Information Flow Control For Standard OS Abstractions

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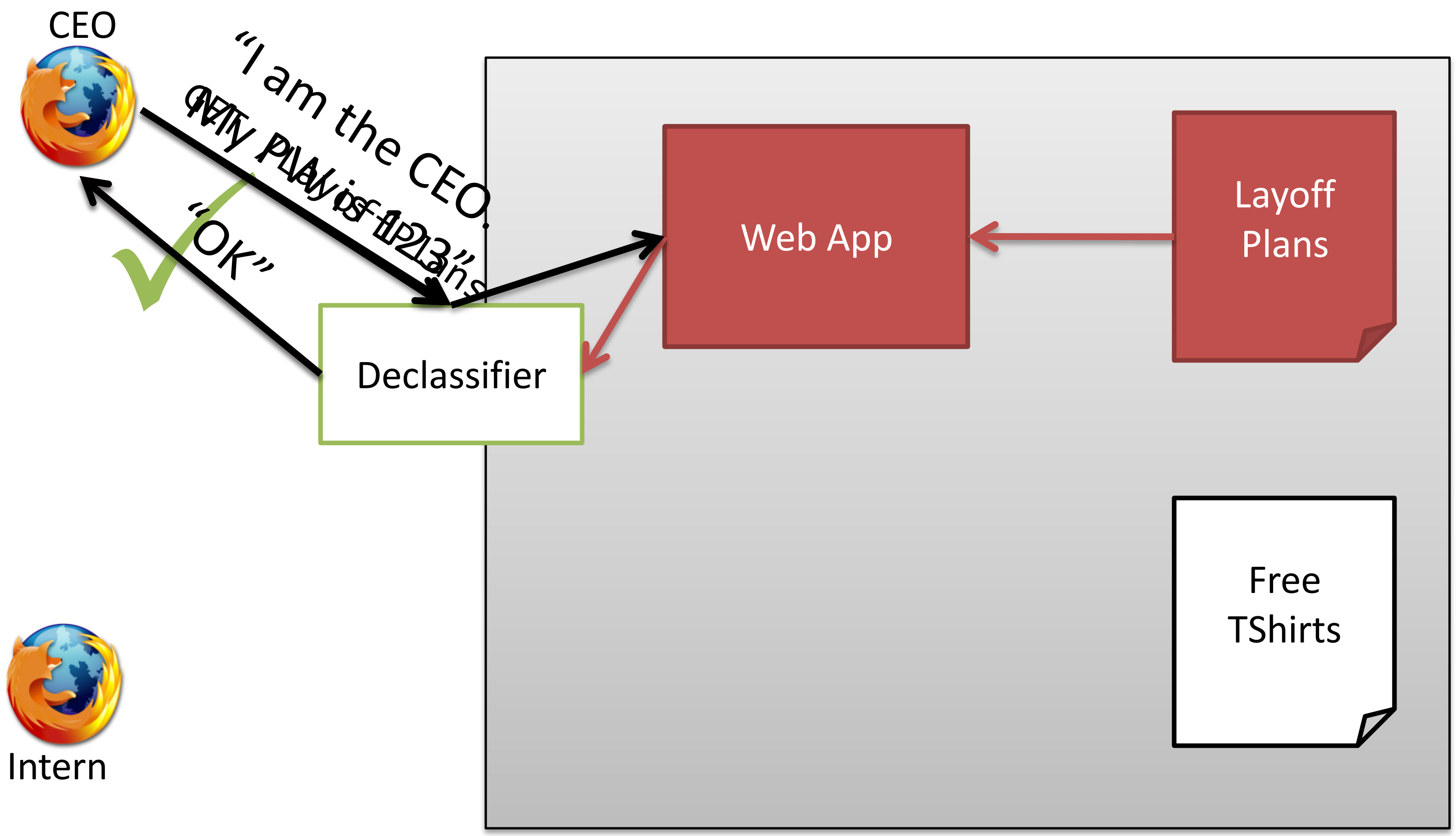
Vulnerabilities in Websites → Exploits

- Web software is buggy
- Attackers find and exploit these bugs
- Data is stolen / Corrupted
  - “USAJobs.gov hit by Monster.com attack, 146,000 people affected”
  - “UN Website is Defaced via SQL Injection”
  - “Payroll Site Closes on Security Worries”
  - “Hacker Accesses Thousands of Personal Data Files at CSU Chico”
  - “FTC Investigates PETCO.com Security Hole”
  - “Major Breach of UCLA’s Computer Files”
  - “Restructured Text Include Directive Does Not Respect ACLs”

Decentralized Information Flow Control (DIFC)



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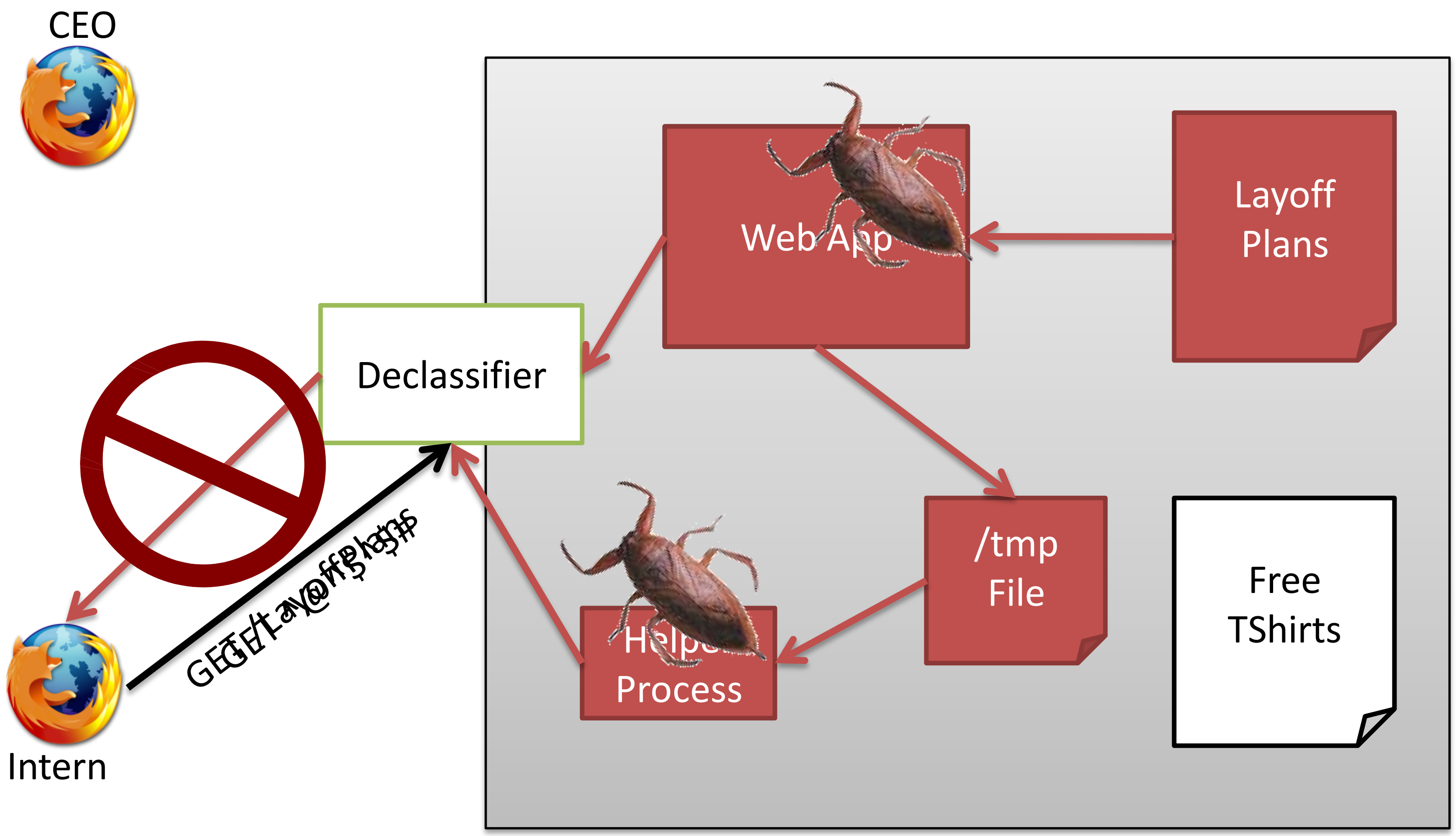
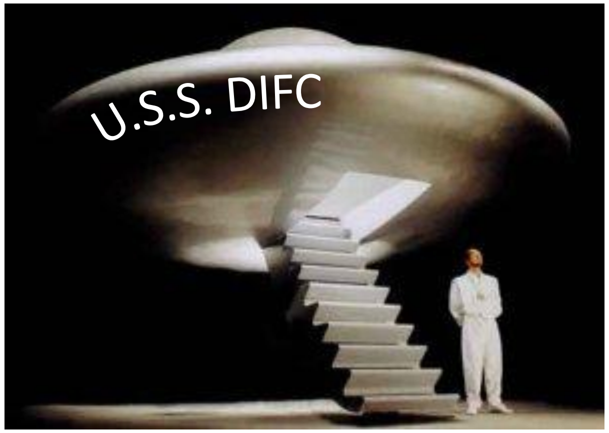
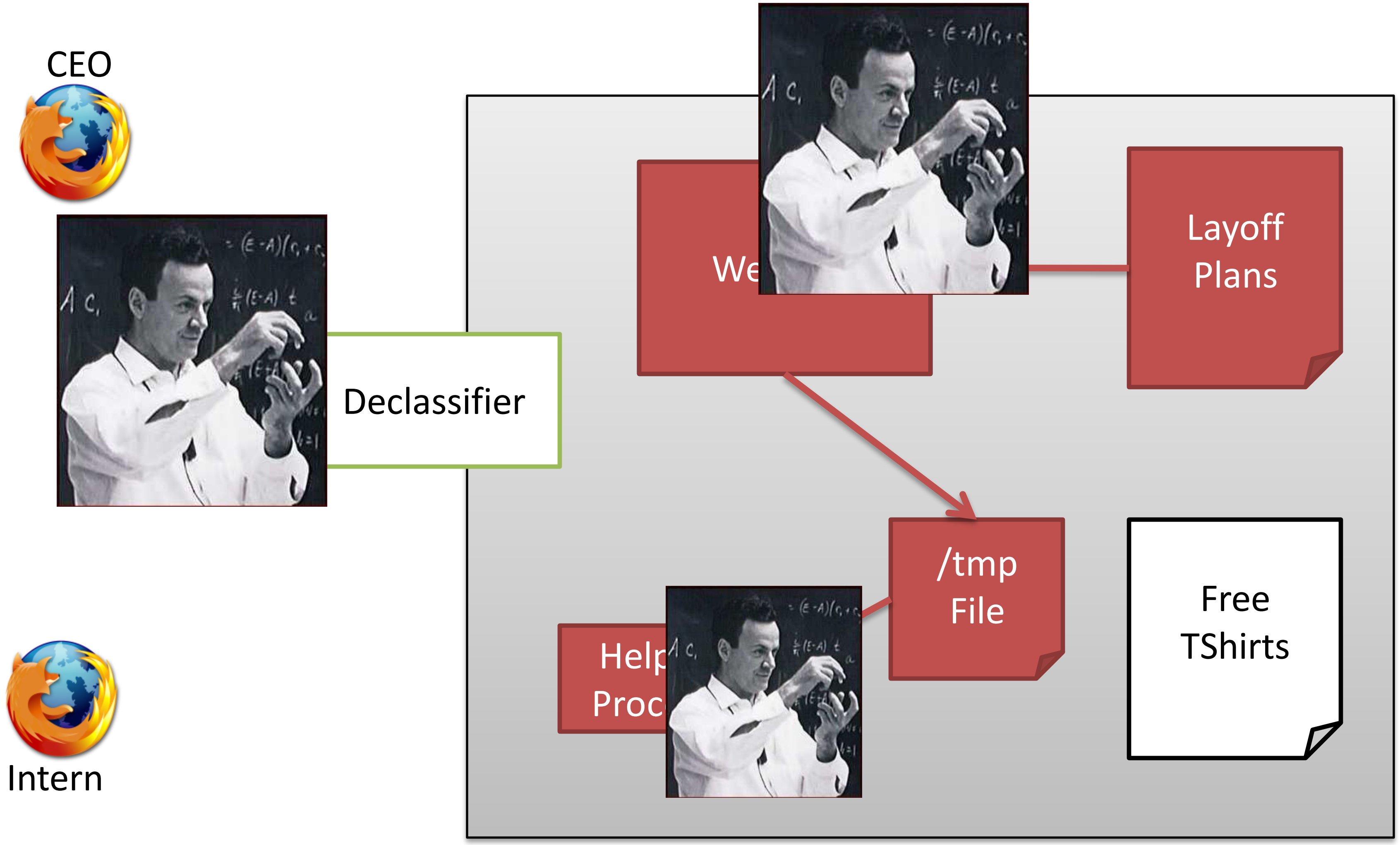


Why is DIFC a cult?



