James Webb Space Telescope XML Database: From the Beginning to Today[1]

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Abstract—The James Webb Space Telescope (JWST) Project has been defining, developing, and exercising the use of a common eXtensible Markup Language (XML) for the command and telemetry (C&T) database structure. JWST is the first large NASA space mission to use XML for databases. The JWST Project started developing the concepts for the C&T database in 2002. The database will need to last at least 20 years since it will be used beginning with flight software development, continuing through Observatory integration and test (I&T) and through operations. Also, a database tool kit has been provided to the 18 various flight software development laboratories located in the United States, Europe, and Canada that allows the local users to create their own databases.

Recently the JWST Project has been working with the Jet Propulsion Laboratory (JPL) and Object Management Group (OMG) XML Telemetry and Command Exchange (XTCE) personnel to provide all the information needed by JWST and JPL for exchanging database information using a XML standard structure. The lack of standardization requires custom ingest scripts for each ground system segment, increasing the cost of the total system. Providing a non-proprietary standard of the telemetry and command database definition format will allow dissimilar systems to communicate without the need for expensive mission specific database tools and testing of the systems after the database translation. The various ground system components that would benefit from a standardized database are the telemetry and command systems, archives, simulators, and trending tools. JWST has exchanged the XML database with the Eclipse®, EPOCH®, ASIST® ground systems, Portable spacecraft simulator (PSS), a front-end system, and Integrated Trending and Plotting System® (ITPS) successfully.

This paper will discuss how JWST decided to use XML, the barriers to a new concept, experiences utilizing the XML structure, exchanging databases with other users, and issues that have been experienced in creating databases for the C&T system.

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1. INTRODUCTION

JWST is a large 6-meter aperture infrared space telescope with a five-year mission (with a design goal of ten years). JWST will continue advancing breakthroughs in our understanding of the origins of the earliest stars by detecting the first starlight and other questions about the early universe. The launch date for JWST is currently planned for no earlier than June 2013, and the JWST will be placed in orbit at L2[2] shown in figure 1. The JWST team includes several partners in multiple locations:

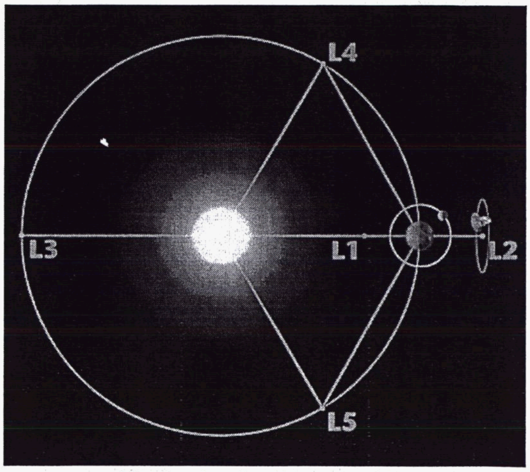

Figure 1 – Lagrange points

[1]U.S. Government work not protected by U.S. copyright
[2] IEEEAC paper #1048, Version 1, Updated 10/11/2005

- Project management is located at Goddard Space Flight Center (GSFC).

- Observatory prime contactor, Northrop-Grumman Space Technologies (NGST), located in Redondo Beach, California and is responsible for building the spacecraft. They are also responsible for integrating the science instruments and Integrated Science Instrument Module (ISIM) to the spacecraft. NGST will test the entire observatory and is the lead in launch and commissioning operations.

- The ISIM is the responsibility of GSFC. The ISIM is a cryogenic instrument module that is integrated with the optical telescope element, science processors, software, and other electronics. The ISIM also provides structure, environment, and data handling for three science instruments and the observatory Fine Guidance Sensor.

- Near Infrared Camera (NIRCam) instrument (University of Arizona and Lockheed Martin), will study wavelengths covering from 0.6 to 5 microns. It will study the formation of galaxies, star formation, brown dwarfs, and planetary system from birth to maturity.

- Near Infrared Multi-Object Spectrometer (NIRSpec) built in Europe will be a spectrograph in the wavelength range of 0.6 to 5 microns. It will study the galaxy formation, clustering, chemical abundances, star formation, kinematics, active galactic nuclei, and young stellar clusters.

- Mid Infrared Instrument (MIRI) will provide JWST with imaging and spectroscopy at wavelengths from 5 through 27 microns. It is an international collaboration between NASA JPL and ESA. MIRI will participate in the discovery of the 'first light', assembly of galaxies, history of star formation, growth of black holes, preduction of heavy elements, how stars and planetary systems form, evolution of planetary systems and conditions for life.

