Using XTCE on the GOES-R series

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OBJECT MANAGEMENT GROUP®

Using XTCE on the GOES-R series

- Overview
- Challenging Initial Conditions
- Customizations and Resolutions
- Communication

GOES-R series Overview

- NOAA's latest generation of Geostationary Operational Environmental Satellites (GOES), known as the GOES-R Series, is the nation's most advanced fleet of geostationary weather satellites.
  - The GOES-R series continues NOAA’s GOES series of satellites. The first GOES satellite was launched in 1975.
- The GOES-R mission is comprised of four satellites: GOES-R, GOES-S, GOES-T, and GOES-U.
  - Six instruments: ABI, EXIS, GLM, MAG, SEISS, SUVI. There are both earth and sun-pointing instruments providing real-time environmental data, along with space weather and solar monitoring capabilities.
- GOES-R/S launched November 2016/March2018 with 6 instruments.
- GOES-T launch date is TBD (NET January 2022).
- GOES-U will launch with an additional instrument: CCOR.
- www.goes-r.gov

GOES-R series Stakeholder Distribution

ABI/Harris/ Fort-Wayne

EXIS/LASP/ Boulder

GLM/LM/ Palo Alto

SEISS/ATC/ Boston

SUVI/LM/Palo Alto

Spacecraft/ LM/Littleton

MAG

GOES-R Flight Project/NASA/ Greenbelt

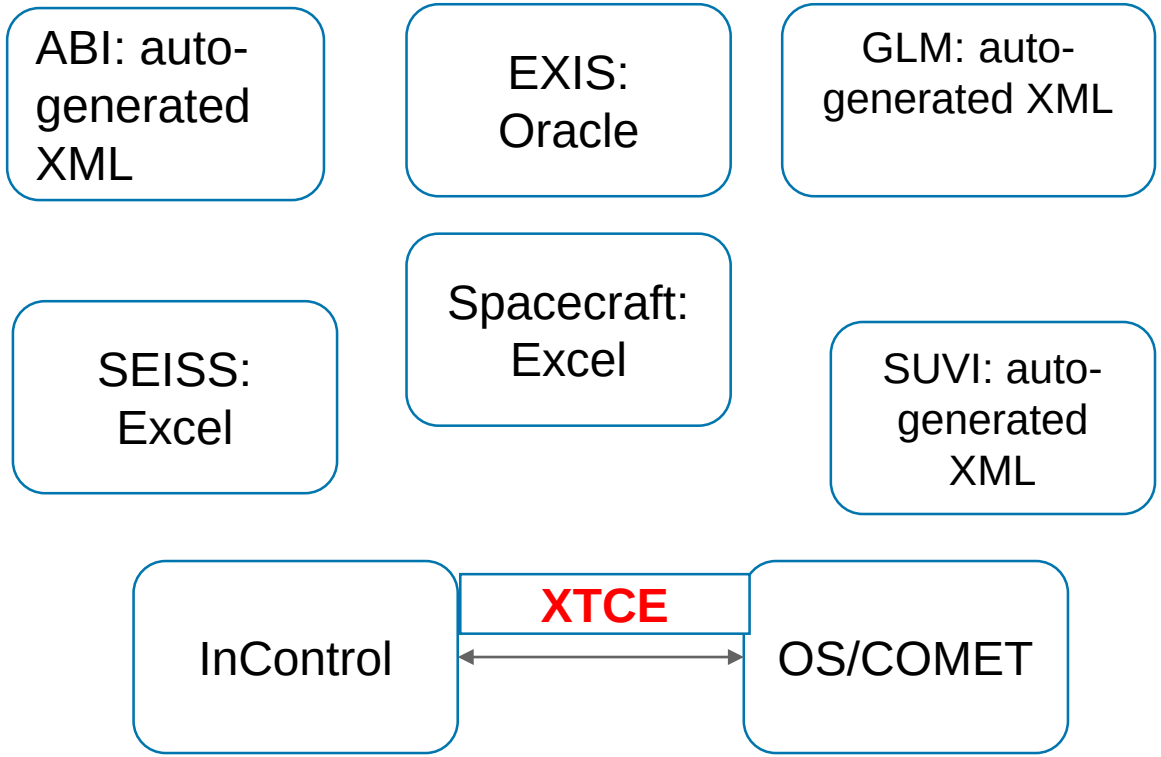
GOES-R Ground Project/NASA/ Greenbelt

Peraton/Melbourne

Stakeholders are spread out over the US, with little to no initial knowledge of even xml and with no idea how to spell XTCE. Each instrument vendor had already developed telemetry processing and commanding capabilities, using their own miniature, proprietary Ground Systems.

