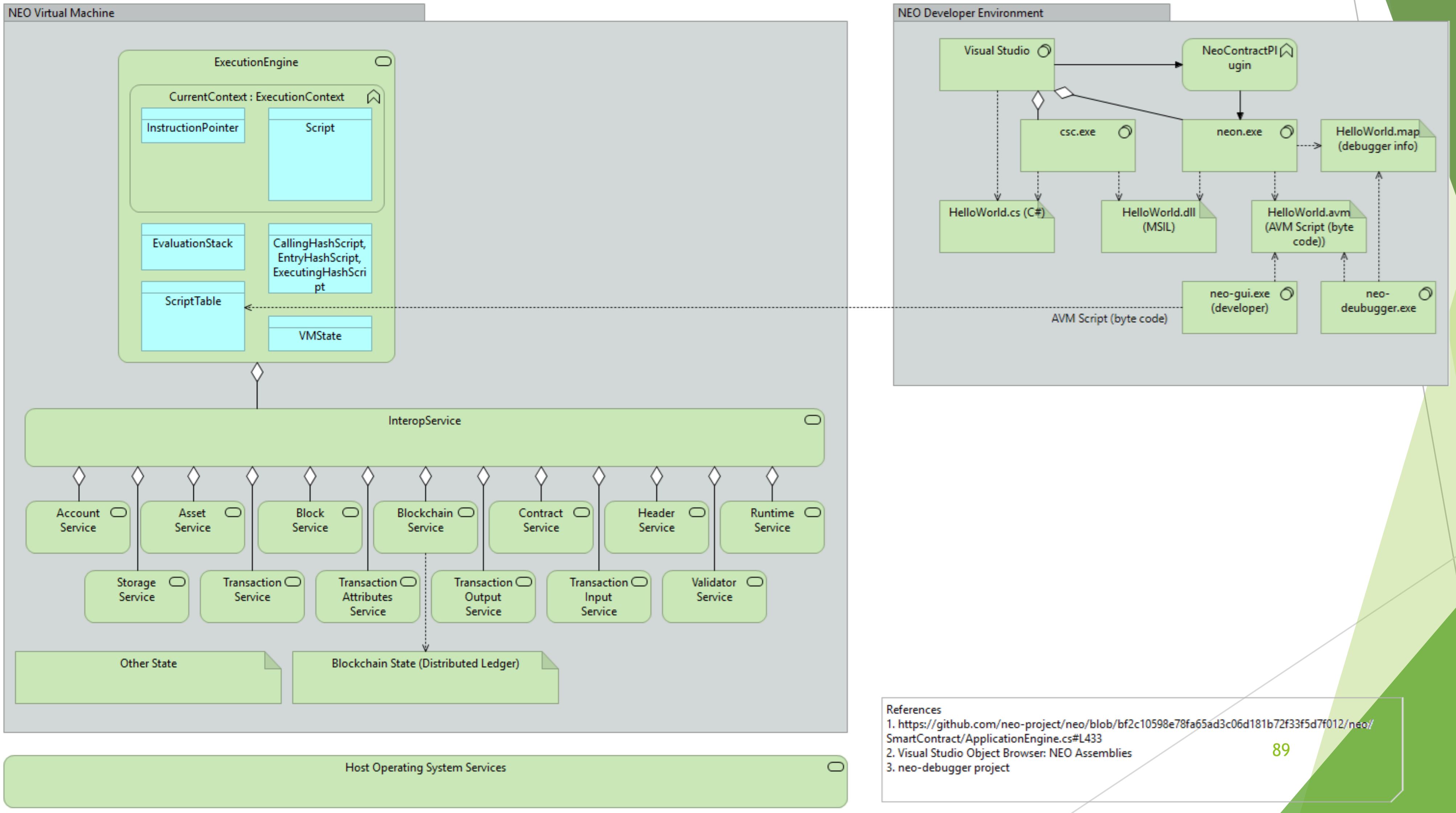
- NPC Level 0 Basic
- NPC Level 1 Managed
- NPC Level 2 Persistable
- NPC Level 3 Deletable (Bury/Tombstone)
- NPC Level 4 Collectible
- NPC Level 5 Extendible (Roadmap)
- NPC Level 6 Authorized (Roadmap)
- NPC Level 6 Optimized (Roadmap

