BitFlip: Determine a Data's Signature Coverage from within the Application

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OWASP
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The OWASP Foundation
http://www.owasp.org

me, myself and this talk

- M.Sc. Information Security from Royal Holloway
- Diplom Informatik from University of Hamburg
- currently PhD student at University of Passau

ReSCUe IT

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ReSCUe IT:

- General: IT supported robust & secure Supply Chains
- Our Goal: Legally compliant & manageable integrity and authenticity statements for the data

Outline

- Problem & Motivation
- BitFlip Approach
- What BitFlip is not ...
- What BitFlip can do ... example XML-wrapping
- Conclusion

Problem: Message Security Layer vs. Application Layer

Design is layered

- Application Layer
  - Application logic works on data
- Data comes in by message
  - Application extracts data from message
- Security layer protects message (or part thereof)
  - Signed messages are verified before given to app.

Layered Security:

interlinking between layers must stay “in-sync”

Example: XML SOAP message security

Available security mechanism for SOAP messages:

- WS-Security (Tokens ...)
- XML Signature (and Encryption)

Security checks considered “good practice”:

- well defined XML schema
- rigorous schema validation
- validity check of signing public-key
- enforce strict security policies

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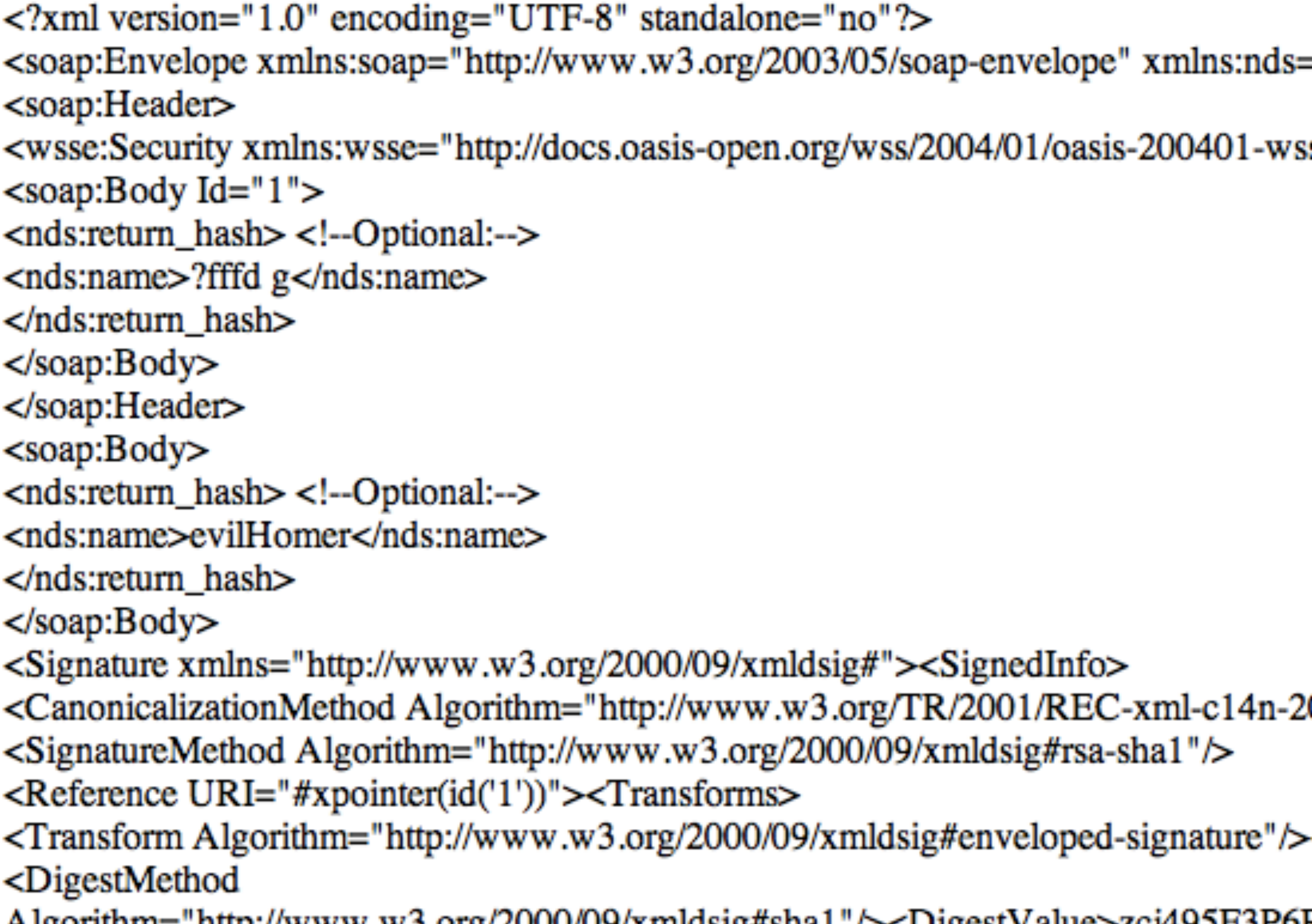
... but attacks on real world web services happen.

Authenticate not just the message,
but everything that is used to determine
the meaning of the message.

Ferguson and Schneier



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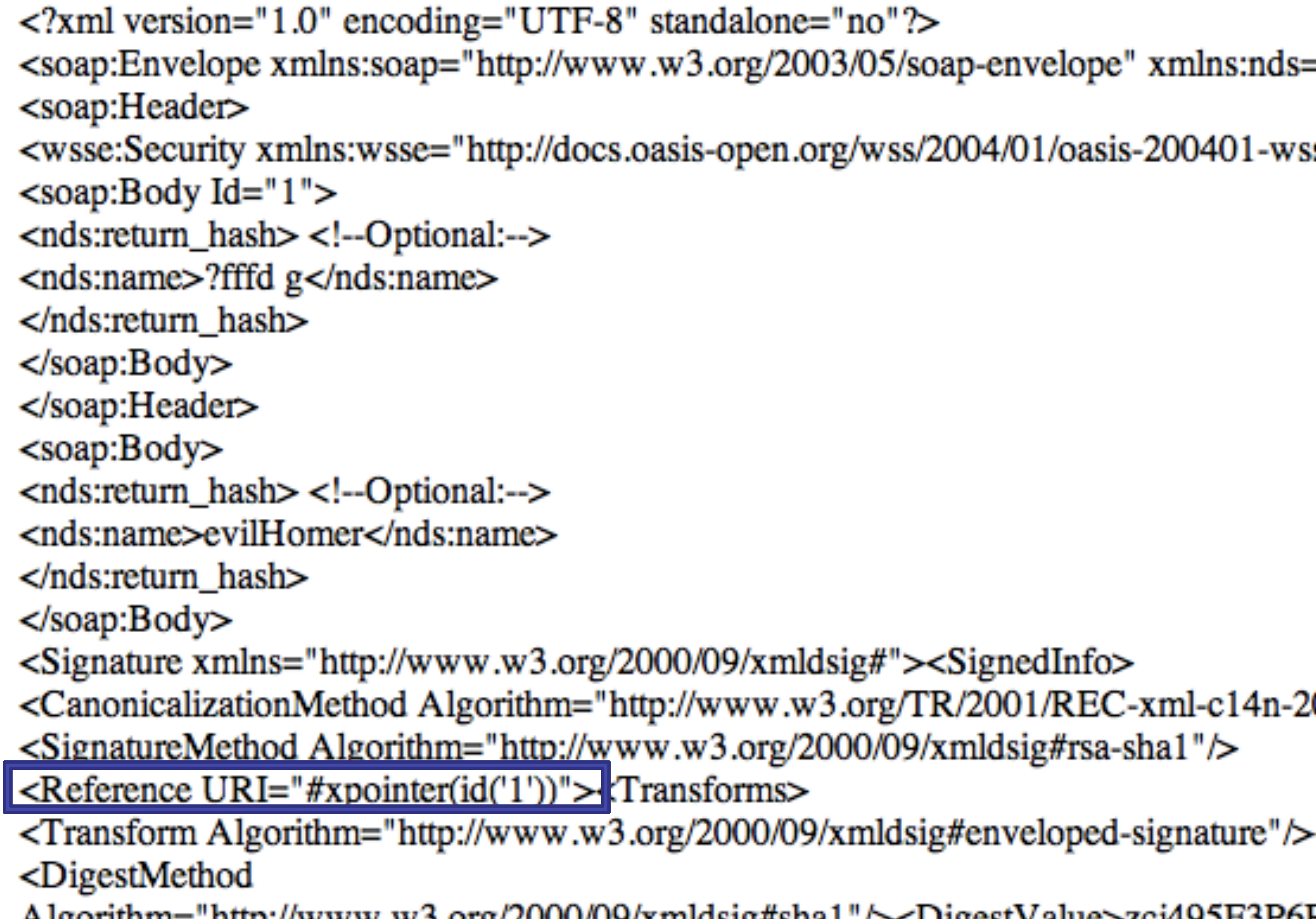