GOES-R series Original Database Formats

Originally, the individual vendor databases existed in diverse formats, there was no standardization: No one was using XTCE, although XTCE was the format required by both of the Ground System vendors.

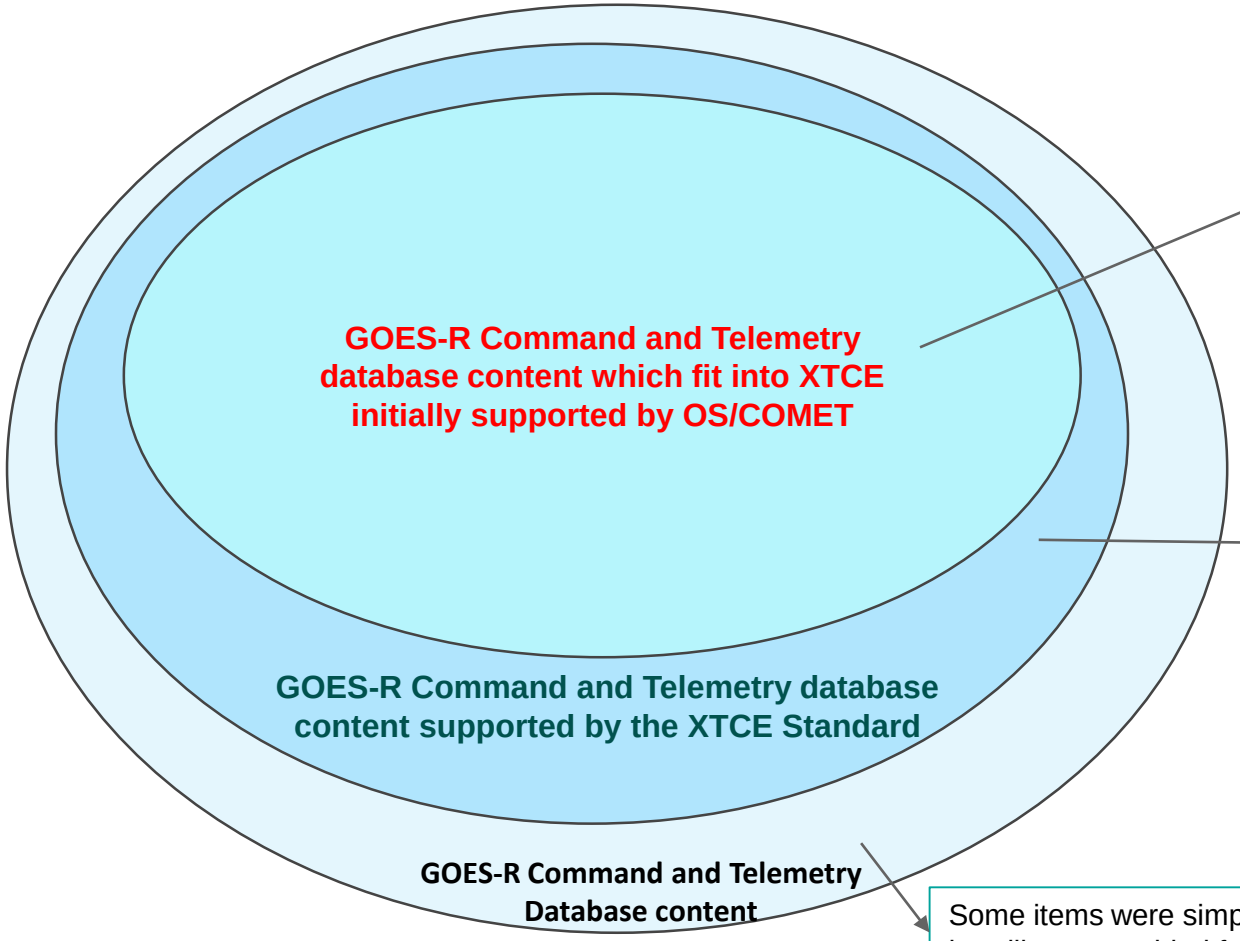


- The immediate predecessor of GOES-R, the GOES-NOP series, used databases which were text files in the Spacecraft vendor's proprietary format.
- OS/COMET was selected as the Ground system for Satellite Operations.
  - OS/COMET has a utility to process XTCE databases: xdbgen, along with a document titled "XTCE Database Converter Guide", documenting the XTCE schema mapping to functionality supported by OS/COMET.
- The Spacecraft vendor was selected as the "Integrator" for the GOES-R Satellite Command and Telemetry Database.
  - The Spacecraft vendor selected InControl as the Ground System for Integration and Test. InControl also supports XTCE databases.

Database Conversion and Development Timeline

- 2010: Spacecraft vendor and Flight Project met to discuss using the XTCE format as the delivery format of the Satellite Command and Telemetry database.
- 2011
  - Flight project shared documentation across all vendors: XTCE schema, XTCE Green and Blue books, and OS/COMET's XTCE Database Converter Guide showing which elements were supported by OS/COMET.
  - Multiple meetings were held between individual instrument vendors and other stakeholders to discuss converting to the XTCE format.
  - Customized prototypes for the conversion were provided to vendors, upon request.
  - As the Integrator, the Spacecraft created an ICD based on the list of XTCE tags supported by OS/COMET.
  - **Initially, the Spacecraft vendor suggested an intermediate format for the Satellite Command and Telemetry database input from the instruments, proposing to subsequently convert the databases delivered in the intermediate format to XTCE.**