- Flight Guidance System (FGS) built in Canada will enable stable pointing at the milli-arcsecond level. Also, the FGS will have three simultaneous fields of view of about 2.3 x 2.3 arcmin.

- NASA's Deep Space Network located at JPL, Madrid, Goldstone and Canberra will provide the command, telemetry, and tracking services from launch to normal operations at L2.

- Science and Operations Center located at the Space Telescope Science Institute (STScI) in Baltimore MD. A view of the JWST spacecraft model can be seen in Figure 2, along with the JWST project personnel at GSFC.

The XML database is key to the different systems exchanging information, migration of ground system components, and reducing testing needed for each database release.

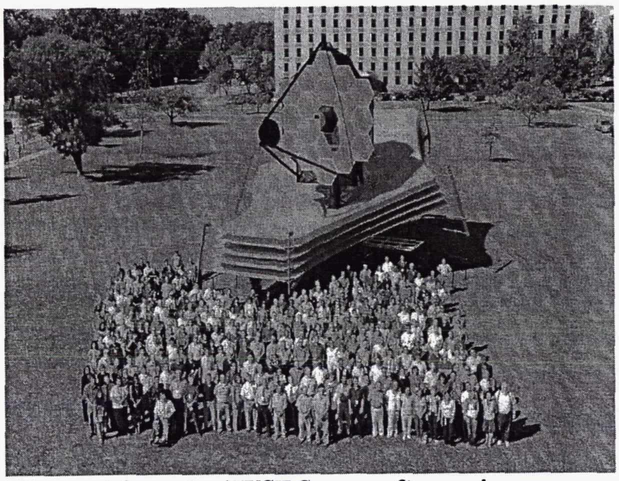

Figure 2 – JWST Spacecraft overview

All of the JWST teams are actively using the JWST XML database in their local facilities in coordination with the central database at STScI. An overview of the interaction between these JWST various teams using the JWST XML database is shown in figure 3.

The success of the JWST database that has been actively used since January of 2002, is due in large part to the flexibility of the XML technology.