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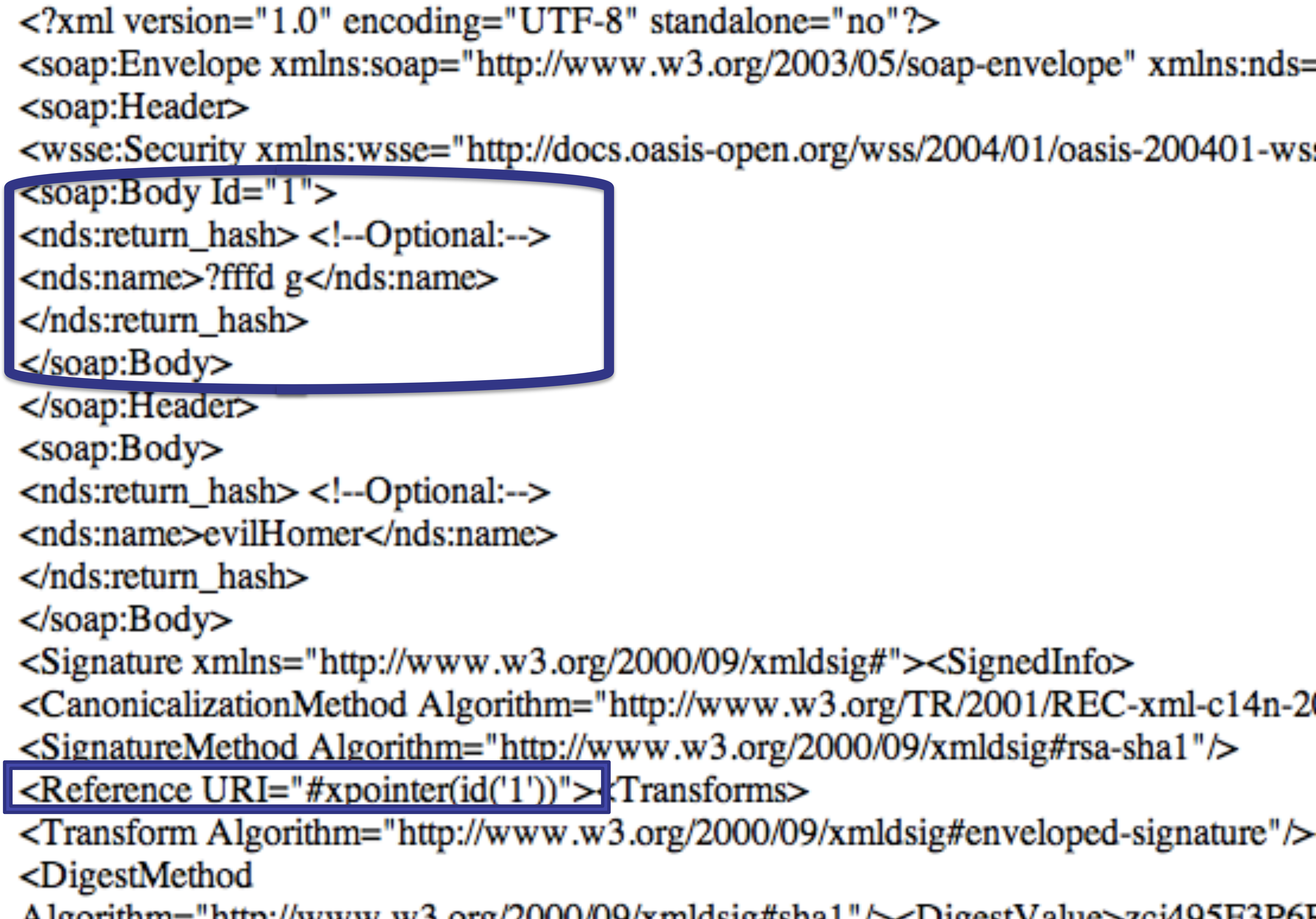

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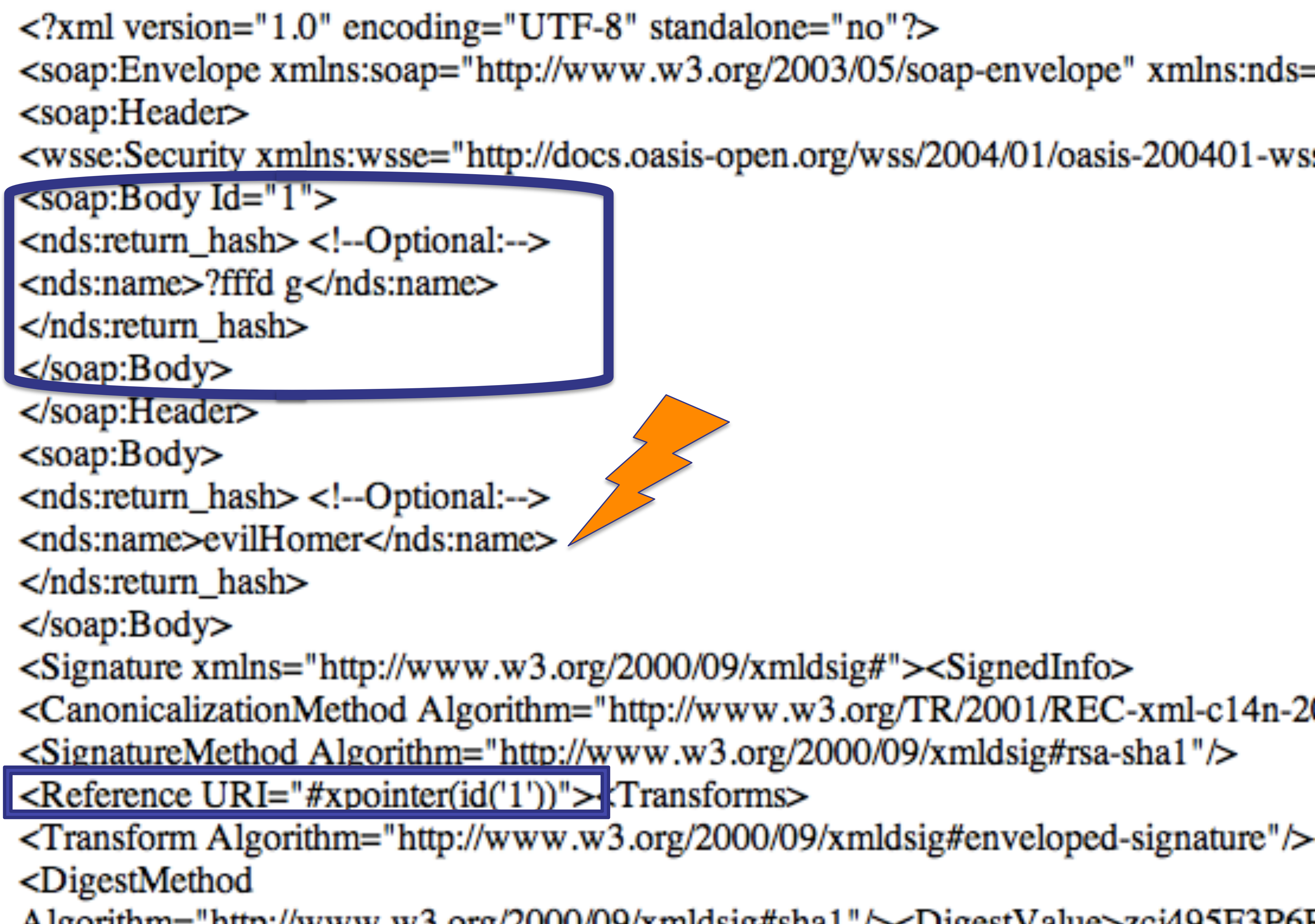

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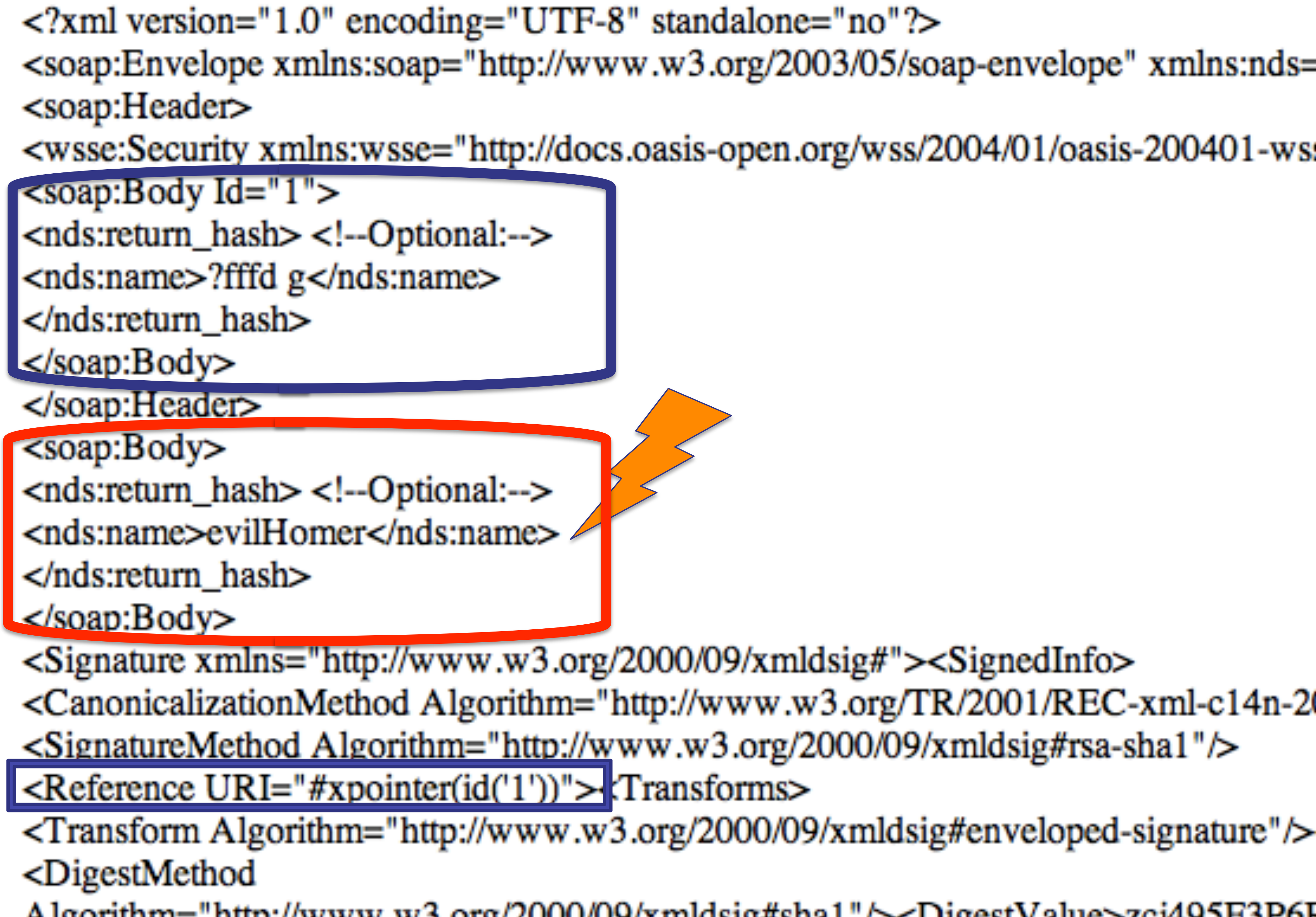

