Automating Retrieval of Earth Orientation Predictions

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Introduction

- Control systems for telescopes require a prediction of earth orientation.

pointing accuracy < 1” requires UT1-UTC to better than 0.07 seconds

- Polar motion marginally significant

Typical operational procedure today

- Telescope operator types numbers from Bulletin A
  - Mistakes happen (especially at 4000m)
    - Operators know the “< 0.9s rule” so the consequences are usually minor
  - It get forgotten
    - It’s several weeks before this matters
- Robotic telescopes have no operator

Robotic Telescope

- Extract UT1-UTC from Bulletin A
  - No guarantee that the format is fixed
  - Code is fragile
  - Errors hard to detect
  - Risk from “invisible” character
  - Can sanity check now – but not in the future

XML

- Mature standard
- Abundance of tools
- Widely deployed
- Easy to generate
- Parsers available for most languages
- Just a text file

Designing the format

- What to put it?
  - All of Bulletin A
  - Target users of UT1-UTC (and polar motions?)

Minimal content

```
<earth_rotation_prediction_table>
  <earth_rotation date="2011-07-02" MJD="55813" x="0.1714" y="0.4109" UT1-UTC="-0.30187" />
  <earth_rotation date="2011-07-03" MJD="55814" x="0.1727" y="0.4099" UT1-UTC="-0.30234" />
  <earth_rotation date="2011-07-04" MJD="55815" x="0.1739" y="0.4088" UT1-UTC="-0.30289" />
  <earth_rotation date="2011-07-05" MJD="55816" x="0.1750" y="0.4077" UT1-UTC="-0.30351" />
  <earth_rotation date="2011-07-06" MJD="55817" x="0.1759" y="0.4065" UT1-UTC="-0.30417" />
 </earth_rotation_prediction_table>
```

Minimal “respectable” content

```
<?xml version="1.0" standalone="yes" ?>
 <earth_rotation_prediction start_date="2011-09-09" end_date="2011-09-13" xmlns="http://www.iers.org/xbulletins">
  <source url="http://data.iers.org/products/6/14858/orig/bulletina-xxiv-036.txt">
IERS Bulletin A Vol. XXIV No. 036
  </source>
  <reference url="http://maia.usno.navy.mil/bullainfo.html" />
  <reference url="http://hpiers.obspm.fr/iers/bul/bulb/explanatory.html" />
 <earth_rotation_prediction_table>
  <earth_rotation date="2011-09-09" MJD="55813" x_arcsec="0.1714" y_arcsec="0.4109" UT1-UTC_sec="-0.30187" />
  <earth_rotation date="2011-09-10" MJD="55814" x_arcsec="0.1727" y_arcsec="0.4099" UT1-UTC_sec="-0.30234" />
  <earth_rotation date="2011-09-11" MJD="55815" x_arcsec="0.1739" y_arcsec="0.4088" UT1-UTC_sec="-0.30289" />
  <earth_rotation date="2011-09-12" MJD="55816" x_arcsec="0.1750" y_arcsec="0.4077" UT1-UTC_sec="-0.30351" />
  <earth_rotation date="2011-09-13" MJD="55817" x_arcsec="0.1759" y_arcsec="0.4065" UT1-UTC_sec="-0.30417" />
  </earth_rotation_prediction_table>
 </earth_rotation_prediction>
```

Safety Critical Applications

- XML signature
  - http://www.w3.org/TR/xmldsig-core/
- Four styles
  - Enveloped
  - Enveloping
  - Detached in same file
  - Detached in separate file