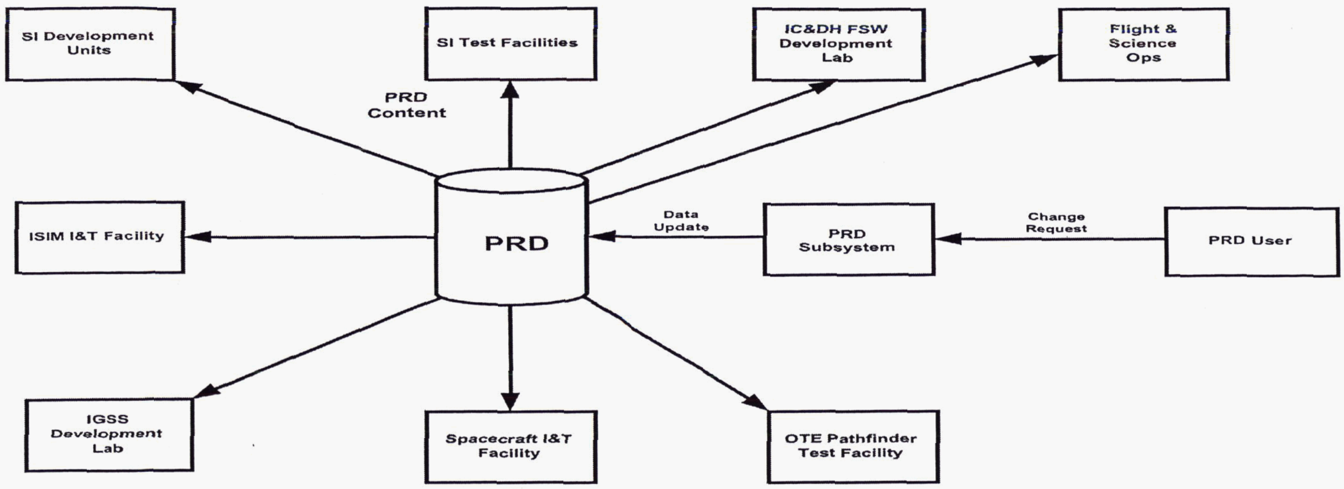

Figure 3 – JWST XML Database Team Interaction

2. JWST DATABASE HISTORY

One of the goals of the JWST Project is to use the same ground system during I&T that will be used in the operational system. A team of JWST system engineers were gathered in 2000 to look at the various options, technologies, and industry trends. It is important to note during the team's deliberations there were no restrictions placed on the team. All database options were open for consideration. The traditional NASA database systems using Microsoft Access® and Oracle® were considered early in the process. Visits to several NASA missions were done as well as bringing in personnel to the team with experience in large-scale database systems. The team, looking at the need for a 20-year database, quickly came to the conclusion that the data needed to be non-proprietary since companies and products will change over time.

Once the team chose XML as the database format for data storage, the immediate challenge was to explain this selection to the JWST Project. Since this was a departure from previous GSFC/NASA database structures and was 'new' technology, there were many skeptics. XML in its raw form, as shown in figure 4, created quite a firestorm. The concept of the application being separated from the data, as well as, the lack of an intuitive relational database were the main reasons cited for rejecting the XML database. The JWST system engineers had been concentrating early in the JWST database development creating and organizing the XML tags. The team also knew in the final product, the user experience was very important and that viewing, editing, and writing raw XML was not desirable. Until the user interfaces were developed, the raw XML is what the various JWST database reviewers saw and manipulated which immediately started questions about the wisdom of using XML, and there were requests for changing back to known, heritage GSFC/NASA database systems using Oracle® and Microsoft Access®.

As the JWST database matured in both its uses and interfaces, the XML took on a life of its own among the JWST Project users. The JWST Project users began not only to accept the use of the XML for command and telemetry definitions, but started adding XML to other systems, such as GSFC spacecraft and table load files.


