Will XTCE work for your organization? It will for us!
Infusion of XTCE to NASA missions

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NASA’s XTCE effort

• Like you, NASA’s Jet Propulsion Laboratory has investigated ways to share and interpret information across centers and agencies.
  • More consistency across products and with commercial software is required.

• XML Telemetric & Command Exchange (XTCE) standard has been considered for telemetry and command information:
  • Needed: perform an examination of its applicability to the JPL Advanced Multi-Mission Operations System (AMMOS) to meet our needs

• We have recently completed processes to allow us to assess the suitability of XTCE to support our missions.
  • Challenge – To rapidly integrate and test command and telemetry metadata from one agency to another agency’s satellite to reduce schedule and cost
  • Solution – We found we can use a common database exchange (XTCE) so integration and test is familiar and straightforward
What is XTCE?

**XML Telemetric and Command Exchange (XTCE)**

- Dictionary exchange standard oriented towards mission operations which describes properties including:
  - Commands, arguments, and other aspects of commanding
  - Telemetry, mnemonics, limits and calibrators
  - Packaging: such as packets or minor frames
  - Derivations/Pseudo-telemetry
  - And so forth

- Formalized as both a CCSDS and Object Management Group (OMG) Standard

- GovSat subset published by OMG last year
  - Hosted on both OMG and CCSDS Websites

- Adopted by several civilian space agencies around the world
  - And by several US DoD groups, possibly others
JPL’s XTCE Method

• We started by quantifying XTCE’s ability to capture the telemetry and command definitions of our current missions
  • The result was a mapping and a percentage of it “in XTCE”.
• Next we carefully crafted extensions into XTCE to cover the missing percentage.
  • Goals:
    • Don’t break existing syntax
    • Have the extensions clearly appear as such in the XML files (for analysis)
  • Result: XTCE_AMMOS
• Thirdly, build tools and use real mission databases to test XTCE_AMMOS:
  • Goal: perform **LOSSLESS** round-trip conversion from original database to XTCE w/extensions
  • Juno and Odyssey were chosen
JPL XTCE-Juno mission
The Juno spacecraft

Juno spacecraft at LMSS. Image credit: NASA/JPL-Caltech/LMSS.
JPL, JIRAM, and LM teams during instrument integration.

JPL, JIRAM, and LM teams during integration. Image credit: NASA/JPL-Caltech/LMSS.
Evaluated XTCE representation of AMMOS Dictionaries

Purpose: Evaluate XTCE representation of AMMOS Dictionaries

- Mapped 11 AMMOS Dictionaries to XTCE
  - Common, Command, Telemetry, APID, EVR, Generic Decom Map, Generic Decom Map by APID, Alarm, Alarm Notification, EVR Notification, Transfer Frame

- Characterized the mapping (%)
  - Identified consistencies and gaps
  - Recommended solution for items that did not map (separate schema, ancillary)
XTCE Specification to AMMOS Dictionaries Flow

- Full XTCE 1.1 Spec.
  - Analyzed general mission needs
  - Too bulky, no field limitations

- GovSat Spec.
  - Analyzed AMMOS needs
  - Good general standard, does not cover all AMMOS needs

- GovSat Spec. with AMMOS Extensions
  - Measured compliance to GovSat and to Extensions
  - AMMOS add-ons extend capability, meet all AMMOS req.

- AMMOS’s 11 Dictionaries
  - Populated with JPL mission definitions
  - Can convert either direction between XTCE and AMMOS dictionaries

- Operational Software ingests AMMOS Dictionaries
  - AMMOS Software

With release of XTCE 1.2 more items covered by standard and less by extensions

- Must show 100% compliance with extension; want to move towards very high compliance to GovSat.
MMD to XTCE Conversion Round-Trip

Key:
MMD = Multi-Mission Dictionary

Goal - demonstrate “Round Trip” of MMD conversion to XTCE and back without loss of content
JPL’s XTCE Method

• Then we did a metric analysis to see how well we did:

  • We wanted to know how much of XTCE we used vs extensions per database

  • We followed a rigorous process to obtain the metrics
## Metrics from MMD to XTCE Conversion