Example signature


```
<Signature xmlns="http://www.w3.org/2000/09/xmldsig#">
 <SignedInfo >
  <CanonicalizationMethod Algorithm="http://www.w3.org/TR/2001/REC-xml-c14n-20010315" />
  <SignatureMethod Algorithm="http://www.w3.org/2000/09/xmldsig#dsa-sha1" />
  <Reference URI="http://data.iers.org/products/6/14858/orig/bulletina-xxiv-036.xml">
   <DigestMethod Algorithm="http://www.w3.org/2000/09/xmldsig#sha1" />
   <DigestValue>j6lwx3rvEPO0vKtMup4NbeVu8nk=</DigestValue>
  </Reference>
 </SignedInfo>
 <SignatureValue>MC0E~LE=</SignatureValue>
 <KeyInfo>
  <X509Data>
   <X509SubjectName>C=UK, O=eScience, OU=CLRC, L=RAL, CN=david terrett</X509SubjectName>
   <X509Certificate>
        MIIE8TCCA9mgAwIBAgICeSswDQYJKoZIhvcNAQEFBQAwUDELMAkGA1UEBhMCVUsx EzARBgNVBAoTCmVTY2lIbmNlQ0ExEjAQBgNVBAsTCUF1dGhvcml0eTEYMBYGA1UE
        AxMPVUsgZS1TY2lIbmNlIENBMB4XDTEwMTEyOTE1MDkyMFoXDTExMTIyOTE1MDky MFowVTELMAkGA1UEBhMCVUsxETAPBgNVBAoTCGVTY2lIbmNlMQ0wCwYDVQQLEwRD
        TFJDMQwwCgYDVQQHEwNSQUwxFjAUBgNVBAMTDWRhdmlkIHRlcnJldHQwggEiMA0G CSqGSIb3DQEBAQUAA4IBDwAwggEKAoIBAQCnaMTrTAcSV1ymri0395EICMIS8w/n kUTKZjE/
        Z9s6ERf59zElzLRoq426utKhZxjKy6HCUmfrAjURUB186DGhWFcFq899 a7k8prl/XVdoQFUT6675JVLhe76kCTDR5c28SB+FN5nB4Bgp5K8lN7XlrhzciuUg bP9sA1ElrPvn+UXcD/tHLM/
        AeEYRwics0YRQDtc9ep2EaDfHcWHj1BijPFi+nQN1 o9KGizRa2uROiROYqBm5ejrZHOcrkPqITPMjhVpnDzxtOqoYP83m/zGo6gvESzAG
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        Af8EBAMCA6gwLAYJYIZIAYb4QgENBB8WHVVLIGUtU2NpZW5jZSBVc2VylENlcnRp ZmljYXRlMB0GA1UdDgQWBBThmWx3Q5YJOBiEiCOETx1oPnEWVDAfBgNVHSMEGDAW
        gBRmYd16DeZf24qFArYxNa3YrF2HEjAjBgNVHREEHDAagRhkYXZpZC50ZXJyZXR0 QHN0ZmMuYWMudWswJQYDVR0SBB4wHIEac3VwcG9ydEBncmlkLXN1cHBvcnQuYWMu
        dWswGQYDVR0gBBIwEDAOBgwrBgEEAdkvAQEBAQgwQAYJYIZIAYb4QgEEBDMWMWh0 dHA6Ly9jYS5ncmlkLXN1cHBvcnQuYWMudWsvcHViL2NybC9yb290LWNybC5jcmww
        PgYJYIZIAYb4QgEDBDEWL2h0dHA6Ly9jYS5ncmlkLXN1cHBvcnQuYWMudWsvcHVi L2NybC9jYS1jcmwuY3JsMEAGA1UdHwQ5MDcwNaAzoDGGL2h0dHA6Ly9jYS5ncmlk
        LXN1cHBvcnQuYWMudWsvcHViL2NybC9jYS1jcmwuY3JsMA0GCSqGSIb3DQEBBQUA A4IBAQCLGBmWOvlAlk7K23d1eQWF3hb9ptR8WqlaOzzmJwNxvq7QiIKAi9BCbI+r v3NccRFdS+816qf+nYFo
        +DZc1ob83aLI1GLA/iZgQbniHJJnLedjGPRs4W6qFLMD +U9LCbo2dlRRIK7IGbX33McKWbuGHqDLEkh8cAqUOwR5Rspw6fefTsznHjIdIXEb gTScS07EqILY/
        uu6HLpfx02HJmCyzyYyufs8rw9PVJGYFd85AMWRr6LaStl0AUgH TefJ7SqB5fJuphYpIO5G8Vfog7IQ8wiMMg1y5heklxIJBMV+0pkhLqmc5/GqlJrs He7OhpJzyqLJSHHp2mlYEmTGLU/F
   </X509Certificate>
  </X509Data>
 </KeyInfo>
</Signature>
```

Is it practical?

- "Signing is not hard"
  - Necessary libraries distributed with Java and MS development IDE
- Needs a certificate
- Verification only likely to be done by experts
- *Can be added later*