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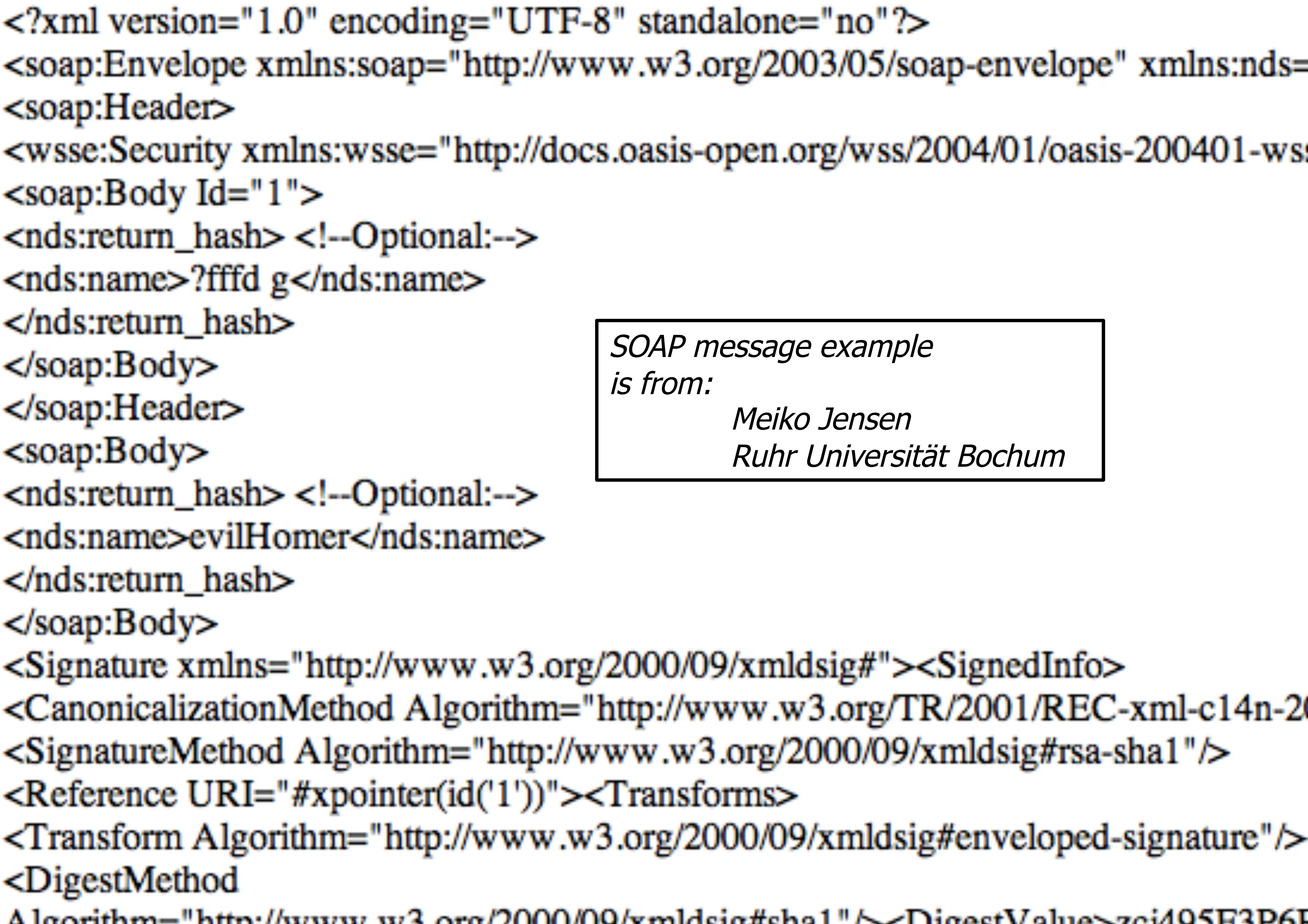

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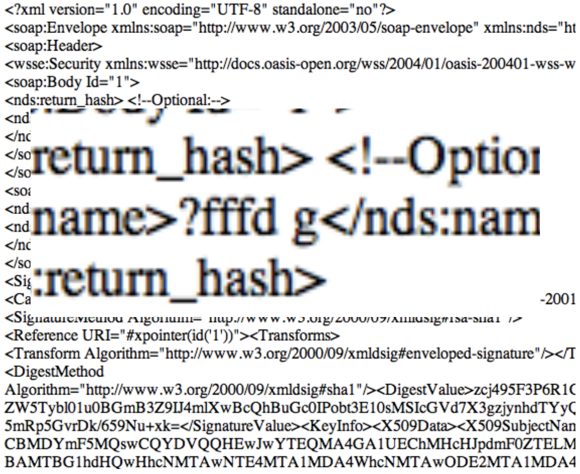
SOAP message example is from:
Meiko Jensen
Ruhr Universität Bochum

BitFlip: Observing the Signature Verification Outcome on Application Induced Errors



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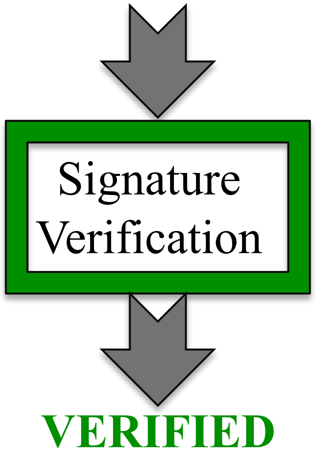

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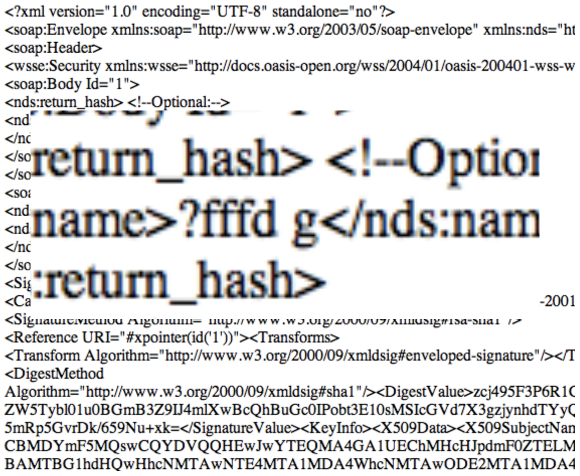

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```

```
return_hash> <!--Optior
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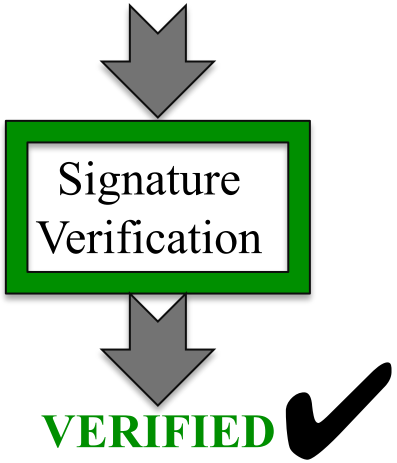

Signature Verification

VERIFIED ✔

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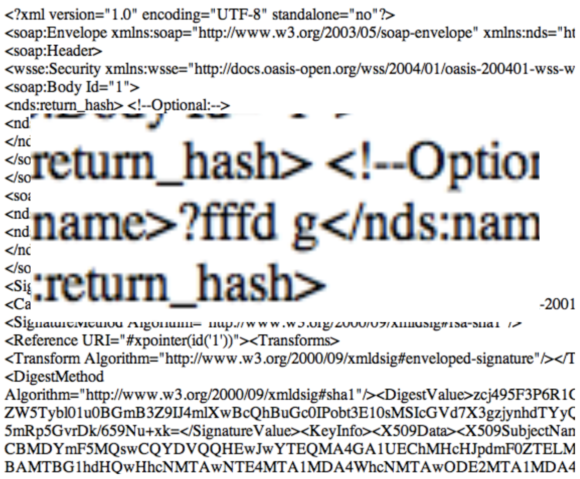

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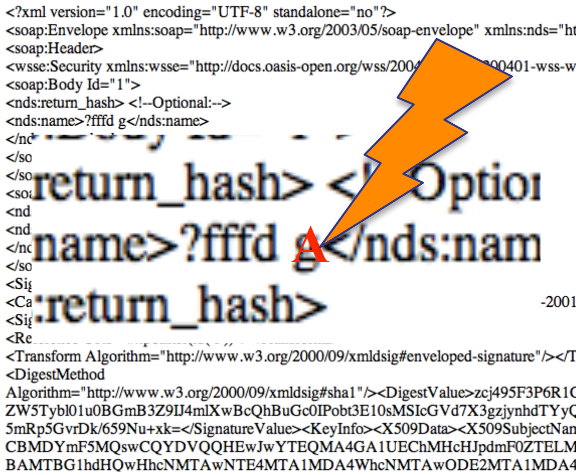
```