    - **This suggestion was the BEST road NOT taken!**
    - XTCE was already a pre-defined, standardized exchange mechanism.
    - Implementing this suggestion would have introduced extraneous intermediate layers and added unnecessary complexity to an already convoluted task.
  - All vendors dedicated personnel and resources to the database conversion task.
- 2012: Database maturation in progress, for all vendors. Meetings were held as issues were encountered and work-arounds were implemented.
- 2013: The first GOES-R Satellite Telemetry and Command database was delivered in XTCE format.
- 2014-2015: Multiple ETE tests were conducted using iteratively delivered Telemetry and Command databases. All commands in the database were sent at least once to the Satellite. Any unexpected responses were investigated.
- 2016: GOES-R launched successfully.
- 2017: Updates to GOES-R and GOES-S databases continued.
- 2018: GOES-S launched successfully.
- 2019: GOES-R, GOES-S database updates continue. GOES-T database development in progress.

Fitting the GOES-R T&C Database into the XTCE format



All vendors use CCSDS packets so the mapping to the XTCE schema was quite simple, in most cases.
The vast majority of GOES-R command and telemetry packet definitions fit directly into the portion of the XTCE schema, which was initially supported by OS/COMET.

Several XTCE elements and attributes were added to support GOES-R's database content. Example: Context dependent limits. The GOES-R database utilized a subset of the XTCE schema's features.

Some items were simply too obtuse to be fit into the XTCE database.. Customized handling was added for these cases.

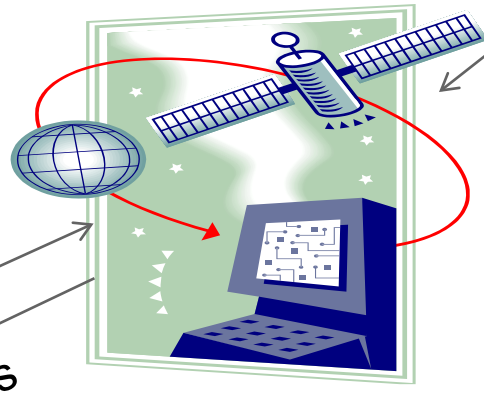
Fitting the GOES-R T&C Database into the XTCE format (cont)