Appendices

Appendix A - NEO Blockchain Architecture Reference Model (ARM)

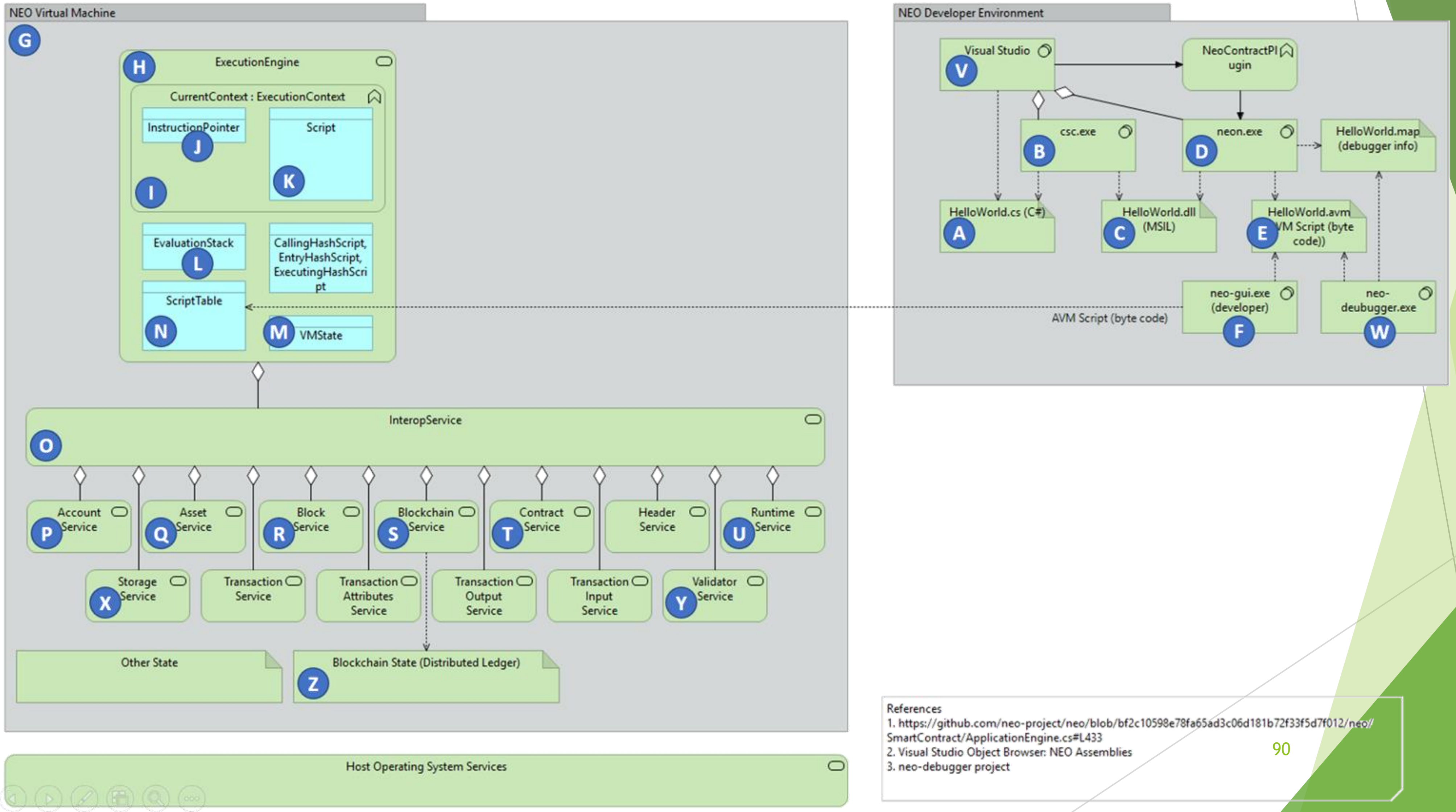
https://github.com/mwherman2000/neo-charm