BitFlip: controlled change of single character



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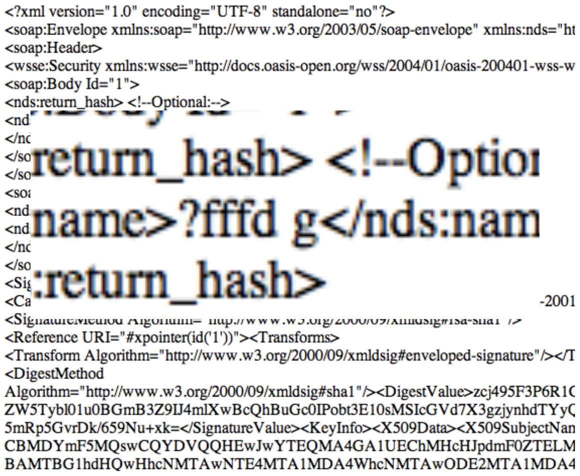

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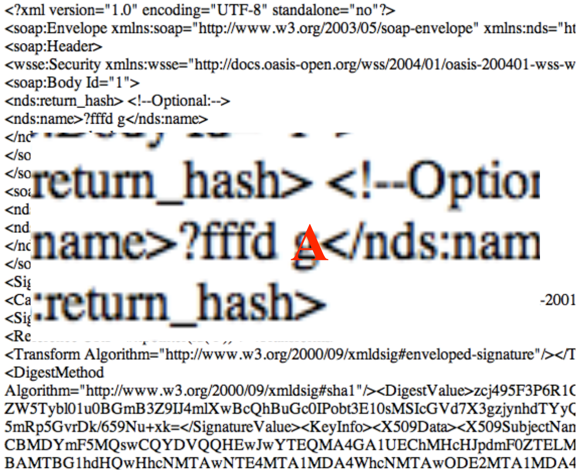

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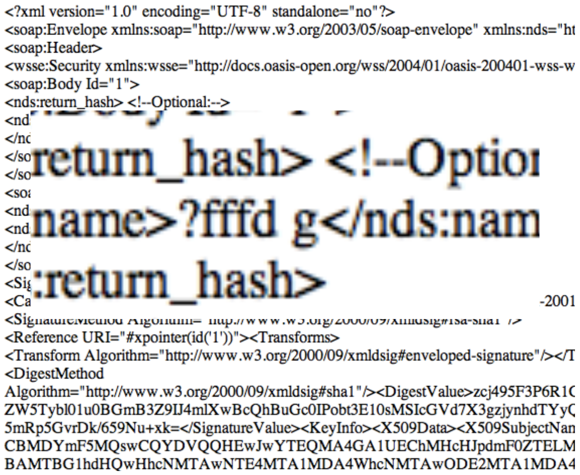

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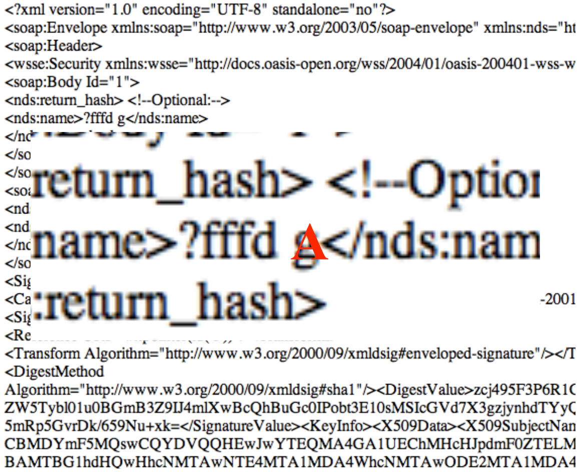
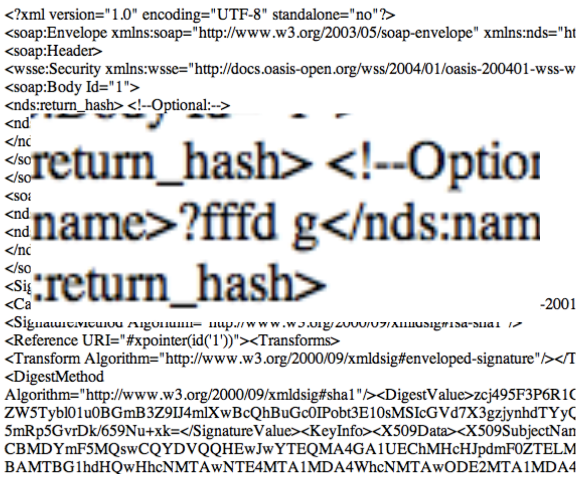


```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope" xmlns:nds="ht
<soap:Header>
<wsse:Security xmlns:wsse="http://docs.oasis-open.org/wss/2004/01/oasis-200401-wss-w
<soap:Body Id="1">
<nds:return_hash> <!--Optional:-->
<nds:name>?fffd g</nds:name>
</nc
</so    return_hash> <!--Optior
</so
<soa
<nd     name>?fffd A</nds:nam
<nd
</nc
</so    :return_hash>
<Sig
<Ca                                                                          -2001
<Sig
<Re
<Transform Algorithm="http://www.w3.org/2000/09/xmldsig#enveloped-signature"/></T
<DigestMethod
Algorithm="http://www.w3.org/2000/09/xmldsig#sha1"/><DigestValue>zcj495F3P6R1C
ZW5Tybl01u0BGmB3Z9IJ4mlXwBcQhBuGc0IPobt3E10sMSIcGVd7X3gzjynhdTYyC
5mRp5GvrDk/659Nu+xk=</SignatureValue><KeyInfo><X509Data><X509SubjectNan
CBMDYmF5MQswCQYDVQQHEwJwYTEQMA4GA1UEChMHcHJpdmF0ZTELM
BAMTBG1hdHQwHhcNMTAwNTE4MTA1MDA4WhcNMTAwODE2MTA1MDA4
```

Signature Verification

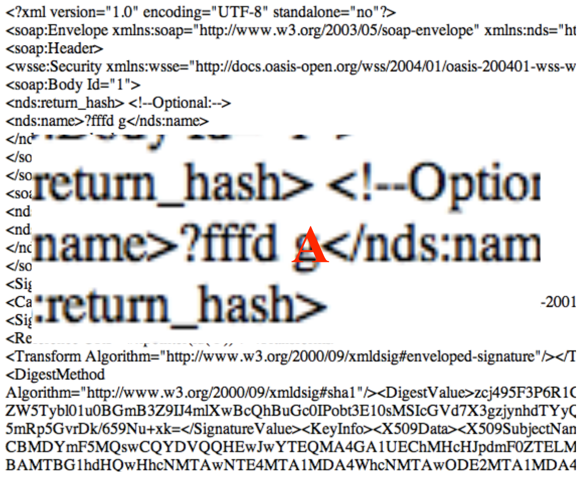
VERIFIED

BitFlip: Observing the Signature Verification Outcome on Application Induced Errors



```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope" xmlns:nds="ht
<soap:Header>
<wsse:Security xmlns:wsse="http://docs.oasis-open.org/wss/2004/01/oasis-200401-wss-w
<soap:Body Id="1">
<nds:return_hash> <!--Optional:-->
<nd
</nc
</so return_hash> <!--Optioı
</so
<so:
<nd name>?fffd g</nds:nam
<nd
</nc
</so
<Si :return_hash>
<Ca                                                                                 -2001
<SignatureMethod Algorithm="http://www.w3.org/2000/09/xmldsig#rsa-sha1" />
<Reference URI="#xpointer(id('1'))"><Transforms>
<Transform Algorithm="http://www.w3.org/2000/09/xmldsig#enveloped-signature"/></T
<DigestMethod
Algorithm="http://www.w3.org/2000/09/xmldsig#sha1"/><DigestValue>zcj495F3P6R1C
ZW5Tybl01u0BGmB3Z9IJ4mlXwBcQhBuGc0IPobt3E10sMSIcGVd7X3gzjynhdTYyC
5mRp5GvrDk/659Nu+xk=</SignatureValue><KeyInfo><X509Data><X509SubjectNan
CBMDYmF5MQswCQYDVQQHEwJwYTEQMA4GA1UEChMHcHJpdmF0ZTELM
BAMTBG1hdHQwHhcNMTAwNTE4MTA1MDA4WhcNMTAwODE2MTA1MDA4
```

BitFlip: controlled change of single character



```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope" xmlns:nds="ht
<soap:Header>
<wsse:Security xmlns:wsse="http://docs.oasis-open.org/wss/2004/01/oasis-200401-wss-w
<soap:Body Id="1">
<nds:return_hash> <!--Optional:-->
<nds:name>?fffd g</nds:name>
</nc
</so
</so return_hash> <!--Optioı
<so:
<nd
<nd name>?fffd A</nds:nam
</nc
</so
<Si
<Ca :return_hash>                                                                   -2001
<Si
<Re
<Transform Algorithm="http://www.w3.org/2000/09/xmldsig#enveloped-signature"/></T
<DigestMethod
Algorithm="http://www.w3.org/2000/09/xmldsig#sha1"/><DigestValue>zcj495F3P6R1C
ZW5Tybl01u0BGmB3Z9IJ4mlXwBcQhBuGc0IPobt3E10sMSIcGVd7X3gzjynhdTYyC
5mRp5GvrDk/659Nu+xk=</SignatureValue><KeyInfo><X509Data><X509SubjectNan
CBMDYmF5MQswCQYDVQQHEwJwYTEQMA4GA1UEChMHcHJpdmF0ZTELM
BAMTBG1hdHQwHhcNMTAwNTE4MTA1MDA4WhcNMTAwODE2MTA1MDA4
```