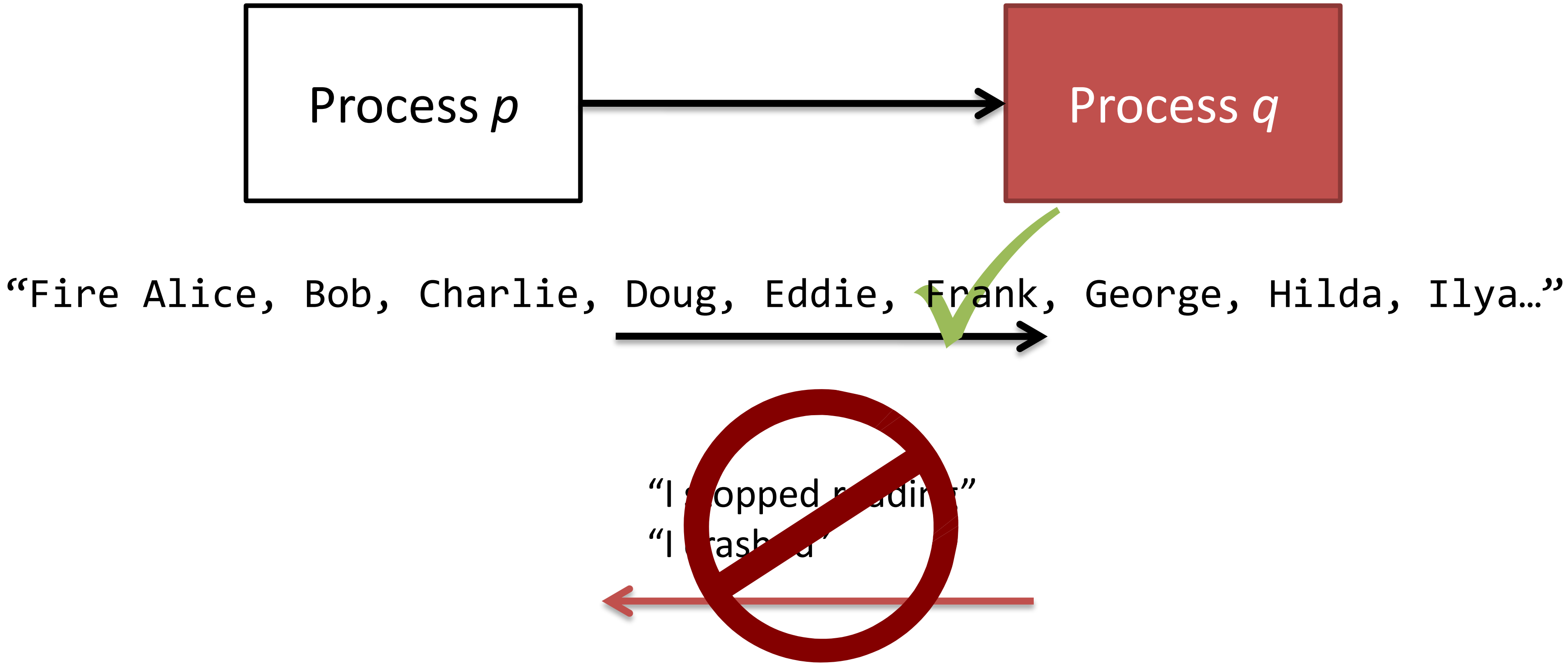
Who Needs to Understand DIFC?



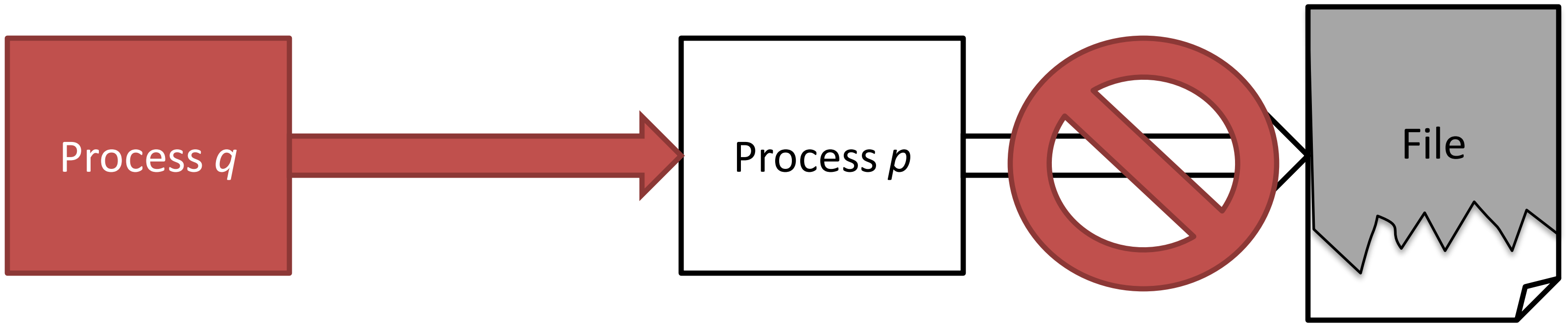
Why is Today's DIFC **DIFfiCult**?

- Label systems are complex
- Unexpected program behavior
- Cannot reuse existing code
  - Drivers, SMP support, standard libraries

Unexpected Program Behavior (Unreliable Communication)


Process *p*
Process *q*
“Fire Alice, Bob, Charlie, Doug, Eddie, Frank, George, Hilda, Ilya…”
“I stopped reading”
“I crashed”

Unexpected Program Behavior (Mysterious Failures)



Solution/Outline

1. Flume: Solves DIFC Problems
   - User-level implementation of DIFC on Linux
   - Simple label system
   - Endpoints: Glue Between Unix API and Labels
2. Application + Evaluation
   - Real Web software secured by Flume

Outline

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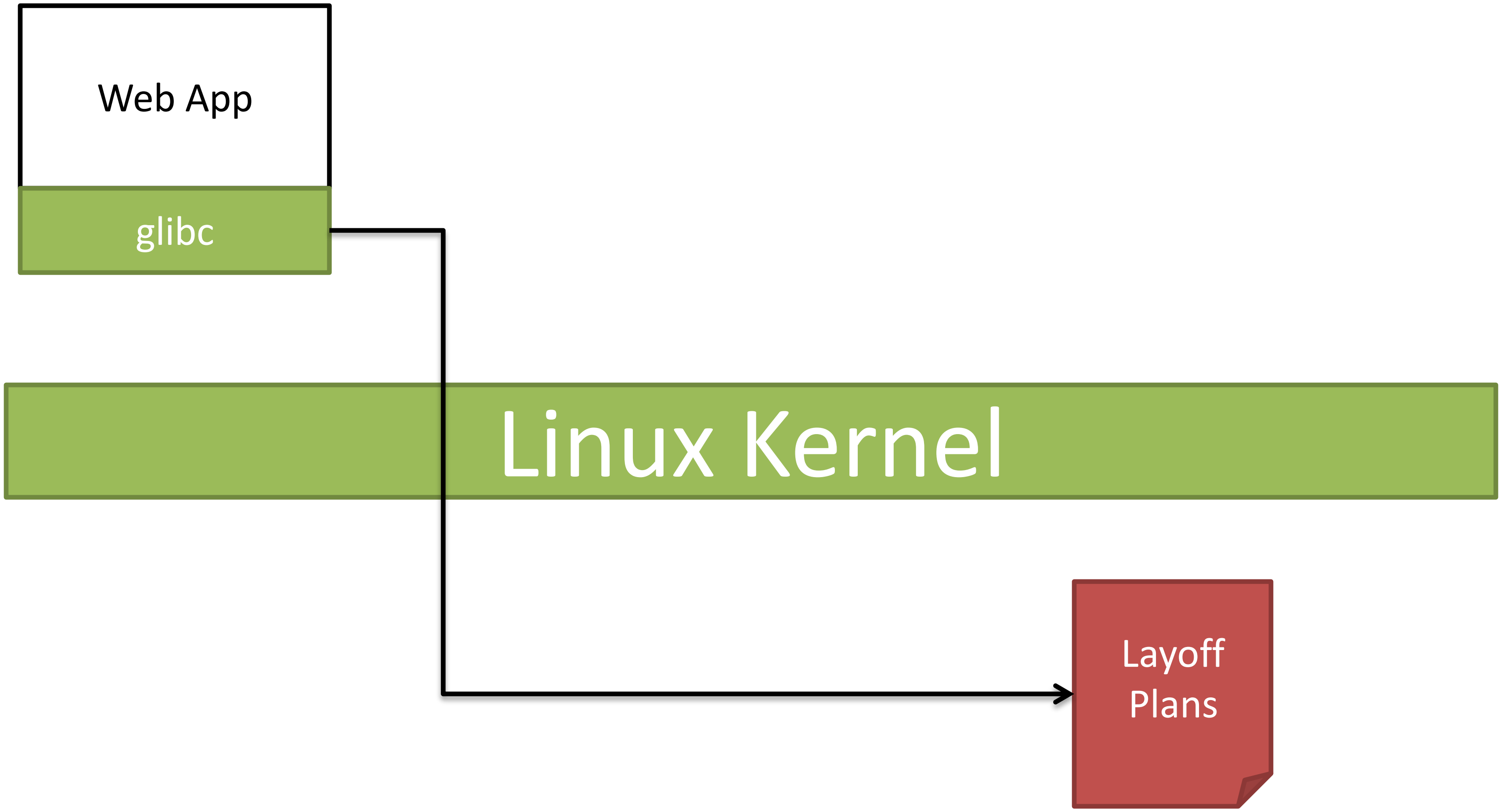
Flume Implementation

- Goal: User-level implementation
  - `apt-get install flume`
- Approach:
  - System Call Delegation [*Ostia* by Garfinkel et al, 2003]
  - Use Linux 2.6 (or OpenBSD 3.9)