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    <FlippedBits></FlippedBits>
    <FlippedWords></FlippedWords>
    <ForcePublish></ForcePublish>
  </TlmCoreElements>
  <TlmDescriptiveInfo>
```


Figure 4 – JWST Raw XML

JWST is a leader in using XML on large-scale spacecraft databases. Working with various NASA and international standards groups, JWST is spreading the knowledge and experiences gained during our database development. The JWST database has three years of use, and with at least 22 more years to go, a lot of history is still to be written.

3. XML THE EARLY YEARS

It became evident very early in the process that for JWST to be successful in its goals the database data portion must be separated from any particular application. Companies and Commercial-Off-the-Shelf (COTS) products[4] will come and go over the 25-year life of the JWST database. XML allows for the data to be stored in a manner that allows it to be easily transformed, ingested, and accessible to many other systems. XML in the commercial industry was taking off with Apple iTunes® and Microsoft's Office® products core being migrated to XML and more tools were becoming available to view and edit XML.

In 2001, the team started prototyping the JWST XML using the Earth Observation System (EOS) AURA satellite database. This database had about 25,000 data items for command and telemetry, which is the expected size of the JWST database. It took approximately two weeks to convert all the data into the JWST XML structure since we were using very basic tools. Now that we had a database with test data the first steps in verifying performance, sizing, and allowed for the development of the first user interfaces for viewing the data.

The performance testing showed that database conversions to multiple formats could be accomplished in minutes using a standard desktop PC running windows 2000NT with 256MB RAM at 1.8GHz. For the JWST database each command and telemetry mnemonic will be a separate container or file. For example, if there are 200 commands in the database, then 200 containers will be delivered in a command folder. The sizing testing indicated no issues with each command and telemetry file about 4KB in size, for a total of 100MB. The user interfaces, as shown in figure 5, were developed using a few key goals. The first goal is to use standard web browser interfaces so any workstation can use the database interface without having special software. The second goal is to remove any of the XML tags and code from the user experience. Third and final goal, the input form is to check for legal values to identify as many errors as far forward in the process as possible to reduce the amount of re-work the user would need to do.

After the prototyping success and demonstrations of the user interface, the JWST database started to prepare the Interface Control Document (ICD), ingest the current GSFC flight software command and telemetry definitions, and work on the exchange of information with the prime contractor.

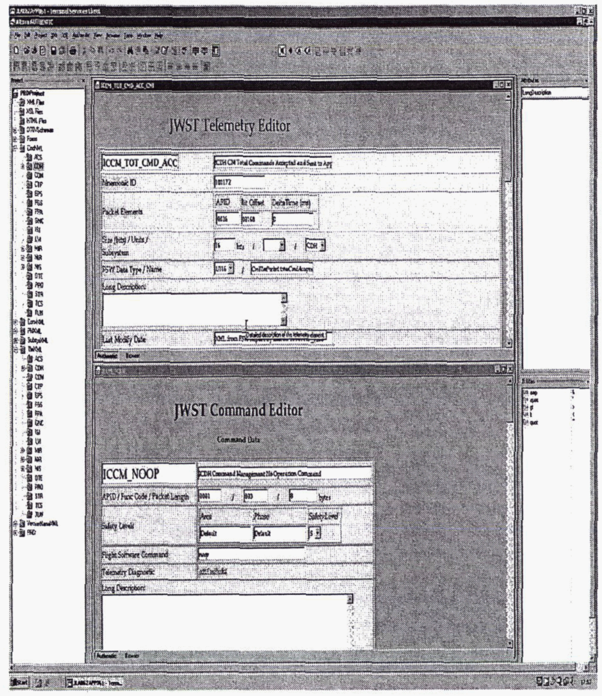

Figure 5 – JWST Database User Interface

Another effort discussed later in this paper is the system compatibility checkouts that were also taking place not only in the early years, but continue today.

4. JWST XML GROWTH

Once the XML standard was approved by the JWST Project and databases were being produced using command and telemetry definitions, many other products including a finer definition of the command and telemetry were added to the database. As can be seen in figure 6, showing the first official JWST database directory, the information was limited to command and telemetry in the JWST database.

Figure 6 – JWST Early Database

The growth beyond this simple beginning was not unforeseen. The JWST database working group maintains a list of potential items to be added to the database. At one time this list included 22 new items and as the working group goes through the list with users; additional, deletions and modifications are completed. Once an item is approved for the JWST database, a need date is determined and the JWST database system engineering team works on the XML structure, organization, and the impacts to the existing database. Figure 7 shows the most recent JWST database directory structure that has 22 directories where the very first database contained only 4 directories.

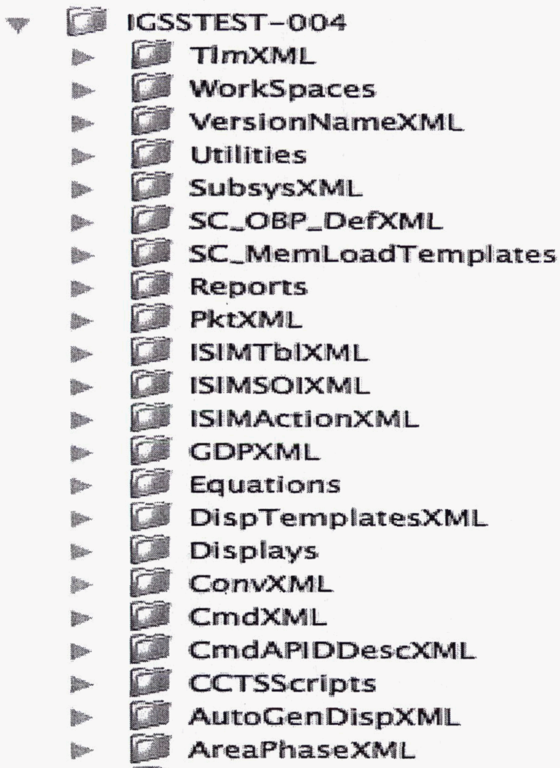

Figure 7 – JWST Current Database