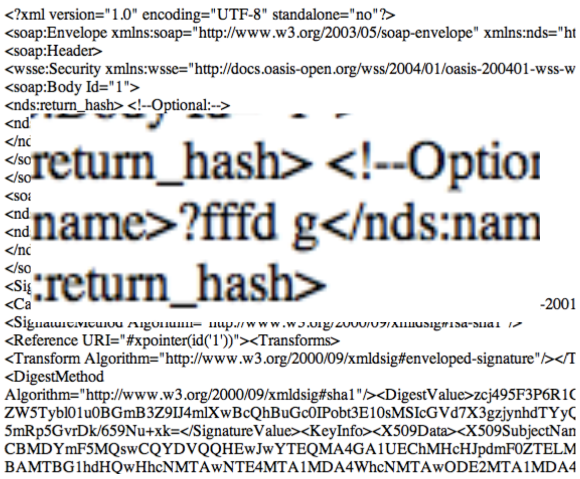
Signature Verification

VERIFIED ✓

Signature Verification

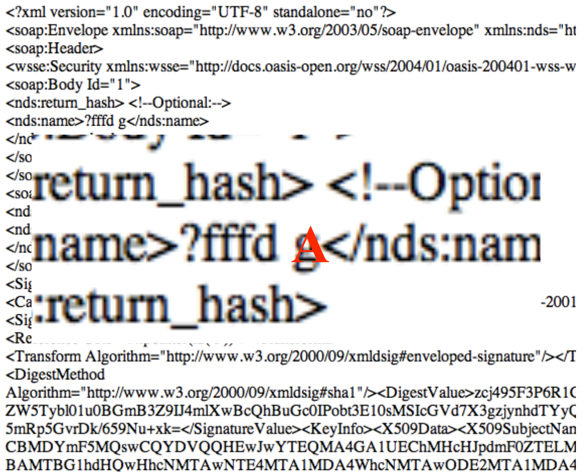
✗ VERIFIED

BitFlip: Observing the Signature Verification Outcome on Application Induced Errors



```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope" xmlns:nds="ht
<soap:Header>
<wsse:Security xmlns:wsse="http://docs.oasis-open.org/wss/2004/01/oasis-200401-wss-w
<soap:Body Id="1">
<nds:return_hash> <!--Optional:-->
<nd
</nc
</so
</so
<soa
<nd
<nd
</nc
</so
<Sig
<Ca                                                                        -2001
<SignatureMethod Algorithm="http://www.w3.org/2000/09/xmldsig#rsa-sha1" />
<Reference URI="#xpointer(id('1'))"><Transforms>
<Transform Algorithm="http://www.w3.org/2000/09/xmldsig#enveloped-signature"/></T
<DigestMethod
Algorithm="http://www.w3.org/2000/09/xmldsig#sha1"/><DigestValue>zcj495F3P6R1C
ZW5Tybl01u0BGmB3Z9IJ4mlXwBcQhBuGc0IPobt3E10sMSIcGVd7X3gzjynhdTYyC
5mRp5GvrDk/659Nu+xk=</SignatureValue><KeyInfo><X509Data><X509SubjectNan
CBMDYmF5MQswCQYDVQQHEwJwYTEQMA4GA1UEChMHcHJpdmF0ZTELM
BAMTBG1hdHQwHhcNMTAwNTE4MTA1MDA4WhcNMTAwODE2MTA1MDA4
```

```
return_hash> <!--Optior
name>?fffd g</nds:nam
:return_hash>
```



```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope" xmlns:nds="ht
<soap:Header>
<wsse:Security xmlns:wsse="http://docs.oasis-open.org/wss/2004/01/oasis-200401-wss-w
<soap:Body Id="1">
<nds:return_hash> <!--Optional:-->
<nds:name>?fffd g</nds:name>
</nc
</so
</so
<soa
<nd
<nd
</nc
</so
<Sig
<Ca                                                                        -2001
<Sig
<Re
<Transform Algorithm="http://www.w3.org/2000/09/xmldsig#enveloped-signature"/></T
<DigestMethod
Algorithm="http://www.w3.org/2000/09/xmldsig#sha1"/><DigestValue>zcj495F3P6R1C
ZW5Tybl01u0BGmB3Z9IJ4mlXwBcQhBuGc0IPobt3E10sMSIcGVd7X3gzjynhdTYyC
5mRp5GvrDk/659Nu+xk=</SignatureValue><KeyInfo><X509Data><X509SubjectNan
CBMDYmF5MQswCQYDVQQHEwJwYTEQMA4GA1UEChMHcHJpdmF0ZTELM
BAMTBG1hdHQwHhcNMTAwNTE4MTA1MDA4WhcNMTAwODE2MTA1MDA4
```

```
return_hash> <!--Optior
name>?fffd gA</nds:nam
:return_hash>
```

BitFlip: controlled change of single character

Result: character not covered

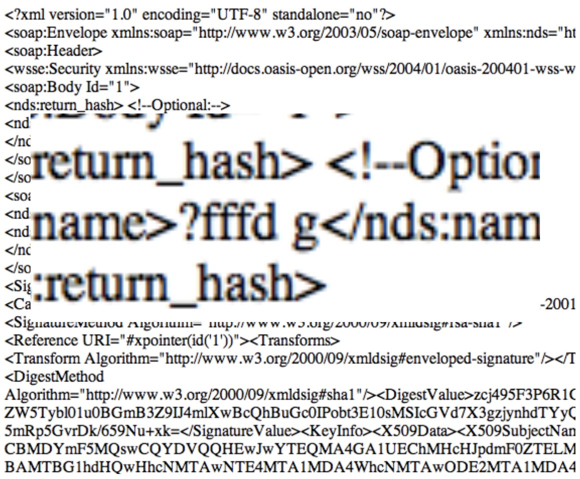
Signature Verification

VERIFIED ✔

Signature Verification

✗ **VERIFIED**

BitFlip: Observing the Signature Verification Outcome on Application Induced Errors

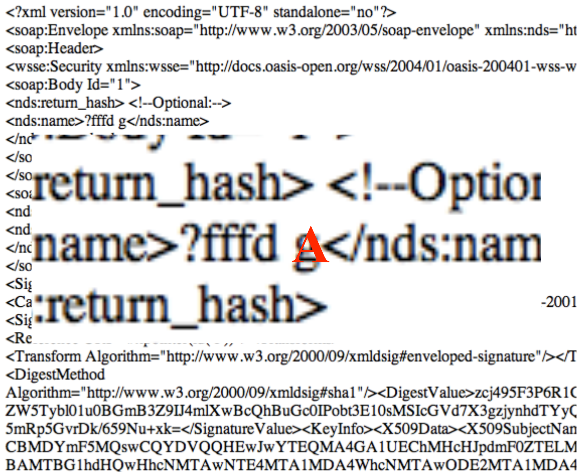


```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope" xmlns:nds="ht
<soap:Header>
<wsse:Security xmlns:wsse="http://docs.oasis-open.org/wss/2004/01/oasis-200401-wss-w
<soap:Body Id="1">
<nds:return_hash> <!--Optional:-->
<nd
</nc
</so return_hash> <!--Optior
</so
<soa
<nd  name>?fffd g</nds:nam
<nd
</nc
</so
<Sig :return_hash>
<Ca                                                         -2001
<SignatureMethod Algorithm="http://www.w3.org/2000/09/xmldsig#rsa-sha1" />
<Reference URI="#xpointer(id('1'))"><Transforms>
<Transform Algorithm="http://www.w3.org/2000/09/xmldsig#enveloped-signature"/></T
<DigestMethod
Algorithm="http://www.w3.org/2000/09/xmldsig#sha1"/><DigestValue>zcj495F3P6R1C
ZW5Tybl01u0BGmB3Z9IJ4mlXwBcQhBuGc0IPobt3E10sMSIcGVd7X3gzjynhdTYyC
5mRp5GvrDk/659Nu+xk=</SignatureValue><KeyInfo><X509Data><X509SubjectNan
CBMDYmF5MQswCQYDVQQHEwJwYTEQMA4GA1UEChMHcHJpdmF0ZTELM
BAMTBG1hdHQwHhcNMTAwNTE4MTA1MDA4WhcNMTAwODE2MTA1MDA4
```