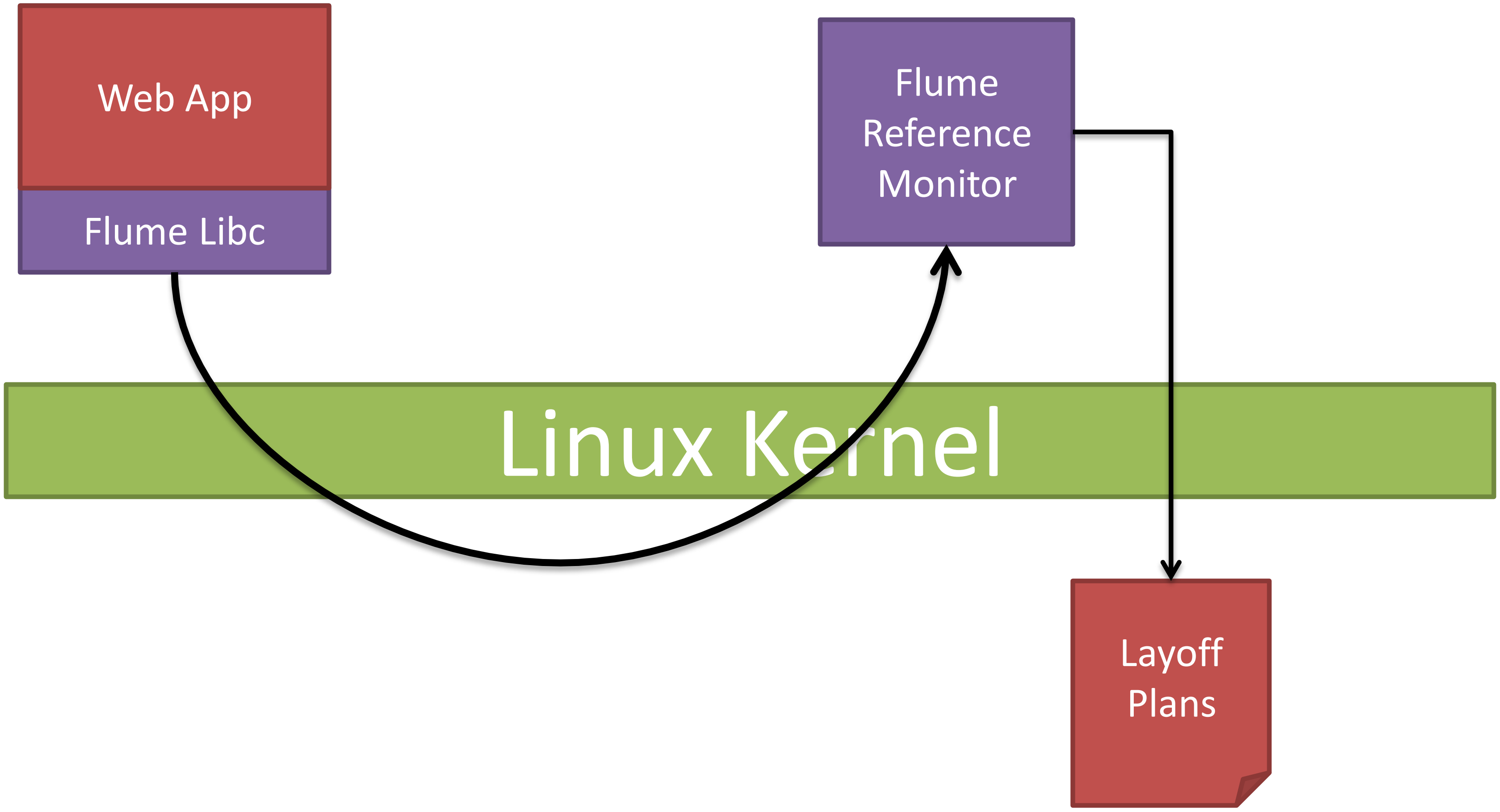
System Call Delegation

```
open("/hr/LayoffPlans", O_RDONLY);
```

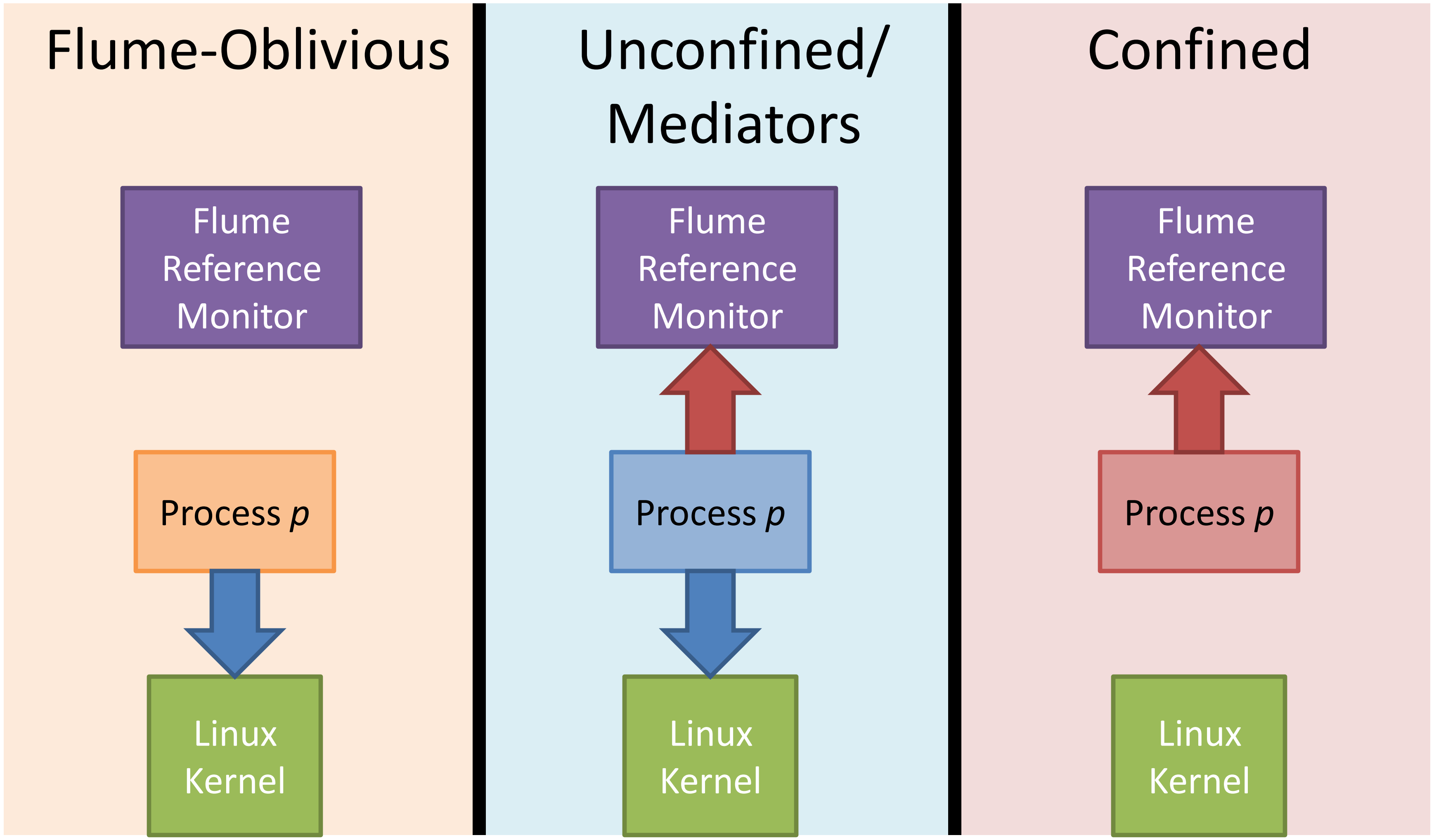


System Call Delegation

```
open("/hr/LayoffPlans", O_RDONLY);
```



Three Classes of Processes



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Information Flow Control (IFC)

- Goal: track which secrets a process has seen
- Mechanism: each process gets a *secrecy label*
  - Label summarizes which categories of data a process is assumed to have s
  - Examples:
    - { “Financial Reports” }
    - { “HR Documents” }
    - { “Financial Reports” *and* “HR Documents” }

“tag”

“label”

Tags + Labels

Process *p*

$S_p = \{ \text{Finance}, \text{HR} \}$

$D_p = \{ \text{HR} \}$

```
change_label({Finance});
tag_t HR = create_tag();
change_l                    R});
change_l
```

Any   cess can add

DIFC Rule: A process can create a new tag; gets ability to declassify it.

in action.

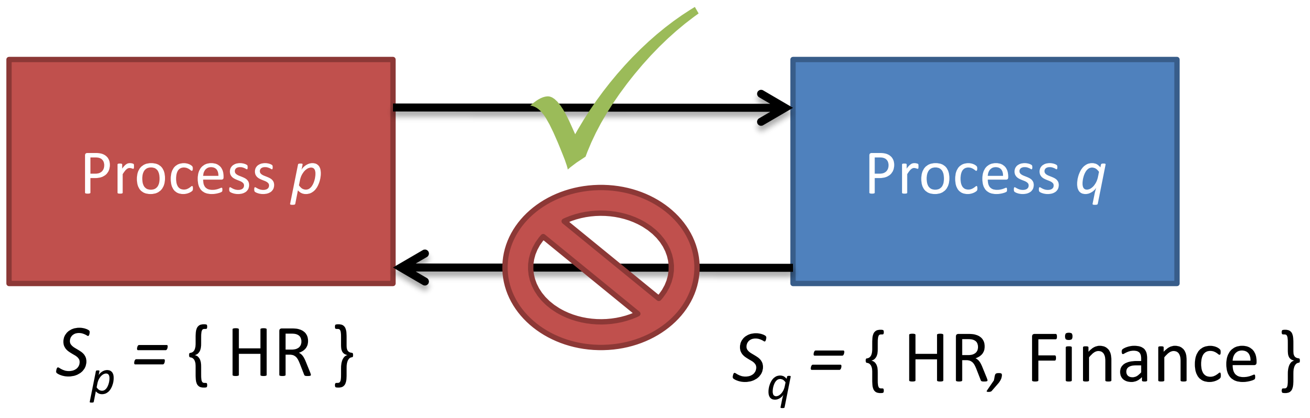
Universe of Tags:

HR

Finance

SecretProjects

Communication Rule



p can send to *q* iff $S_p \subseteq S_q$

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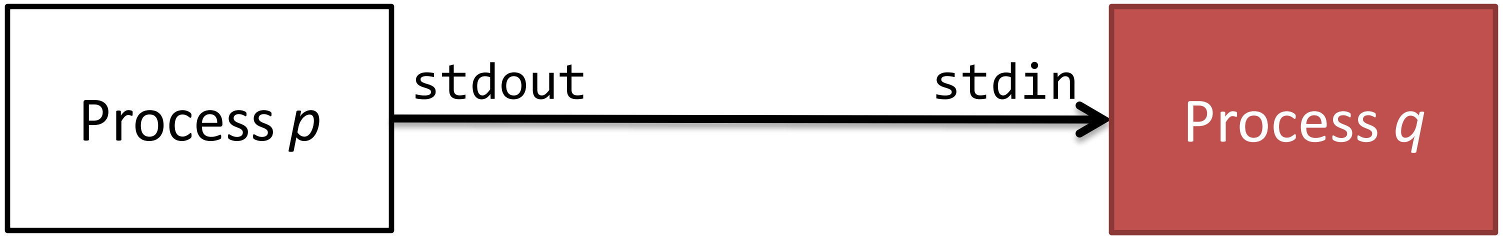
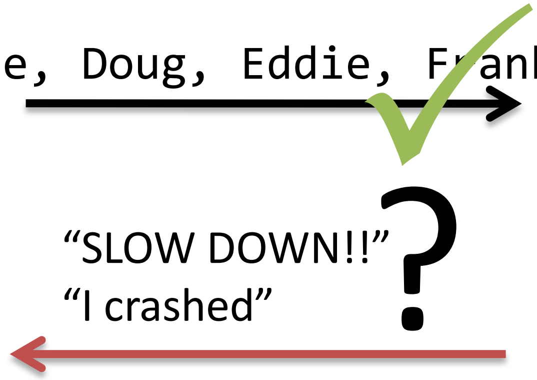
Recall: Communication Problem