- More than 90% of the telemetry and command content fit directly into XTCE fields, which were already supported by OS/COMET. Additional XTCE features were added upon request. However, as expected, some telemetry and commands couldn't fit into the XTCE schema.
- File loads required special processing, since multiple CCSDS packets were required to send files with a size larger than the maximum payload of a CCSDS packet.
- Customized handling was required for table dumps, file dumps, memory dumps, and dwell packets which are configured dynamically. One of the instrument's telemetry packets required special handling for a packet which included dynamic content; the XTCE element IncludeCondition could have been used to support this packet. However, since only a few packets required this functionality, the decision was to implement specialized processing only upon receipt of these packets.
- The "Abstract" attribute was set to true, to identify which commands and telemetry packets required customized processing.
- Complex calibration equations were supported by code snippets embedded into the database.
  - PolynomialCalibrators were not sufficient for all calibrations. The AlgorithmSet element supports more esoteric equations. Vendors utilized c and CCL (OS/COMET's language) code for conversions beyond polynomial calibrations; the vendors also included corresponding AlgorithmSets written in JAS (InControl's language). This way, we were able to utilize the full set of possible math functions. Using AlgorithmSet also allowed for logical operators and decisions, example: the calibration could be different based on which side of the instrument is used.
- Byte Order: Both little and big endian parameters are used by GOES-R but the XTCE schema only had a field for bit order. AncillaryData fields were used to specify Byte Order.
- The AncillaryData field was also used by vendor to include non-XTCE compliant content, in order to provide traceability to the vendors' original database format.

SpaceSystem Hierarchy vital to GOES-R series mission timeline success.

A sentinel role of the T&C database is to provide a bit level definition for commands and telemetry, for a Ground system. The Ground and on-board FSW definitions of the telemetry and command packets need to match. With six different vendors, running six different FSW versions on six different development cycles en route to launch, GOES-R fully utilized XTCE's structure of unique, independent SpaceSystems. Each vendor's database was placed into one SpaceSystem, with a parent GOES-R SpaceSystem.

T&C packets expected and produced by on-board FSW.



Command Packets

Telemetry Packets

T&C database

SpaceSystem name = "GOES-R"
- SpaceSystem name = "ABI"
- SpaceSystem name = "EXIS"
- SpaceSystem name = "GLM"
- SpaceSystem name = "SEISS"
- SpaceSystem name = "Spacecraft"
- SpaceSystem name = "SUVI"

The Spacecraft, ABI, EXIS, GLM, SEISS, and SUVI have independent on-board FSW, corresponding to independent databases. Asynchronous and frequent changes were a regular part of the development cycle. Multiple revisions of databases and FSW were received from the vendors. New satellite databases were created as needed, leaving unaffected SpaceSystems unchanged.

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Dedicated discussions: Database Change Coordination Board

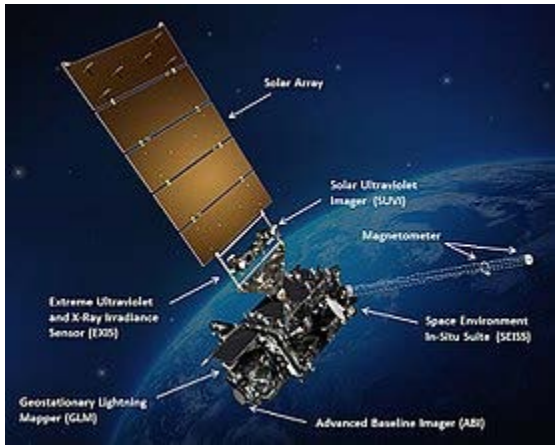
- Even with XTCE as a common exchange format, OS/COMET and InControl had individual dependencies and constraints, which weren't documented and manifested as surprise system malfunctions.
  - Example: One instrument database had SequenceContainers with two duplicated RestrictionCriteria. After removing the duplication, one Ground System could no longer process the (still XTCE compliant) database.
- Subsequently, all database changes were discussed between all stakeholders before implementation, to assess and mitigate impacts before the changes were deployed.

- A GOES-R series Database Change Coordination Board was convened. Attendees included Flight and Ground representatives, all vendors, and the Ground system developers.
- **Consistent communication is still required, even with a common exchange format.**

GOES-R mission owes part of its success to the XTCE standard

1849 Polynomial conversions

56873 Mnemonics



2024 Commands

Two different Ground Systems

Nine years and counting!

12482 Limits

Six vendors

Thank you OMG!