<table>
<thead>
<tr>
<th>Input</th>
<th>Odyssey Mission Dictionaries</th>
<th>Juno Mission Channel Dictionaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Apid (apid table)</td>
<td>- Apid (apid table)</td>
<td></td>
</tr>
<tr>
<td>- Channel (telemetry)</td>
<td>- Channel (telemetry)</td>
<td></td>
</tr>
<tr>
<td>- Command</td>
<td>- Generic decom by apid</td>
<td></td>
</tr>
<tr>
<td>- Generic decom by apid</td>
<td>- decom maps (13 packet files)</td>
<td></td>
</tr>
<tr>
<td>- decom map (1 packet file)</td>
<td>- Transfer frame</td>
<td></td>
</tr>
<tr>
<td>- Transfer frame (front end)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- alarms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Evr (event)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Output</th>
<th>Events</th>
<th>DataSource</th>
<th>DecomMap</th>
<th>DecomMapApid</th>
<th>XferFrame</th>
<th>Alarms</th>
<th>Fill/Repeat</th>
<th>CmdArg AbsTime</th>
<th>CmdArg EnumRange</th>
<th>MaxLen Strings</th>
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</thead>
<tbody>
<tr>
<td>Odyssey Mission Dictionaries</td>
<td>225497</td>
<td>5662</td>
<td>208</td>
<td>168</td>
<td>25</td>
<td>5279</td>
<td>190</td>
<td>10</td>
<td>19559</td>
<td>306</td>
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<tr>
<td>Juno Mission Channel Dictionaries</td>
<td>23682</td>
<td>8707</td>
<td>:904</td>
<td>:136</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measurement</th>
<th>XTCE 1.1</th>
<th>XTCE 1.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>XTCE+JPL extensions</td>
<td>714,701</td>
<td>100.00%</td>
</tr>
<tr>
<td>XTCE</td>
<td>356,166</td>
<td>49.83%</td>
</tr>
<tr>
<td>JPL Extensions</td>
<td>358,535</td>
<td><strong>50.17%</strong></td>
</tr>
</tbody>
</table>

**High due to number of Events in MMD File.**

- XTCE 1.1 does NOT handle events
- XTCE 1.2 WILL handle events

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**XTCE AMMOS completely supports the Odyssey MMDs and Juno Channel Dictionary**
JPL’s XTCE Method

- Brought JPL extensions to OMG/CCSDS standard community:
  - Discussed for inclusion into XTCE 1.2
    - Some were accepted, some deferred and some were rejected
  - Face-To-Face meetings with the OMG Space Domain Task Force
  - Final OMG meeting in Austin solidified all issues relevant to XTCE 1.2 and JPL
    - By participating our voice was heard, many of the extensions made it in
    - But a few will still be needed

- XTCE 1.2 soon to be published
JPL Items in XTCE 1.2 OMG Summary

• OMG accepted many suggested enhancements to XTCE in version 1.2, but chose to defer or reject some, which must be accommodated in JPL extensions to support AMMOS

• Update at the last OMG meeting:

22 items in original JPL files not addressed in XTCE, change requests were then submitted

- 19 Accepted
- 1 Rejected
- 2 Deferred
JPL Infusion Tasks

• Finally we moved to infusion at JPL:

  • FSW Core, Instrument Software, Ground Software, and Project System Engineering

  • Identified and worked with additional NASA missions and interfaces to incorporate standard

  • XTCE demonstration with the FSW Core and Europa Clipper mission

    • Potentially others, such as Mars 2020, INSPIRE CubeSat, JSC

  • Support implementation and use of standard across other NASA centers
JPL collaboration with ESA
TGO Electra Instrument

• The Trace Gas Orbiter (TGO) will be a Mars telecommunications orbiter and atmospheric gas analyzer mission (launch 2016)

• It will deliver the ExoMars EDM lander and then proceed to map the sources of methane on Mars and select a landing site of the ExoMars Rover (launch 2018)

• NASA will provide an Electra telecommunications relay and navigation instrument to assure communications between probes and rovers on the surface of Mars and controllers on Earth (till 2022)
Conclusions

• XTCE can work for you -- Gaps can be handled 100% is critical: 98% is not good enough!
  • It is important to assess compliance between your existing systems and XTCE
  • as suggested by updates to the standard
  • as local extensions
• Benefits may come in several ways
  • Easier coordination across different existing or new tools
  • Simplified data exchange with external partners
  • More efficient operations
  • Reduce maintenance costs
    • Reduces variation among dictionaries (for different missions)
• Import XTCE from others: Big Savings
  • definitions of instruments
  • or even entire satellites developed by others in XTCE,
  • and automatically create the corresponding AMMOS dictionaries.