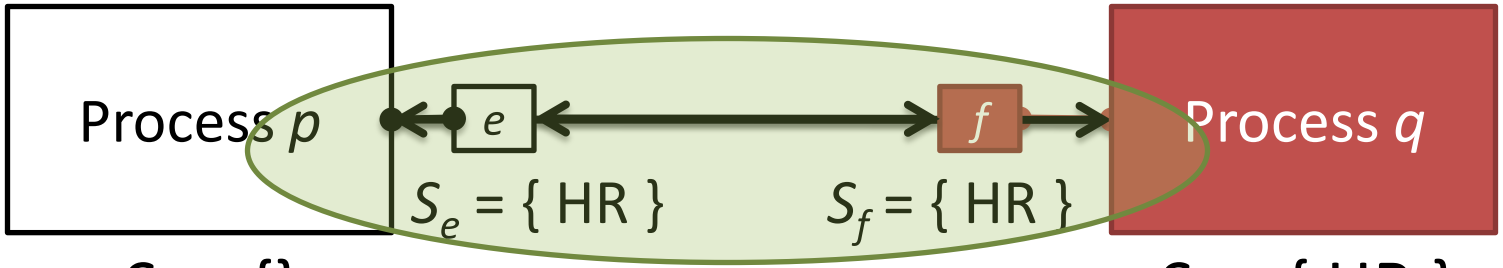
$S_p = \{\}$
$D_p = \{ \text{HR} \}$

$S_q = \{ \text{HR} \}$

`“Fire Alice, Bob, Charlie, Doug, Eddie, Frank, George, Hilda, Ilya…”`



New Abstraction: Endpoints



$S_p = \{\}$

D_p = { HR }

S_q = { HR }

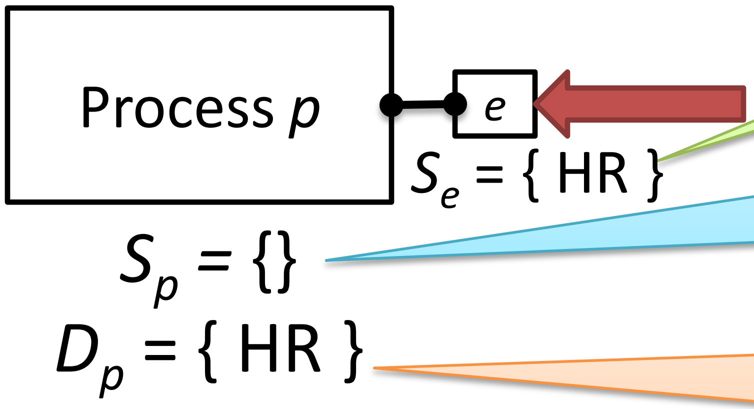
- If $S_e \subseteq S_f$, then allow *e* to send to *f*
- If $S_f \subseteq S_e$, then allow *f* to send to *e*
- If $S_f = S_e$, then allow bidirectional flow

```
“Fire Alice, Bob, Charlie, Doug, Eddie, Frank, George, Hilda, Ilya…”
```

“SLOW DOWN!!”

“I crashed”

Endpoints Declassify Data



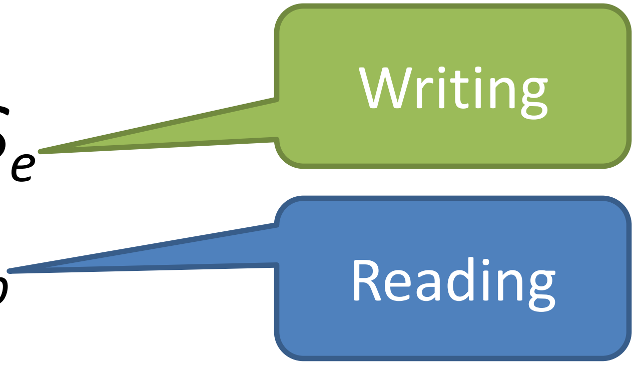
Data enters process p with secrecy { HR }

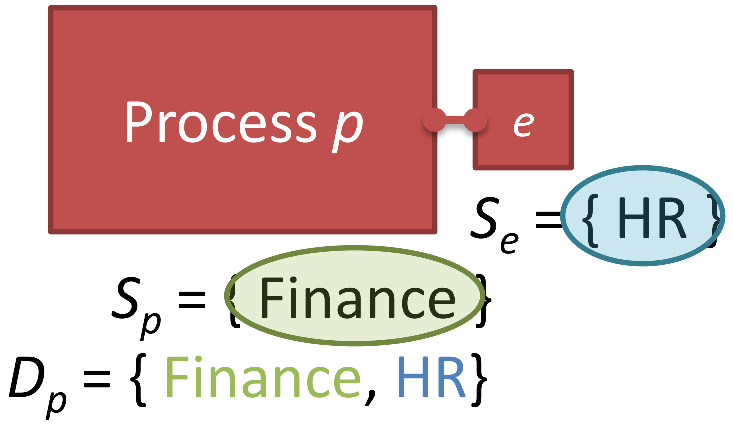
But p keeps its label $S_p = \{\}$

Thus p needs $\text{HR} \in D_p$

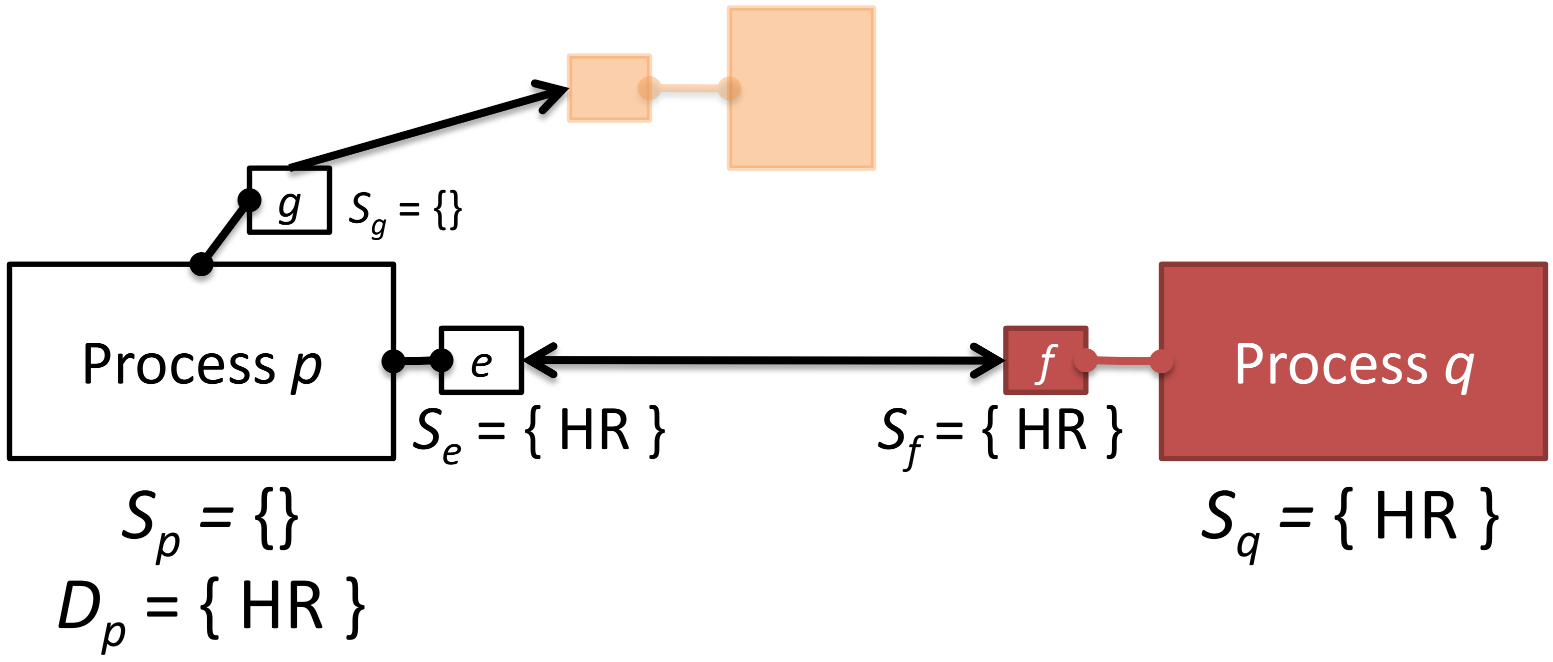
Endpoint Invariant

- For any tag $t \in S_p$ and $t \notin S_e$
- Or any tag $t \in S_e$ and $t \notin S_p$
- It must be that $t \in D_p$