Signature Verification

VERIFIED ✔

BitFlip: controlled change of single character

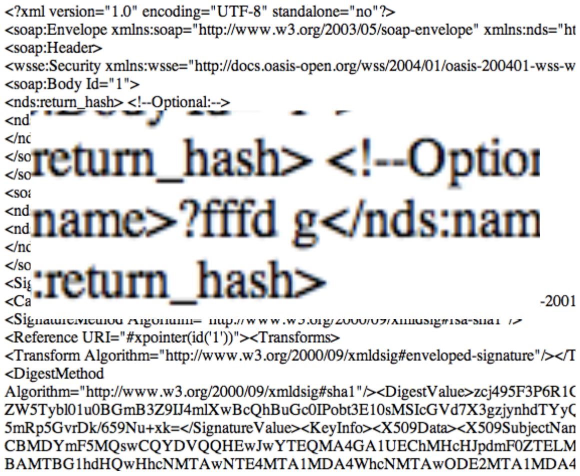


```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope" xmlns:nds="ht
<soap:Header>
<wsse:Security xmlns:wsse="http://docs.oasis-open.org/wss/2004/01/oasis-200401-wss-w
<soap:Body Id="1">
<nds:return_hash> <!--Optional:-->
<nds:name>?fffd g</nds:name>
</nc
</so
</so return_hash> <!--Optior
<soa
<nd
<nd  name>?fffd A</nds:nam
</nc
</so
<Sig
<Ca  :return_hash>                                          -2001
<Sig
<Re
<Transform Algorithm="http://www.w3.org/2000/09/xmldsig#enveloped-signature"/></T
<DigestMethod
Algorithm="http://www.w3.org/2000/09/xmldsig#sha1"/><DigestValue>zcj495F3P6R1C
ZW5Tybl01u0BGmB3Z9IJ4mlXwBcQhBuGc0IPobt3E10sMSIcGVd7X3gzjynhdTYyC
5mRp5GvrDk/659Nu+xk=</SignatureValue><KeyInfo><X509Data><X509SubjectNan
CBMDYmF5MQswCQYDVQQHEwJwYTEQMA4GA1UEChMHcHJpdmF0ZTELM
BAMTBG1hdHQwHhcNMTAwNTE4MTA1MDA4WhcNMTAwODE2MTA1MDA4
```

Signature Verification

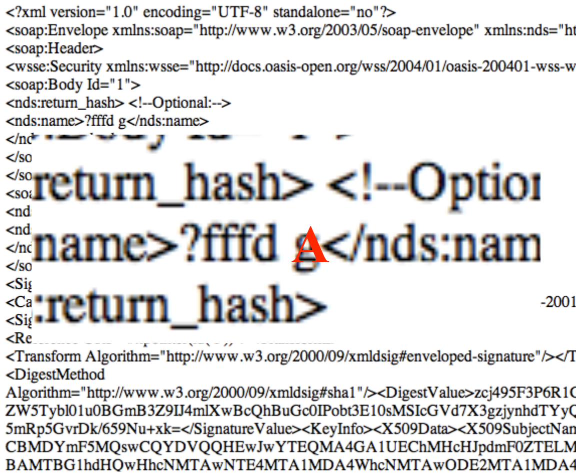
✔ FAILURE

BitFlip: Observing the Signature Verification Outcome on Application Induced Errors



```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope" xmlns:nds="ht
<soap:Header>
<wsse:Security xmlns:wsse="http://docs.oasis-open.org/wss/2004/01/oasis-200401-wss-w
<soap:Body Id="1">
<nds:return_hash> <!--Optional:-->
<nd
</nc
</so
</so
<soa
<nd
<nd
</nc
</so
<Sig
<Ca                                                                          -2001
<SignatureMethod Algorithm="http://www.w3.org/2000/09/xmldsig#rsa-sha1" />
<Reference URI="#xpointer(id('1'))"><Transforms>
<Transform Algorithm="http://www.w3.org/2000/09/xmldsig#enveloped-signature"/></T
<DigestMethod
Algorithm="http://www.w3.org/2000/09/xmldsig#sha1"/><DigestValue>zcj495F3P6R1C
ZW5Tybl01u0BGmB3Z9IJ4mlXwBcQhBuGc0IPobt3E10sMSIcGVd7X3gzjynhdTYyC
5mRp5GvrDk/659Nu+xk=</SignatureValue><KeyInfo><X509Data><X509SubjectNan
CBMDYmF5MQswCQYDVQQHEwJwYTEQMA4GA1UEChMHcHJpdmF0ZTELM
BAMTBG1hdHQwHhcNMTAwNTE4MTA1MDA4WhcNMTAwODE2MTA1MDA4
```

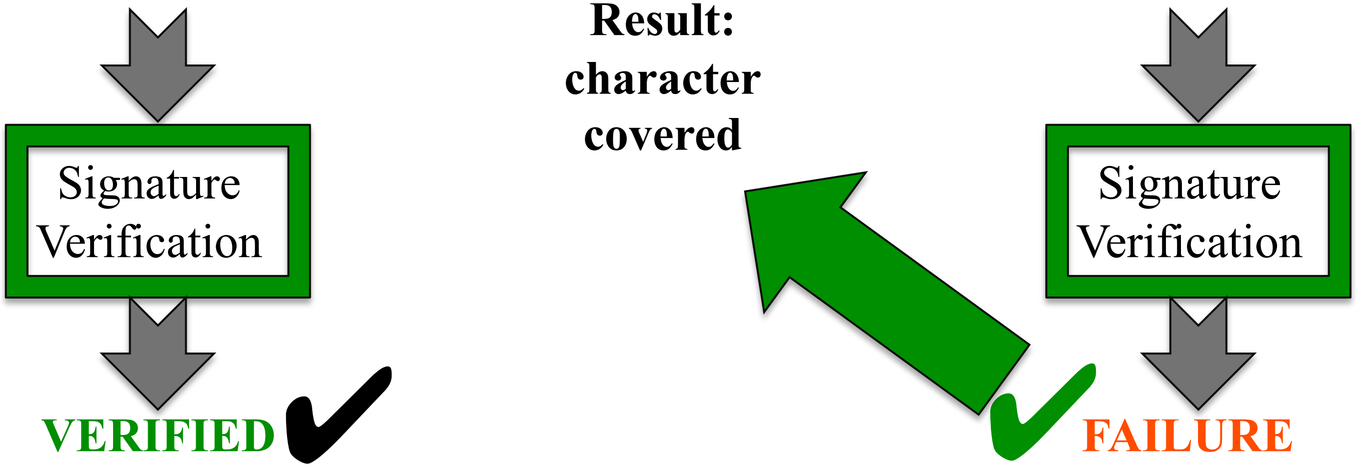
```
return_hash> <!--Optio
name>?fffd g</nds:nam
:return_hash>
```



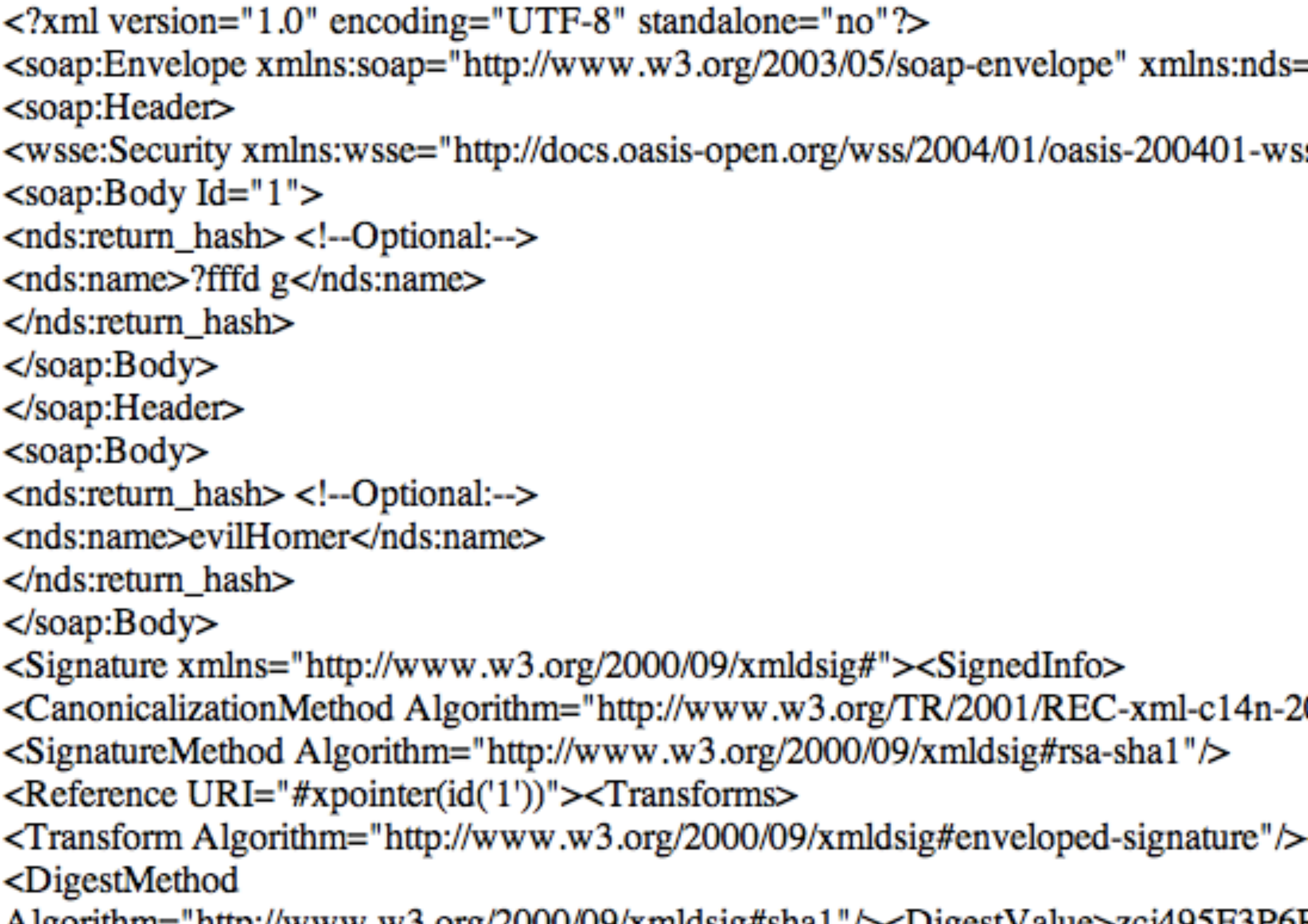
```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope" xmlns:nds="ht
<soap:Header>
<wsse:Security xmlns:wsse="http://docs.oasis-open.org/wss/2004/01/oasis-200401-wss-w
<soap:Body Id="1">
<nds:return_hash> <!--Optional:-->
<nds:name>?fffd g</nds:name>
</nd
</so
</so
<soa
<nd
<nd
</nc
</so
<Sig
<Ca                                                                          -2001
<Sig
<Re
<Transform Algorithm="http://www.w3.org/2000/09/xmldsig#enveloped-signature"/></T
<DigestMethod
Algorithm="http://www.w3.org/2000/09/xmldsig#sha1"/><DigestValue>zcj495F3P6R1C
ZW5Tybl01u0BGmB3Z9IJ4mlXwBcQhBuGc0IPobt3E10sMSIcGVd7X3gzjynhdTYyC
5mRp5GvrDk/659Nu+xk=</SignatureValue><KeyInfo><X509Data><X509SubjectNan
CBMDYmF5MQswCQYDVQQHEwJwYTEQMA4GA1UEChMHcHJpdmF0ZTELM
BAMTBG1hdHQwHhcNMTAwNTE4MTA1MDA4WhcNMTAwODE2MTA1MDA4
```

```
return_hash> <!--Optio
name>?fffd g</nds:nam
:return_hash>
```