NEO Blockchain Architecture Reference Model (ARM)



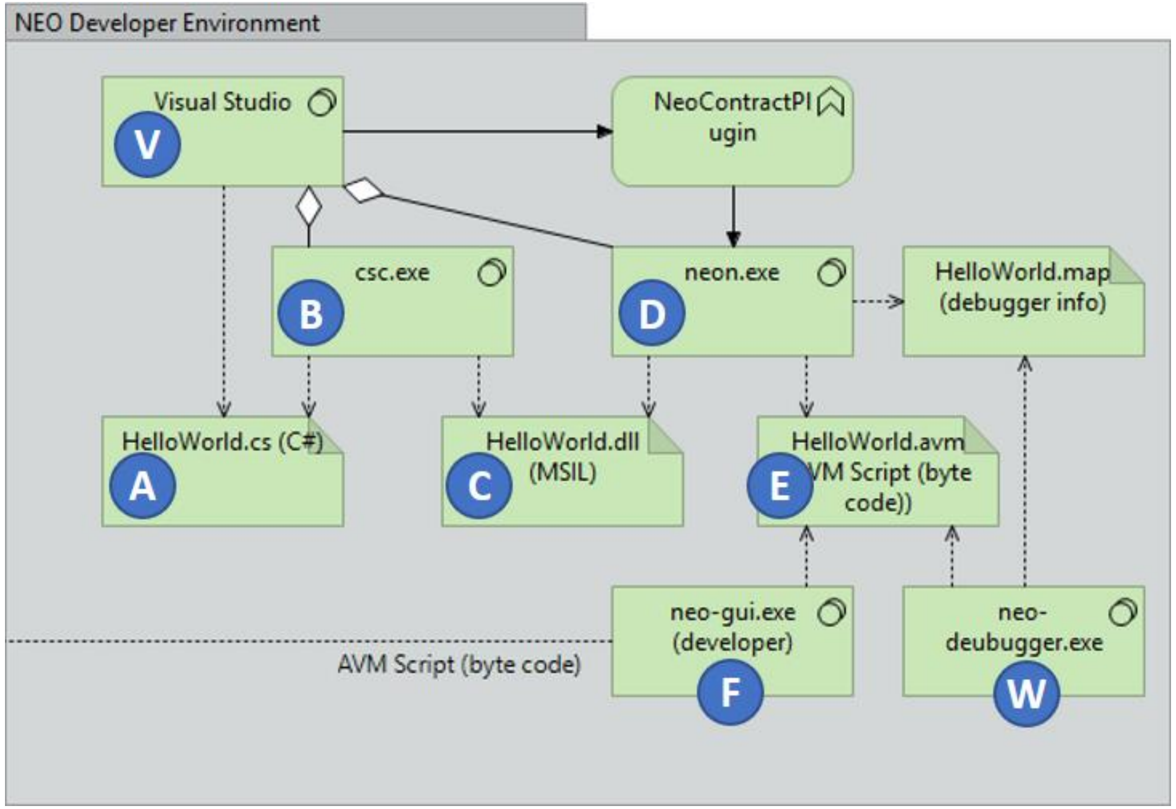
References
1. https://github.com/neo-project/neo/blob/bf2c10598e78fa65ad3c06d181b72f33f5d7f012/neo/SmartContract/ApplicationEngine.cs#L433
2. Visual Studio Object Browser: NEO Assemblies
3. neo-debugger project