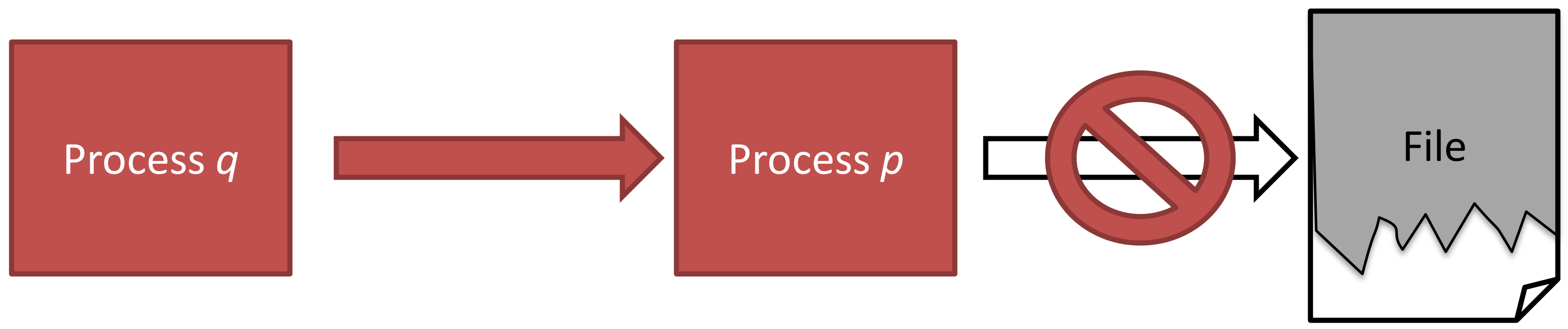




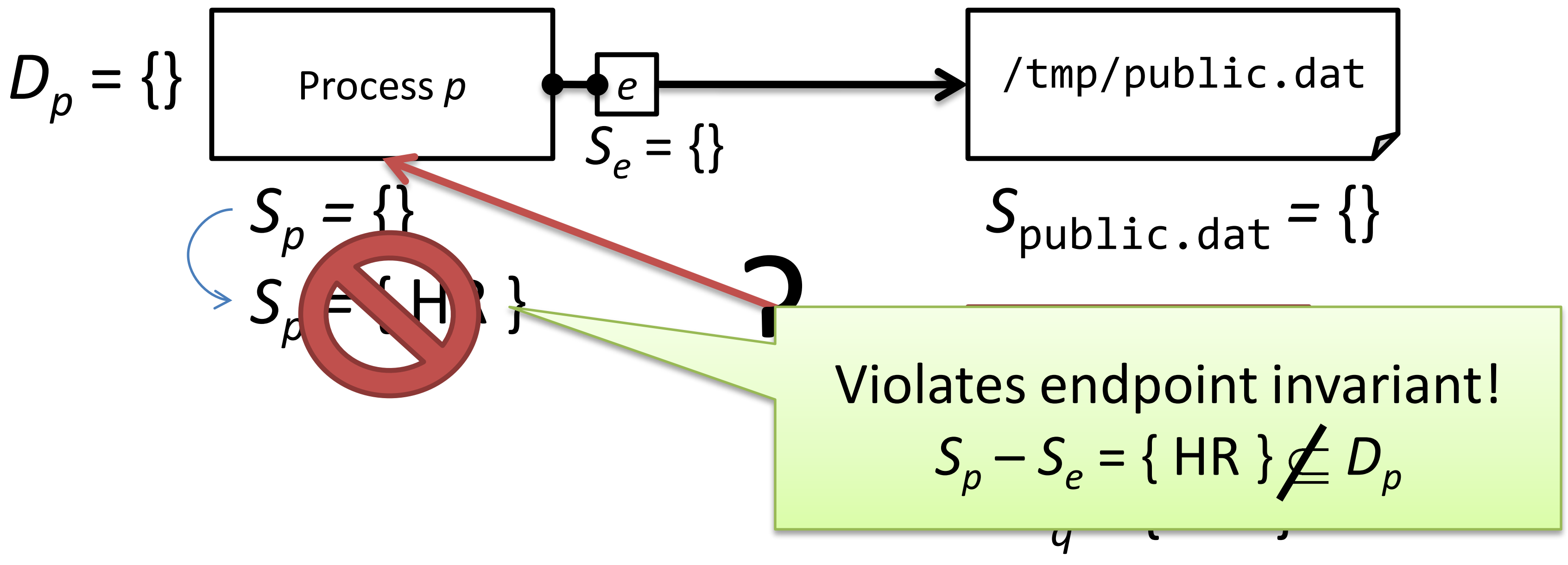
Endpoints Labels Are Independent



Recall: Mysterious Failures



Endpoints Reveal Errors Eagerly

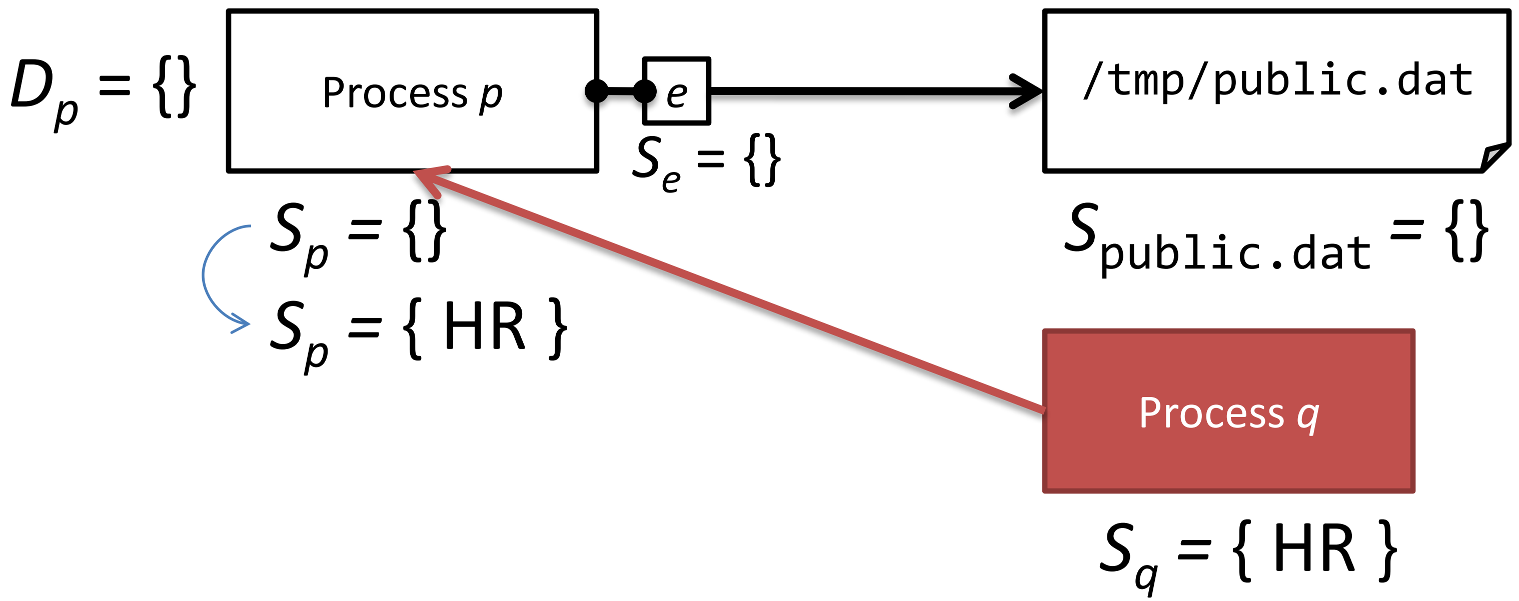


Violates endpoint invariant!

$S_p - S_e = \{ \text{HR} \} \not\sqsubseteq D_p$

```
→open("/tmp/public.dat", O_WRONLY);
→change_label({HR})
```

Endpoints Reveal Errors Eagerly



```
→fd = open("/tmp/public.dat", O_WRONLY);
→close(fd);
→change_label({HR})
```

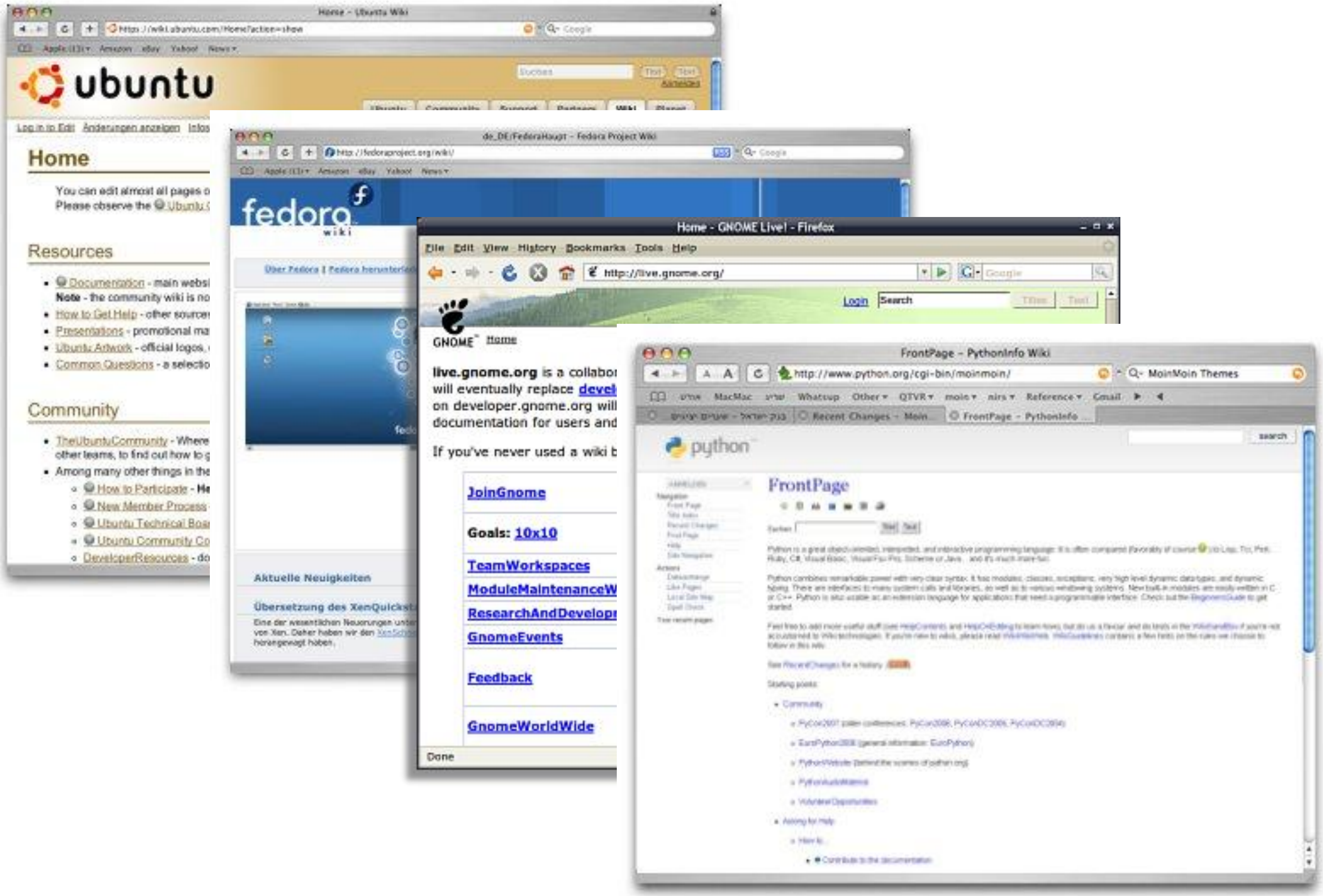
Outline

1. Flume: Solves DIFC Problems
2. Application + Evaluation

Questions for Evaluation

- Does Flume allow adoption of Unix software?
- Does Flume solve security vulnerabilities?
- Does Flume perform reasonably?

Example App: MoinMoin Wiki


Home - Ubuntu Wiki

http://wiki.ubuntu.com/Home?action=show

ubuntu

Home

You can edit almost all pages o
Please observe the Ubuntu C

Resources

- Documentation - main websi
  Note - the community wiki is no
- How to Get Help - other source
- Presentations - promotional ma
- Ubuntu Artwork - official logos,
- Common Questions - a selectio

Community

- TheUbuntuCommunity - Where
  other teams, to find out how to g
- Among many other things in the
  - How to Participate - He
  - New Member Process
  - Ubuntu Technical Boa
  - Ubuntu Community Co
  - DeveloperResources - do

de_DE/FedoraHaupt - Fedora Project Wiki

http://fedoraproject.org/wiki/

fedora wiki

Aktuelle Neuigkeiten

Übersetzung des XenQuickst

Home - GNOME Live! - Firefox

http://live.gnome.org/

GNOME Home

live.gnome.org is a collabor
will eventually replace devel
on developer.gnome.org will
documentation for users and