• Standards participation works!
Future plans

• Continue infusion process with NASA and ESA missions:
  • Collaboration towards a joint international standard (NASA/ESA tailoring)

• Or Use XTCE as AMMOS native dictionary:
  • Some up front cost, but would make sharing even easier/cheaper
Acknowledgments

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- References:
  - OMG XTCE: [http://www.omg.org/space/xtce/](http://www.omg.org/space/xtce/)
  - Juno mission: [http://missionjuno.swri.edu/](http://missionjuno.swri.edu/)
  - ESA TGO: [http://exploration.esa.int/mars/46475-trace-gas-orbiter/](http://exploration.esa.int/mars/46475-trace-gas-orbiter/)
Questions?

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<table>
<thead>
<tr>
<th>Issue #</th>
<th>Title</th>
<th>Disposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>19367</td>
<td>Bit Extract</td>
<td>Supported (XTCE 1.2)</td>
</tr>
<tr>
<td>19368</td>
<td>Alarm count in and out</td>
<td>Accept</td>
</tr>
<tr>
<td>19369</td>
<td>Re-architect XTCE alarm model.</td>
<td>Partially Accept</td>
</tr>
<tr>
<td>19371</td>
<td>Mask Alarm needed</td>
<td>Supported (XTCE 1.1, 1.2)</td>
</tr>
<tr>
<td>19372</td>
<td>Digital Alarm needed</td>
<td>Supported (XTCE 1.2)</td>
</tr>
<tr>
<td>19373</td>
<td>Change alarm</td>
<td>Supported (XTCE 1.1, 1.2)</td>
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<tr>
<td>19374</td>
<td>Combination alarm</td>
<td>Defer</td>
</tr>
<tr>
<td>19375</td>
<td>Off Alarm</td>
<td>Partially Supported (XTCE 1.1, 1.2)</td>
</tr>
<tr>
<td>19376</td>
<td>Elevate annotation specifying time string formats to an attribute</td>
<td>Accepted</td>
</tr>
<tr>
<td>19378</td>
<td>Expand Telemetry data source</td>
<td>Accepted</td>
</tr>
<tr>
<td>19379</td>
<td>Raw units</td>
<td>Defer</td>
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<tr>
<td>19380</td>
<td>Title</td>
<td>Supported (XTCE 1.1, 1.2)</td>
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<tr>
<td>19381</td>
<td>Categorization (Label Set)</td>
<td>Duplicate</td>
</tr>
<tr>
<td>19382</td>
<td>Variable in decom map</td>
<td>Partially Supported (XTCE 1.1, 1.2)</td>
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<tr>
<td>19383</td>
<td>width semantics</td>
<td>Partially Supported (XTCE 1.1, 1.2)</td>
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<tr>
<td>19384</td>
<td>Gap spacer in container</td>
<td>Supported (XTCE 1.1, 1.2)</td>
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<tr>
<td>19385</td>
<td>Switch in container</td>
<td>Partially Supported (XTCE 1.1, 1.2)</td>
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<tr>
<td>19386</td>
<td>Front-end Processing encodings</td>
<td>Reject - Possible New SpaceDTF Standard Specification</td>
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<tr>
<td>19387</td>
<td>Identifying List(s) -- APID to decom map</td>
<td>Supported (XTCE 1.1, 1.2)</td>
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<tr>
<td>19388</td>
<td>Events not supported</td>
<td>Accept</td>
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<tr>
<td>19403</td>
<td>Fill arguments</td>
<td>Supported (XTCE 1.1, 1.2)</td>
</tr>
<tr>
<td>19404</td>
<td>Repeat arguments</td>
<td>Supported (XTCE 1.2)</td>
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