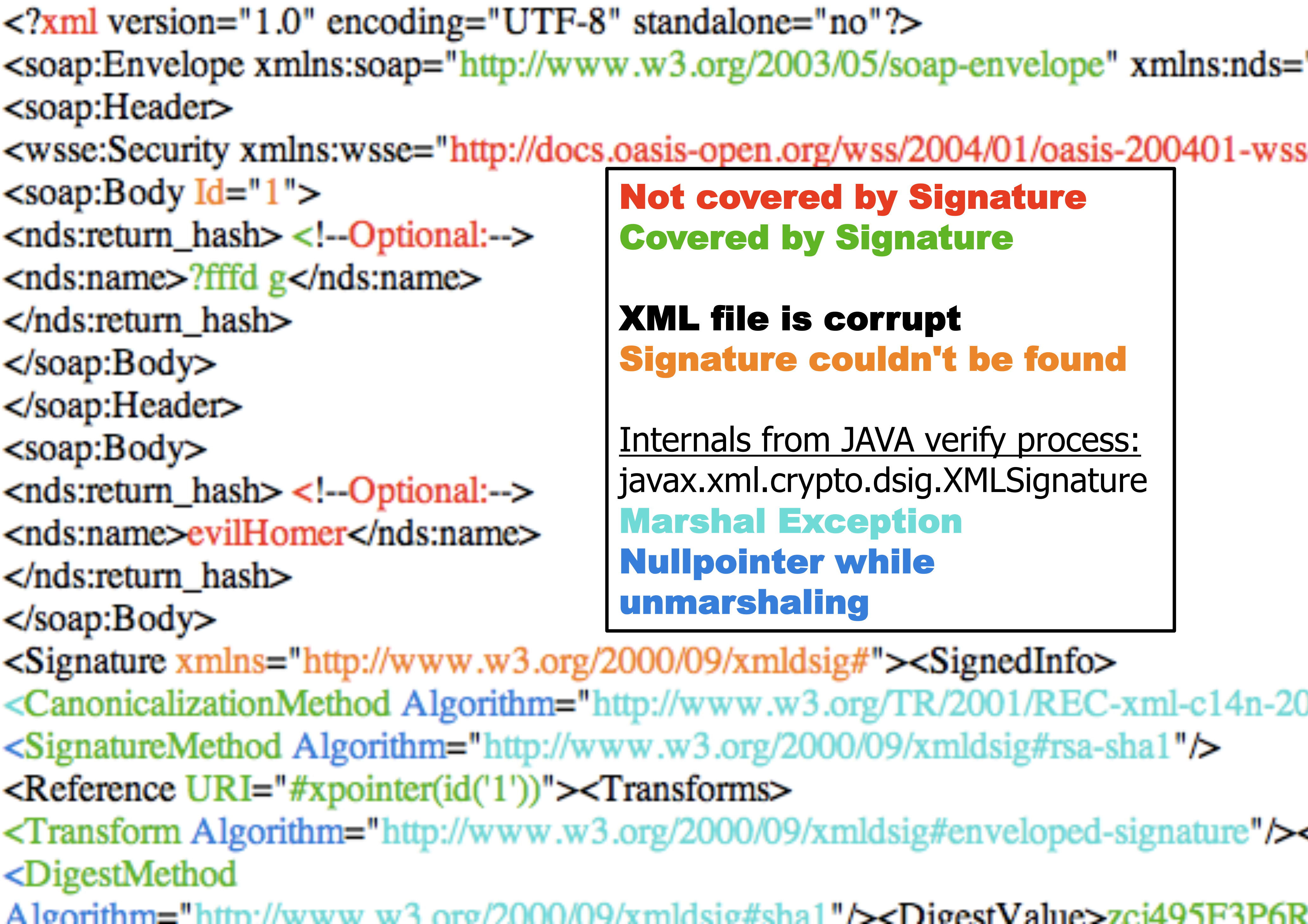
BitFlip: controlled change of single character



Result: character covered



```xml
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope" xmlns:nds=
<soap:Header>
<wsse:Security xmlns:wsse="http://docs.oasis-open.org/wss/2004/01/oasis-200401-ws
<soap:Body Id="1">
<nds:return_hash> <!--Optional:-->
<nds:name>?fffd g</nds:name>
</nds:return_hash>
</soap:Body>
</soap:Header>
<soap:Body>
<nds:return_hash> <!--Optional:-->
<nds:name>evilHomer</nds:name>
</nds:return_hash>
</soap:Body>
<Signature xmlns="http://www.w3.org/2000/09/xmldsig#"><SignedInfo>
<CanonicalizationMethod Algorithm="http://www.w3.org/TR/2001/REC-xml-c14n-2
<SignatureMethod Algorithm="http://www.w3.org/2000/09/xmldsig#rsa-sha1"/>
<Reference URI="#xpointer(id('1'))"><Transforms>
<Transform Algorithm="http://www.w3.org/2000/09/xmldsig#enveloped-signature"/>
<DigestMethod
Algorithm="http://www.w3.org/2000/09/xmldsig#sha1"/><DigestValue>zci495F3P6
```



```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope" xmlns:nds="
<soap:Header>
<wsse:Security xmlns:wsse="http://docs.oasis-open.org/wss/2004/01/oasis-200401-wss
<soap:Body Id="1">
<nds:return_hash> <!--Optional:-->
<nds:name>?fffd g</nds:name>
</nds:return_hash>
</soap:Body>
</soap:Header>
<soap:Body>
<nds:return_hash> <!--Optional:-->
<nds:name>evilHomer</nds:name>
</nds:return_hash>
</soap:Body>
<Signature xmlns="http://www.w3.org/2000/09/xmldsig#"><SignedInfo>
<CanonicalizationMethod Algorithm="http://www.w3.org/TR/2001/REC-xml-c14n-20
<SignatureMethod Algorithm="http://www.w3.org/2000/09/xmldsig#rsa-sha1"/>
<Reference URI="#xpointer(id('1'))"><Transforms>
<Transform Algorithm="http://www.w3.org/2000/09/xmldsig#enveloped-signature"/><
<DigestMethod
Algorithm="http://www.w3.org/2000/09/xmldsig#sha1"/><DigestValue>zci495F3P6R
```