If you've never used a wiki b

JoinGnome

Goals: 10x10

TeamWorkspaces

ModuleMaintenanceW

ResearchAndDevelop

GnomeEvents

Feedback

GnomeWorldWide

Done

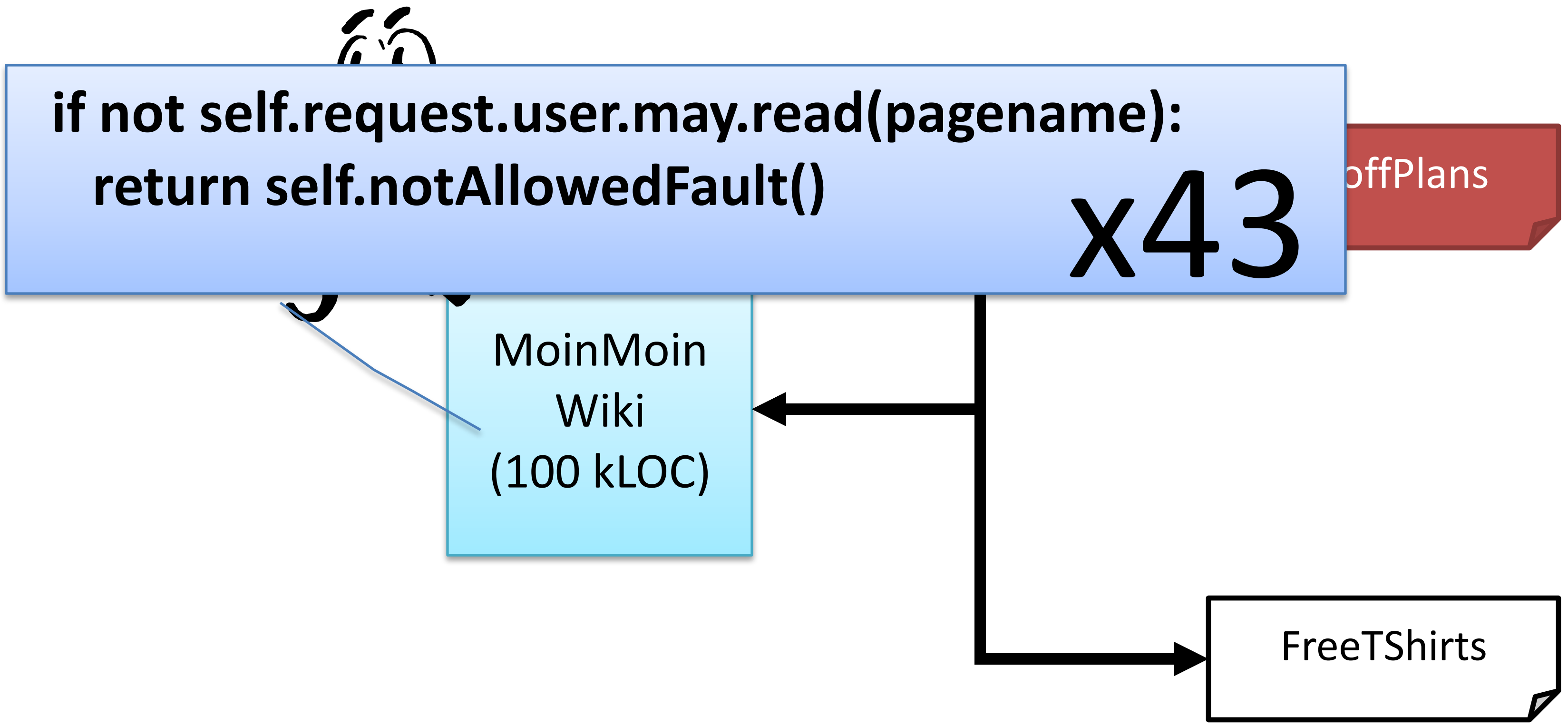
FrontPage - PythonInfo Wiki

http://www.python.org/cgi-bin/moinmoin/

python

FrontPage

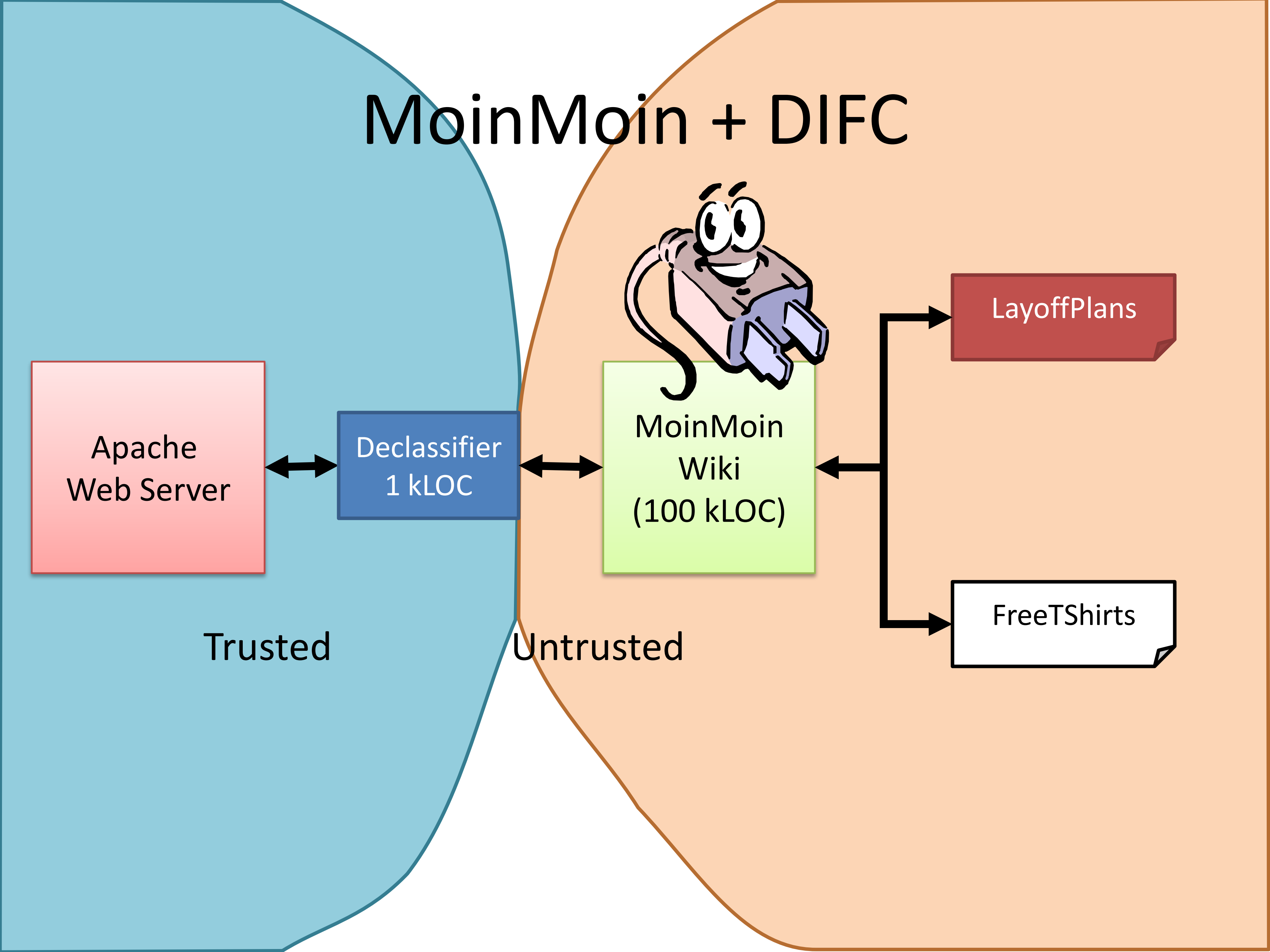
How Problems Arise…



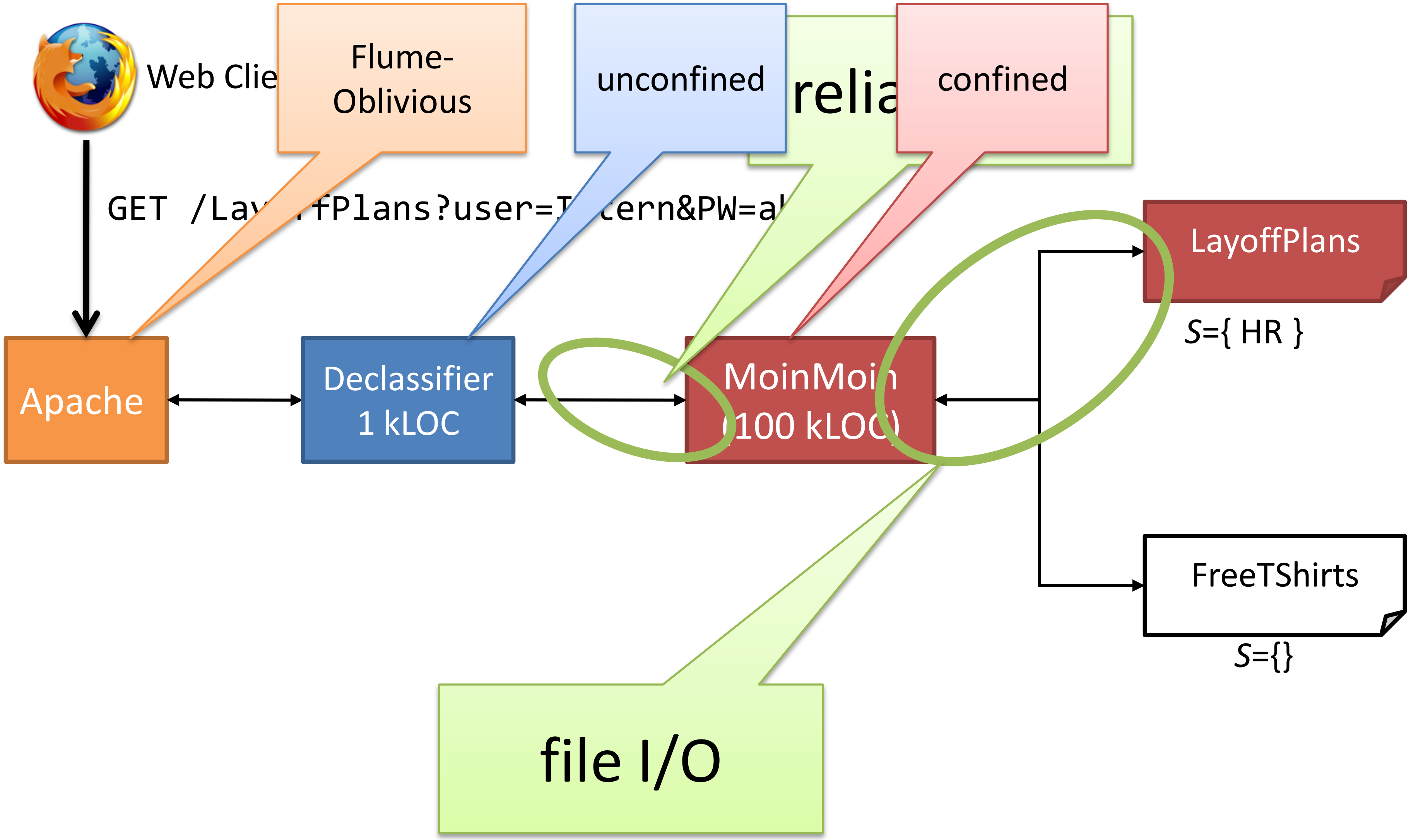
```
if not self.request.user.may.read(pagename):
    return self.notAllowedFault()
```