NEO Blockchain ARM

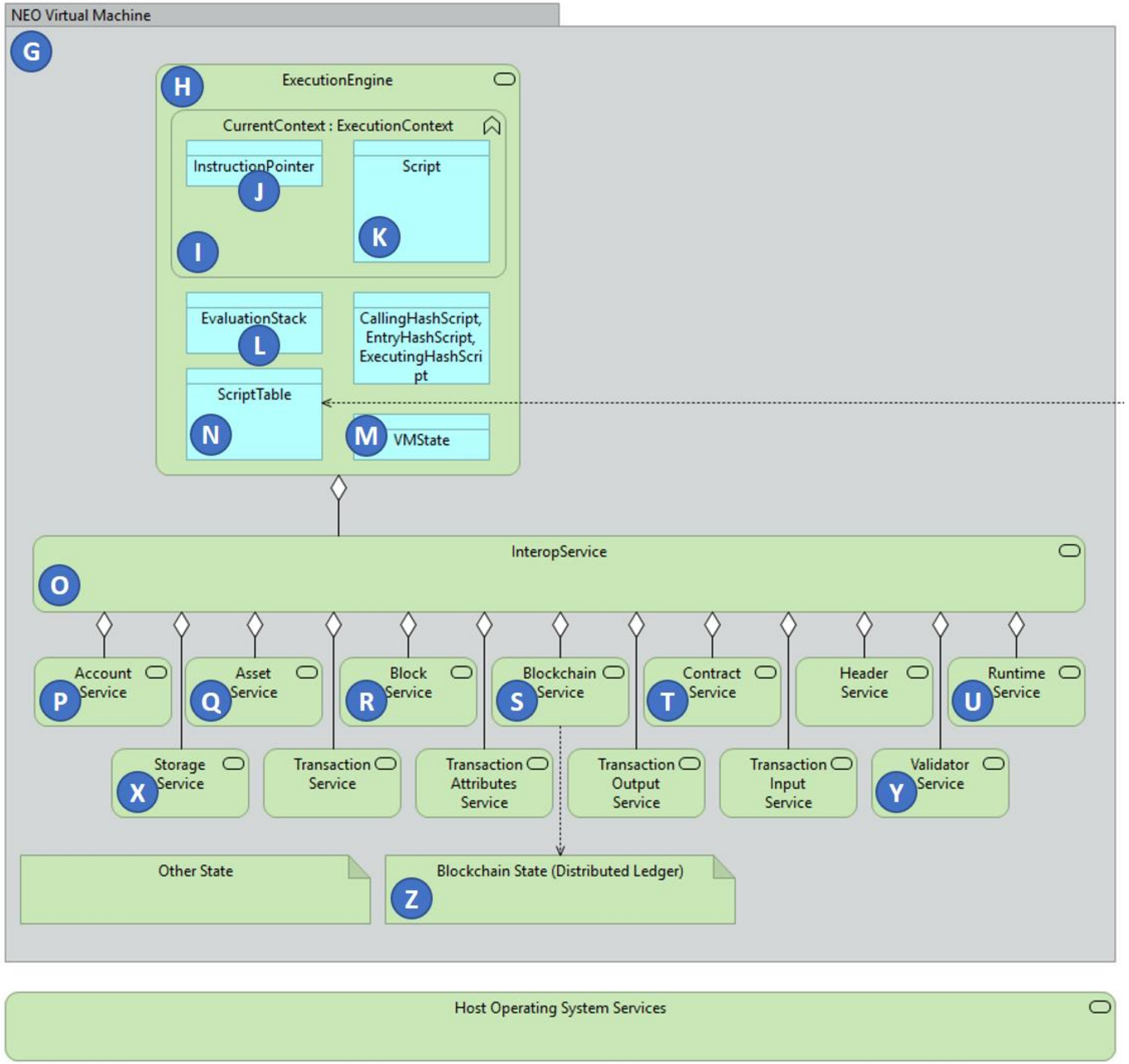


References
1. https://github.com/neo-project/neo/blob/bf2c10598e78fa65ad3c06d181b72f33f5d7f012/neo/SmartContract/ApplicationEngine.cs#L433
2. Visual Studio Object Browser: NEO Assemblies
3. neo-debugger project

NEO Developer Environment



NEO Virtual Machine



Questions?

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