Not covered by Signature

Covered by Signature

XML file is corrupt

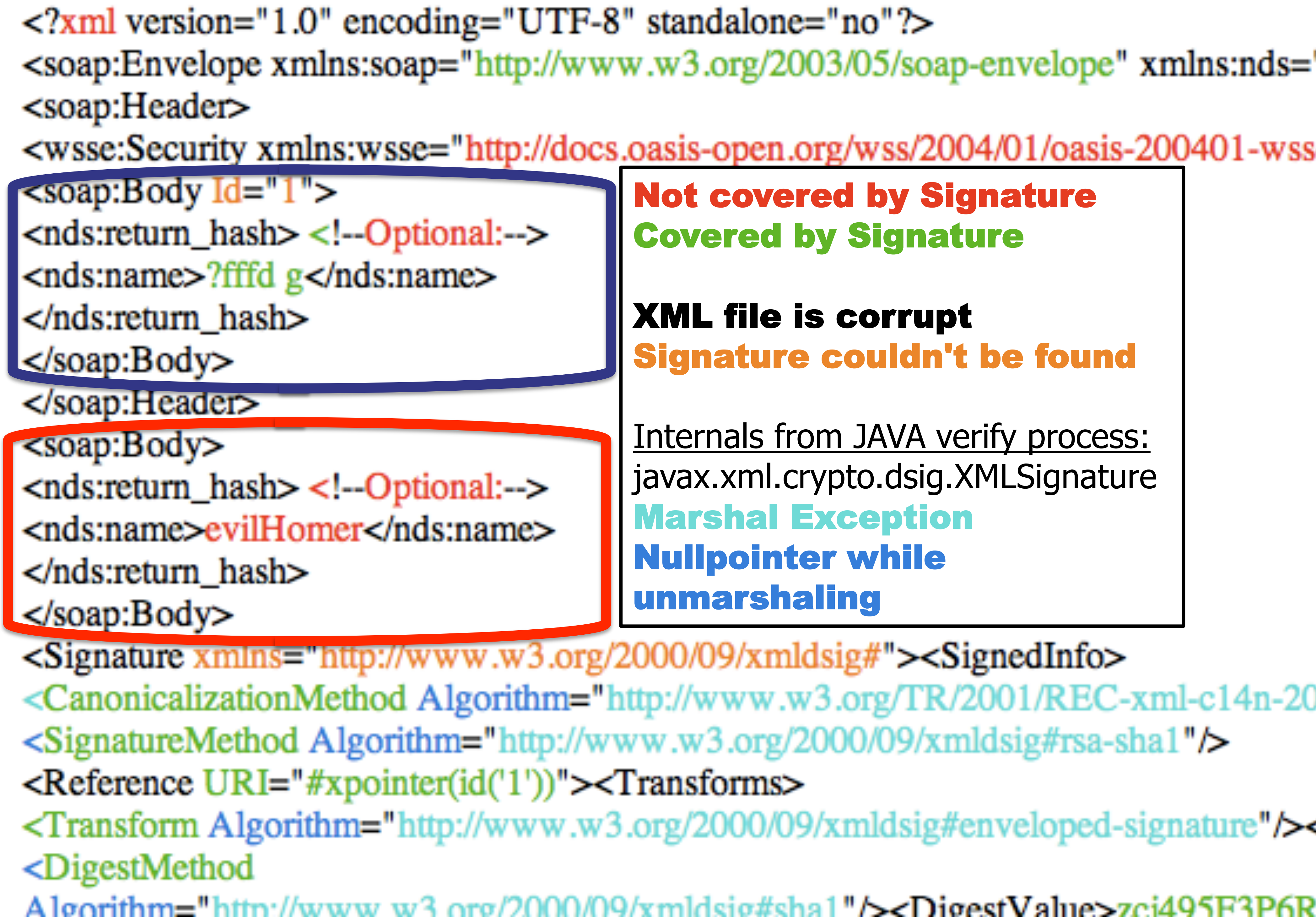
Signature couldn't be found

Internals from JAVA verify process:

javax.xml.crypto.dsig.XMLSignature

Marshal Exception

Nullpointer while unmarshaling



```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope" xmlns:nds="
<soap:Header>
<wsse:Security xmlns:wsse="http://docs.oasis-open.org/wss/2004/01/oasis-200401-wss
<soap:Body Id="1">
<nds:return_hash> <!--Optional:-->
<nds:name>?fffd g</nds:name>
</nds:return_hash>
</soap:Body>
</soap:Header>
<soap:Body>
<nds:return_hash> <!--Optional:-->
<nds:name>evilHomer</nds:name>
</nds:return_hash>
</soap:Body>
<Signature xmlns="http://www.w3.org/2000/09/xmldsig#"><SignedInfo>
<CanonicalizationMethod Algorithm="http://www.w3.org/TR/2001/REC-xml-c14n-20
<SignatureMethod Algorithm="http://www.w3.org/2000/09/xmldsig#rsa-sha1"/>
<Reference URI="#xpointer(id('1'))"><Transforms>
<Transform Algorithm="http://www.w3.org/2000/09/xmldsig#enveloped-signature"/><
<DigestMethod
Algorithm="http://www.w3.org/2000/09/xmldsig#sha1"/><DigestValue>zci495F3P6R
```

Not covered by Signature

Covered by Signature

XML file is corrupt

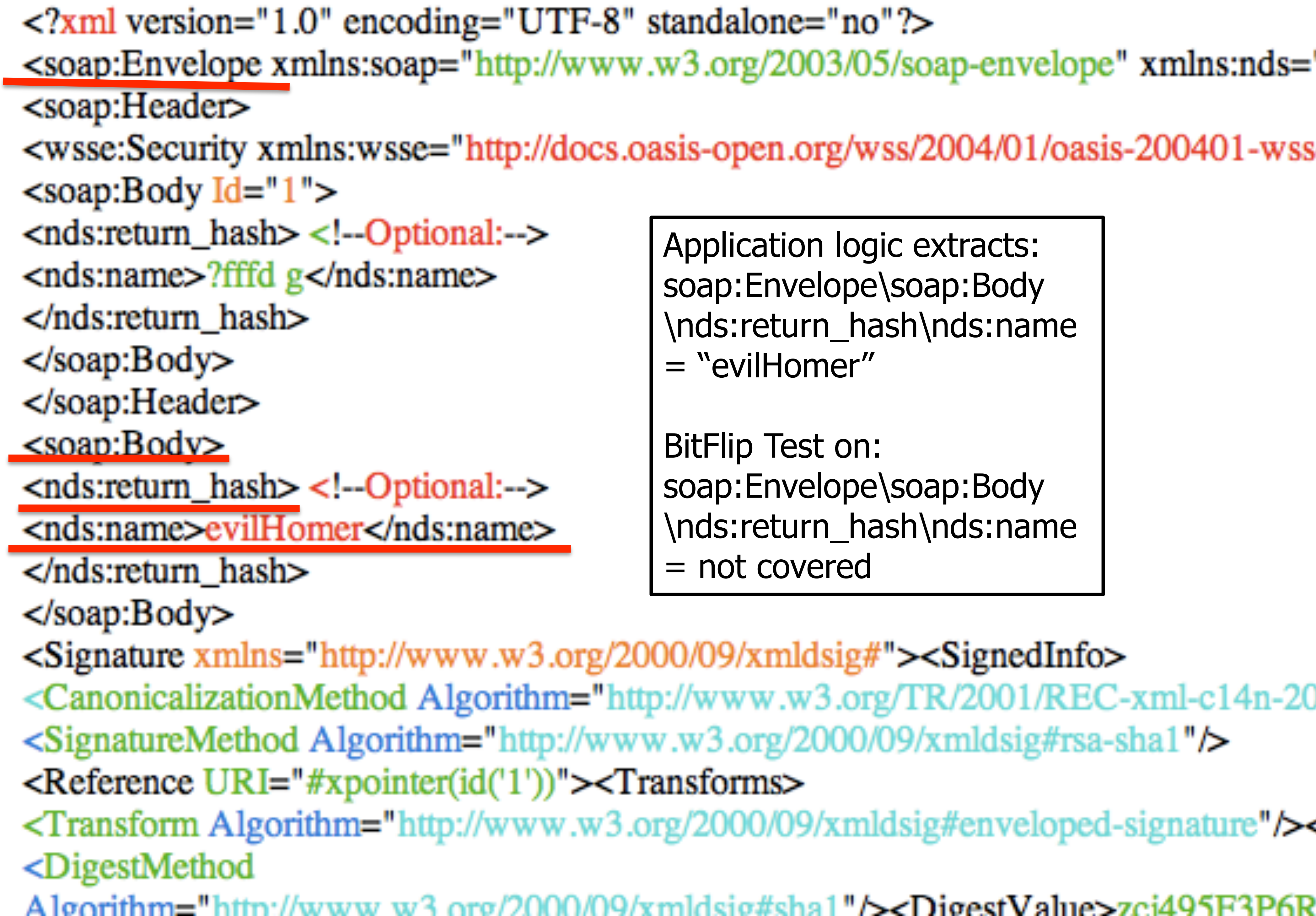
Signature couldn't be found

<u>Internals from JAVA verify process:</u>

javax.xml.crypto.dsig.XMLSignature

Marshal Exception

Nullpointer while unmarshaling



```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope" xmlns:nds="
<soap:Header>
<wsse:Security xmlns:wsse="http://docs.oasis-open.org/wss/2004/01/oasis-200401-wss
<soap:Body Id="1">
<nds:return_hash> <!--Optional:-->
<nds:name>?fffd g</nds:name>
</nds:return_hash>
</soap:Body>
</soap:Header>
<soap:Body>
<nds:return_hash> <!--Optional:-->
<nds:name>evilHomer</nds:name>
</nds:return_hash>
</soap:Body>
<Signature xmlns="http://www.w3.org/2000/09/xmldsig#"><SignedInfo>
<CanonicalizationMethod Algorithm="http://www.w3.org/TR/2001/REC-xml-c14n-20
<SignatureMethod Algorithm="http://www.w3.org/2000/09/xmldsig#rsa-sha1"/>
<Reference URI="#xpointer(id('1'))"><Transforms>
<Transform Algorithm="http://www.w3.org/2000/09/xmldsig#enveloped-signature"/><
<DigestMethod
Algorithm="http://www.w3.org/2000/09/xmldsig#sha1"/><DigestValue>zcj495F3P6R
```

Application logic extracts:
soap:Envelope\soap:Body
\nds:return_hash\nds:name
= "evilHomer"

BitFlip Test on:
soap:Envelope\soap:Body
\nds:return_hash\nds:name
= not covered

What BitFlip does NOT and can NOT offer …

BitFlip does not do “positive verification”:

- no assurance that the parts that seem covered are secured against all kinds of attacks
- does not check for exploits in the signature verification process
- is not a “fuzzer”

What BitFlip does ...

- detects absence of integrity protection ("white spots")
- works independently of signature verification process ("black-box")
- implemented on application level
  - application controlled
  - use same "parser logic" to select flipping data
- absence can be detected by a single "flip"
  - overhead of one additional signature verification

BitFlip: Conclusion

- Allows Applications to test if Signature Verification Process covers the data the application logic extracted
- Independent of Verification Process (black-box)
  - Full Verification not necessary if no black-box
- Tool to evaluate the Verification Process
  - detect errors during application design
  - testing the layers below before application roll-out
  - re-run tests after changes to the policy or the verification process