x43

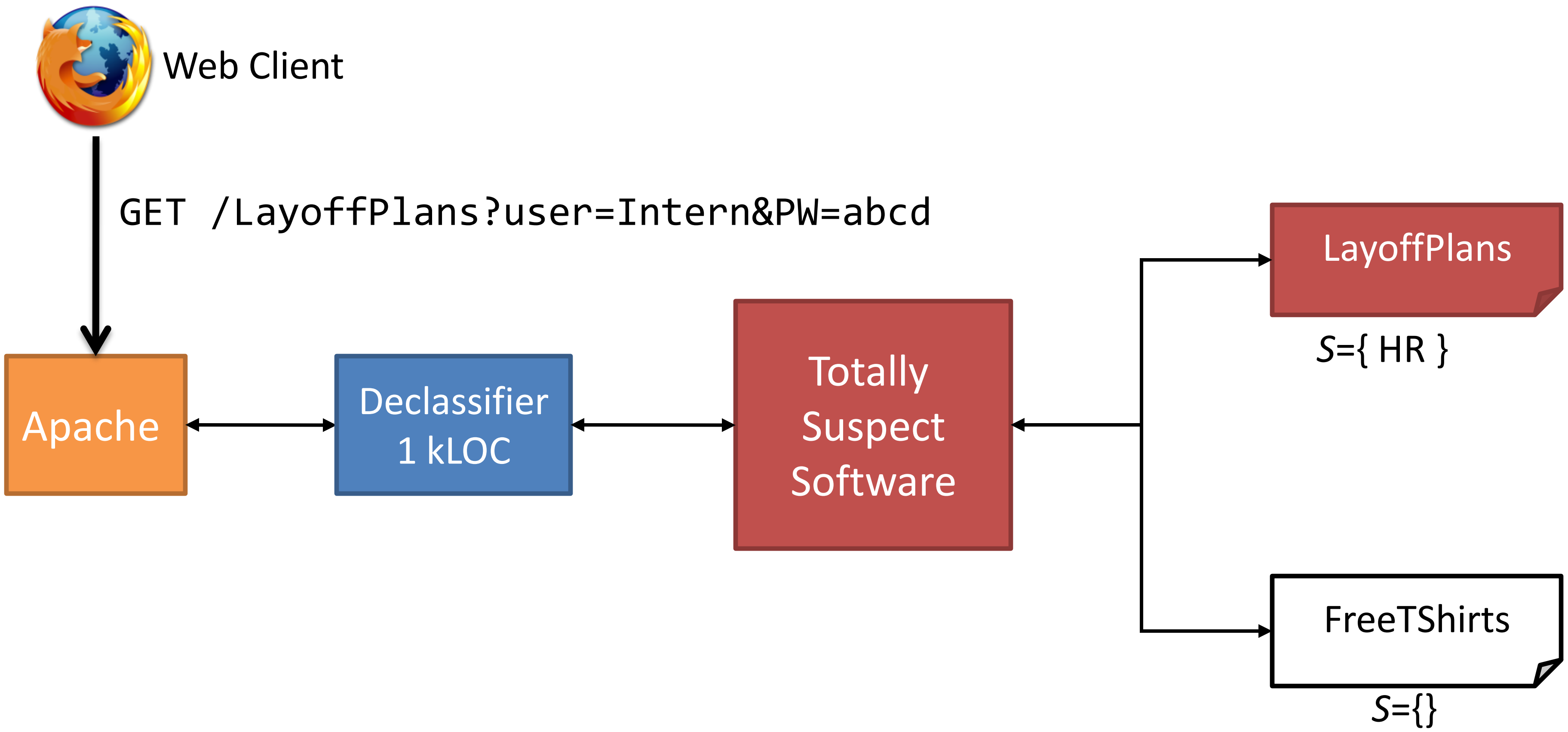
MoinMoin + DIFC



FlumeWiki


Web Clie
Flume-Oblivious
unconfined
relia
confined
GET /Lay fPlans?user=I ern&PW=a
LayoffPlans
S={ HR }
Apache
Declassifier
1 kLOC
MoinMoin
(100 kLOC)
FreeTShirts
S={}
file I/O

Future Work



Web Client
GET /LayoffPlans?user=Intern&PW=abcd
Apache
Declassifier
1 kLOC
Totally Suspect Software
LayoffPlans
S={ HR }
FreeTShirts
S={}

Results

- Does Flume allow adoption of Unix software?
  - 1,000 LOC launcher/declassifier
  - 1,000 out of 100,000 LOC in MoinMoin changed
  - Python interpreter, Apache, unchanged
- Does Flume solve security vulnerabilities?
  - Without our knowing, we inherited two ACL bypass bugs from MoinMoin
  - Both are not exploitable in Flume's MoinMoin
- Does Flume perform reasonably?
  - Performs within a factor of 2 of the original on read and write benchmarks

Most Related Work

- Asbestos, HiStar: New DIFC OSes
- Jif: DIFC at the language level
- Ostia, Plash: Implementation techniques
- Classical MAC literature (Bell-LaPadula, Biba, Orange Book MAC, Lattice Model, etc.)

Limitations

- Bigger TCB than HiStar / Asbestos
  - Linux stack (Kernel + glibc + linker)
  - Reference monitor (~22 kLOC)
- Covert channels via disk quotas
- Confined processes like MoinMoin don't get full POSIX API.
  - `spawn()` instead of `fork()` & `exec()`
  - `flume_pipe()` instead of `pipe()`

Summary

- DIFC is a challenge to Programmers
- Flume: DIFC in User-Level
  - Preserves legacy software
  - Complements today’s programming techniques
- MoinMoin Wiki: Flume works as promised
- Invite you to play around:

`http://flume.csail.mit.edu`

Thanks!

To: ITRI, Nokia, NSF and You

Reasons to Read the Paper

- Generalized security properties
  - Including: Novel integrity policies
- Support for very large labels
- Support for clusters of Flume Machines

Flume’s Rule is Fast

- Recall:

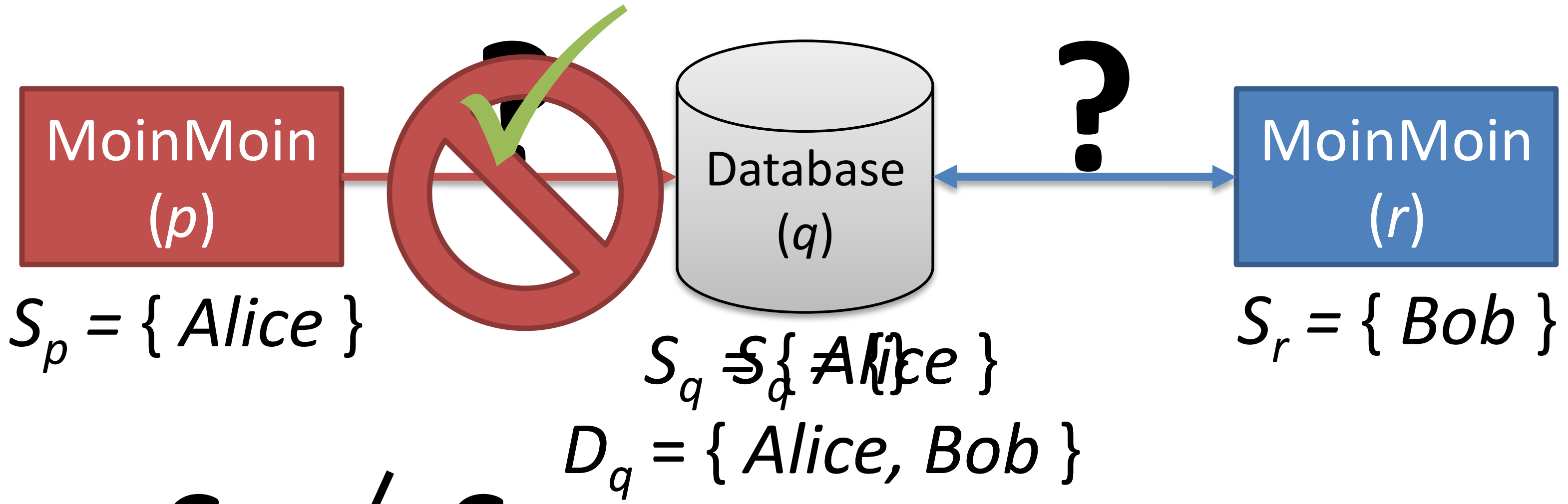
  p can send to *q* iff: $S_p - D_p \subseteq S_q \cup D_q$

- To Compute:

```
– for each tag $t \in S_p$:
    • If $t \notin S_q$ and $t \notin D_p$ and $t \notin D_q$:
        – output “NO”
– output “OK”
```

- Runs in time proportional to size of S_p.
- *No need to enumerate D_p or D_q !!!*

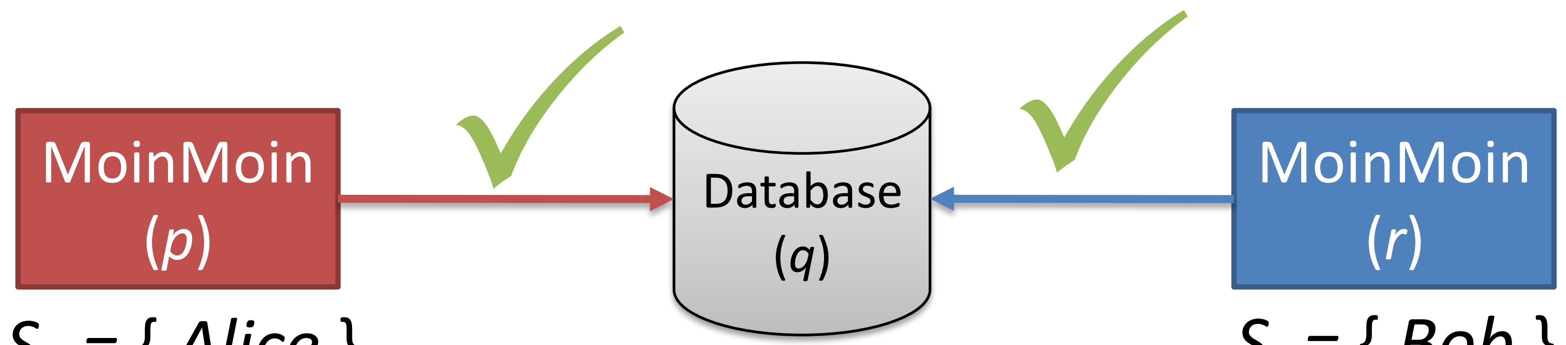
Flume Communication Rule



$$S_p \not\subseteq S_q$$

1. *q* changes to S_q = { *Alice* }
2. *p* sends to *q*
3. *q* changes back to S_q= {}

Flume Communication Rule



$S_p = \{ Alice \}$

$S_q = \{\}$

$D_q = \{ Alice, Bob$

$S_r = \{ Bob \}$

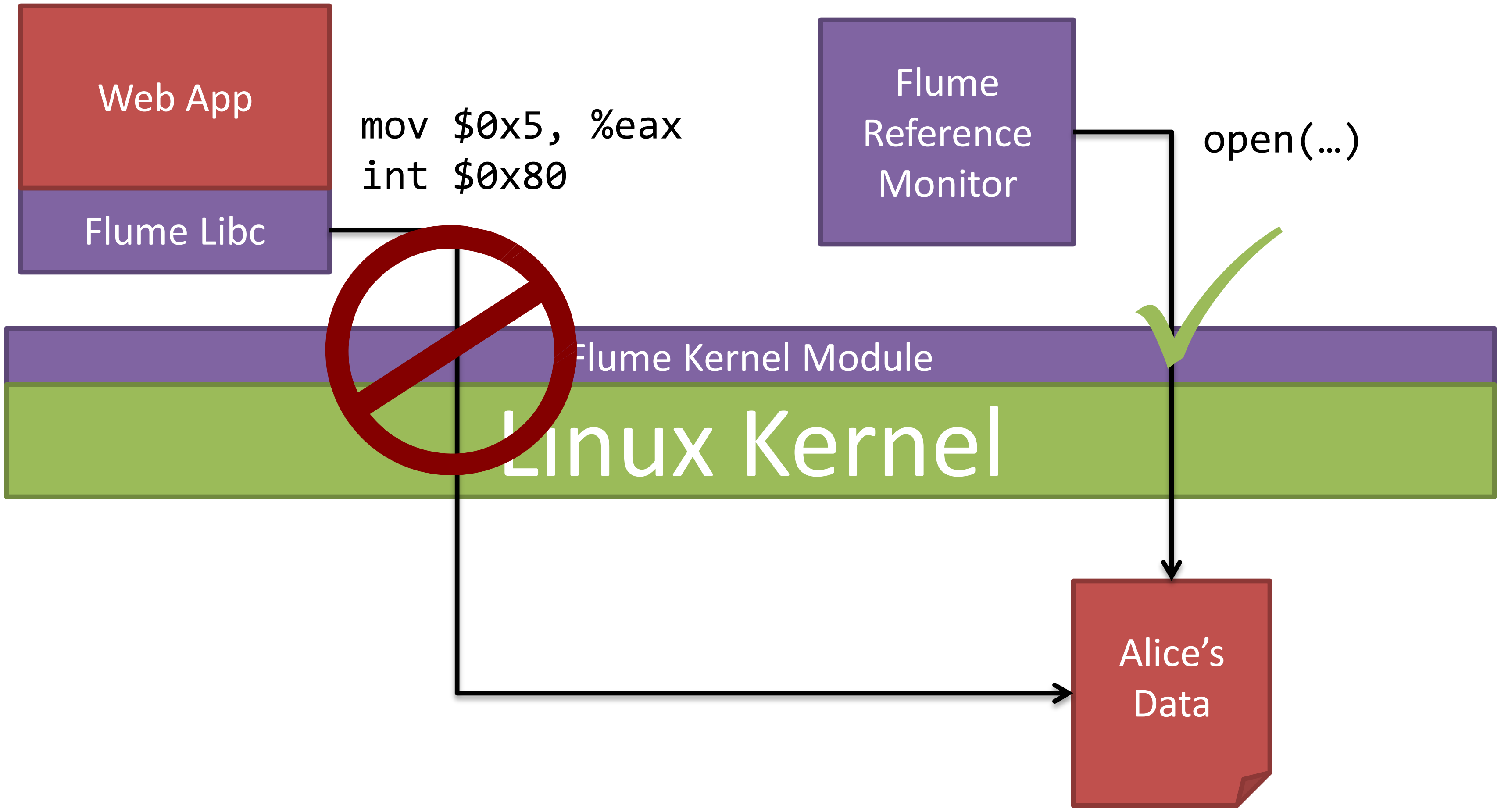
Senders get extra latitude

Receivers get extra latitude

- *p* can send to *q* iff:
  - In IFC: $S_p \subseteq S_q$
  - In Flume: $S_p - D_p \subseteq S_q \cup D_q$

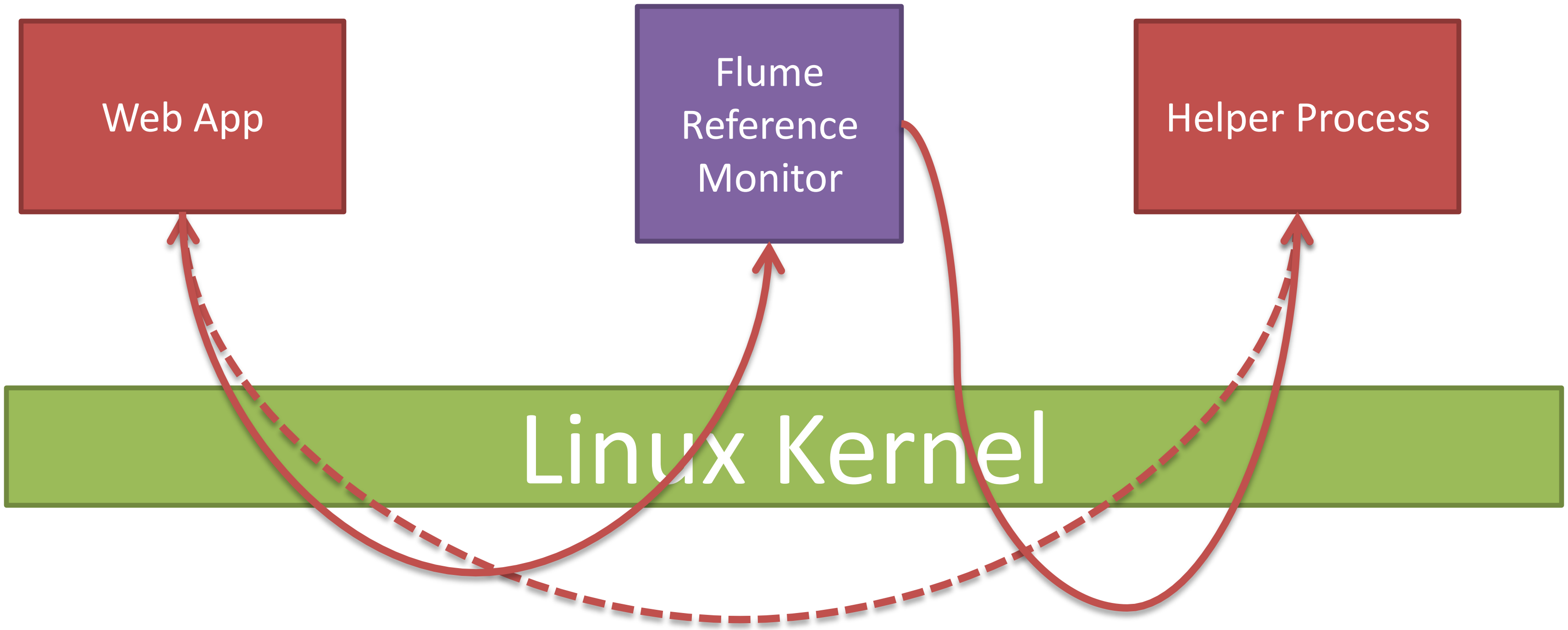
Flume Kernel Module

```
open("/alice/inbox.dat", O_RDONLY);
```

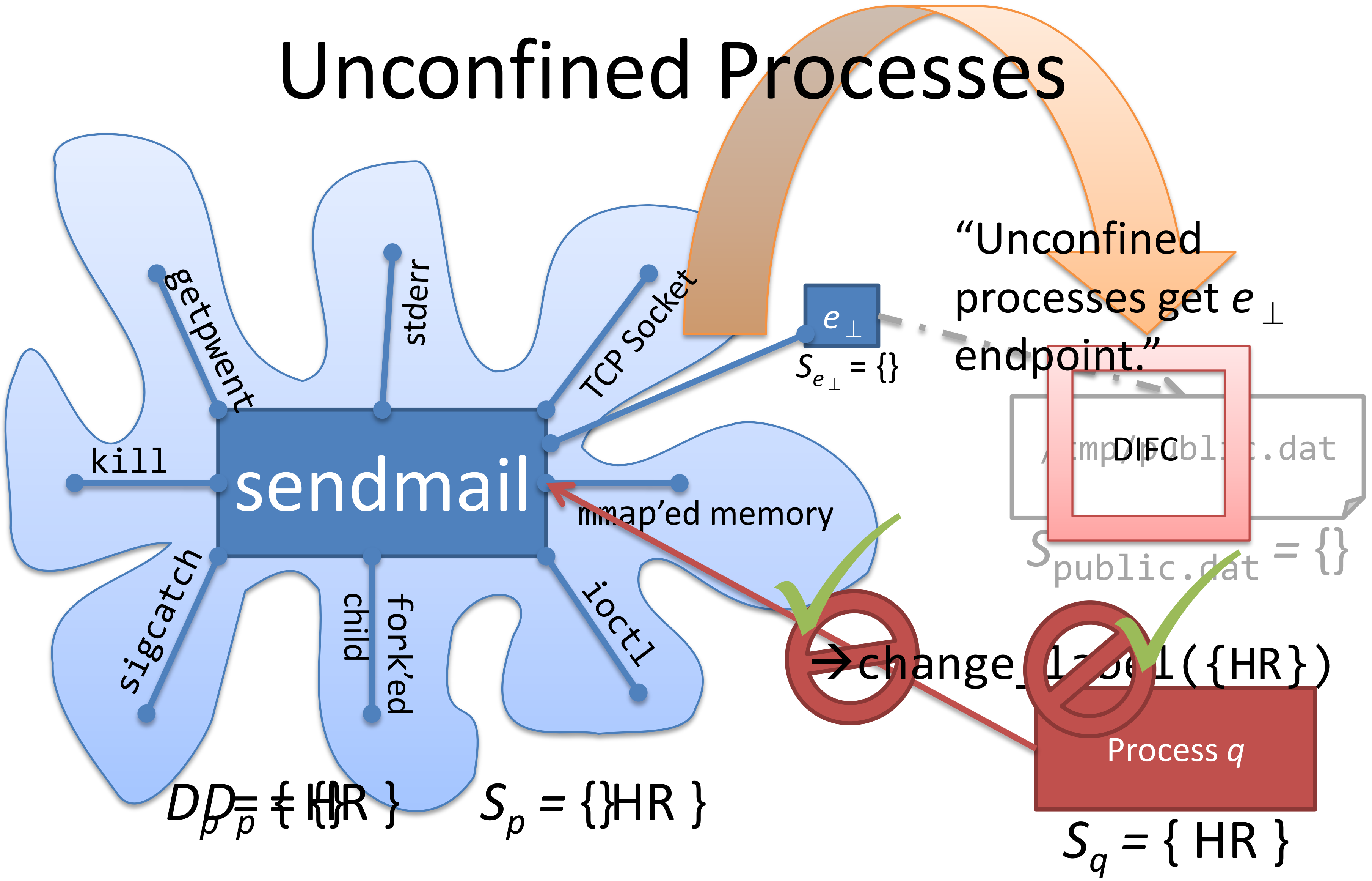


Reference Monitor Proxies Pipes

```
write(0, “some data”, 10);
```



Unconfined Processes



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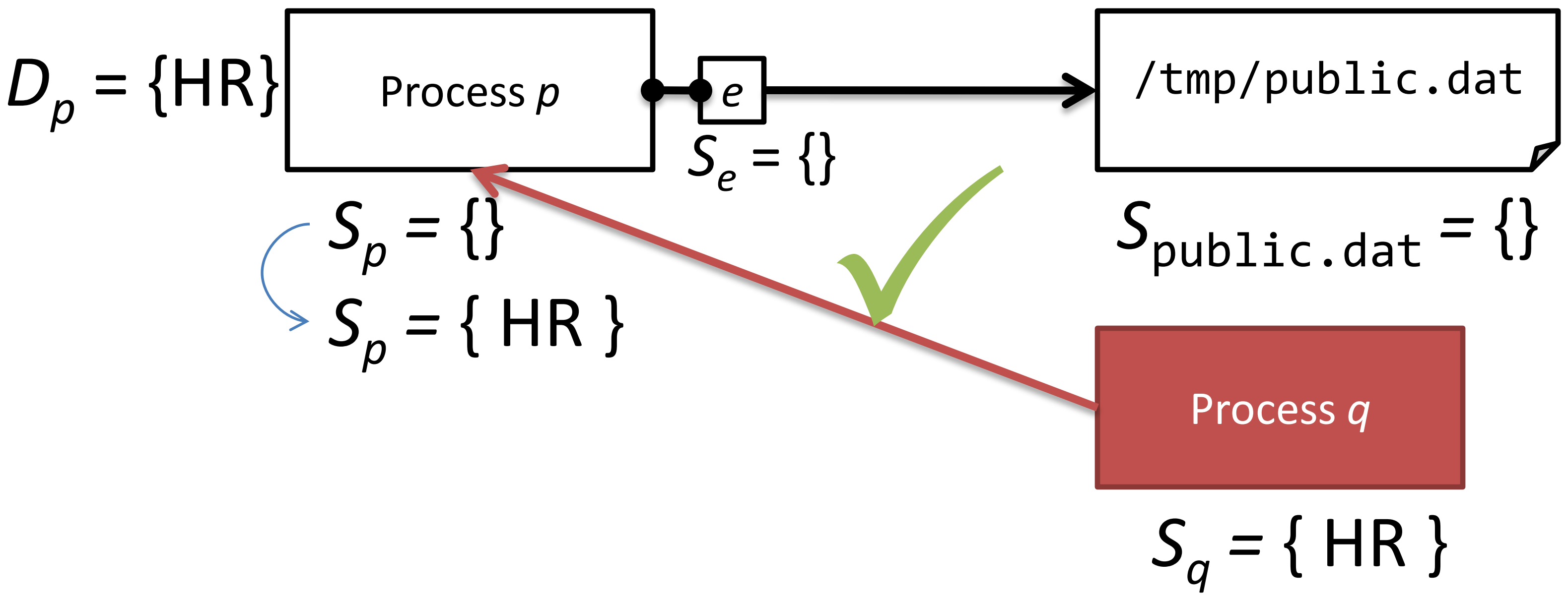
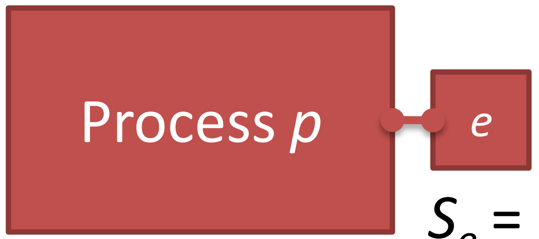


```
→open("/tmp/public.dat", O_WRONLY);
→change_label({HR})
```

Why Do We Need S_p?



S_e = { Finance, HR }

S_p = { Finance }

D_p = { HR }