The growth of the JWST XML database, as with the growth of any system, maintaining compatibility with the tools being used, the systems ingesting the data, and with the existing data in the database presents a challenge. The JWST has implemented a Change Control Board (CCB) for the database that includes a wide range of users and well as JWST system engineers not only to evaluate the merits of a change request, but also the impact of such a change. The JWST database tools, available to all user, includes a cross referencing tool to allow a user to evaluate the impact of a change prior to proposing.

5. JWST XML TODAY

The JWST database today is still one of the largest XML spacecraft at NASA. Figure 8 shows the current database system available to 24 distinct laboratories, each geographically dispersed, having local database tools to work with the XML databases. Each of these laboratories database tools are used for the exporting and importing of data both locally and to the central database system, inputting data to the database certification process, and providing various reports. The JWST centralized certified database repository is maintained by the STScI.

JWST is working with various suppliers of systems to incorporate the XML in a more direct manner, limiting the conversions including the Eclipse® system. JWST has found that these conversion processes, while not difficult will add time to the whole database build process time. JWST's goal is to build a complete database within 15 minutes. This goal is to reduce the database 'short cuts' found in some I&T environments that do not follow the configuration management process. If the database is built quick enough the users will be less likely to implement the 'short cuts'. Using a direct XML import, such as with the PSS, there is no database build time. However with the Eclipse® system, the database currently has to be converted to a Microsoft® Access database and then to a flat file that takes 13 minutes.

JWST is participating and meeting with the various industry standard groups, such as the Object Management Group (OMG) and the CCSDS spacecraft monitor and control working group, to ensure the JWST XML maintains a level of compatibility. JWST Project also works with various GSFC projects and the JPL Mars missions to provide a level of consistency between the various NASA projects.

6. JWST XML COMPATIBILITY

One of the cost items noted with several projects the JWST system engineers had worked on in the past, has been the cost of coding database translators for the various ground system components. Generally the spacecraft database format is provided by the spacecraft vendor and often unique to the spacecraft vendor. While this is fine for the spacecraft vendor systems they are often difficult to ingest into other system needed to complete the needed mission ground system components. Transforming XML for other ground system components is relatively minor with the advantage of separating the data from any particular application. The JWST XML database has been used in many systems, including several command and control systems, simulators, front-end processors, engineering archives, and engineering analysis systems. Also the JWST database is being used to assist the CCSDS in defining the XML database exchange format, XTCE. There are several United States programs that require the vendor of spacecraft components to deliver a database in XTCE format. The advantage of XTCE is simple, it provides a predetermined XML database or exchange format that vendors or organizations can use, instead of designing the XML database from scratch.

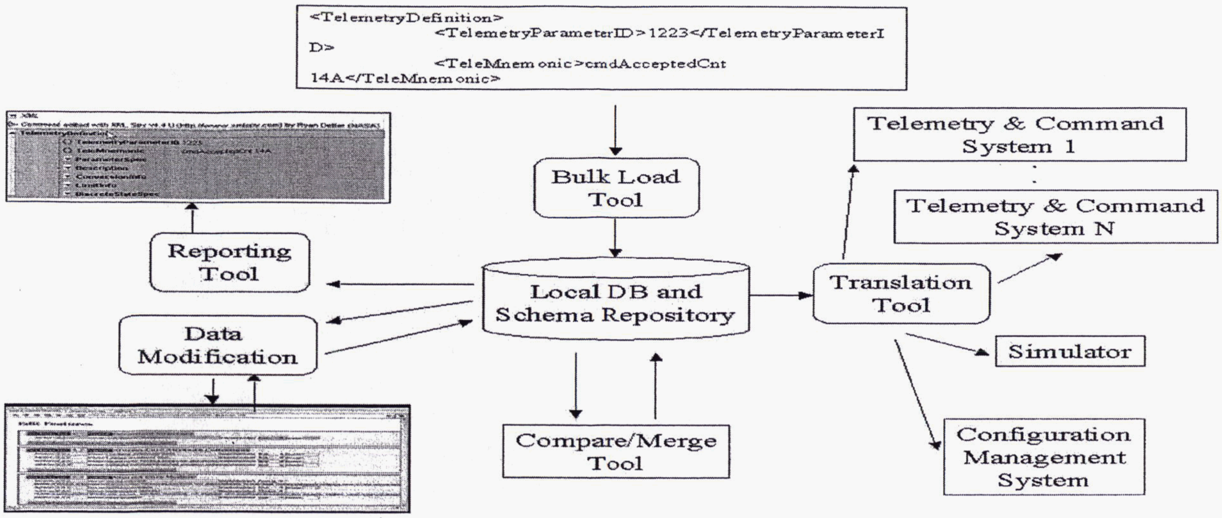

Figure 8 – JWST Current Database System

XTCE in its current state (Oct. 2005) is still not ready for acceptance by CCSDS. XTCE when first reviewed by JWST did not meet the needs of an exchange or for a mission format. The difference is an exchange format contains commonality for only the core command and telemetry definitions while a mission format contains all the elements needed for a spacecraft mission. The additional items in a mission format include items such as page displays, scripts, equations, etc. JWST and JPL embarked on a joint effort to define a common XML tags between the organizations. This effort was to see if a mission format between dissimilar systems is possible and that XTCE could be used as an exchange format between the JWST and JPL systems. This effort is still ongoing, but we have found the following:

- A common mission XML format between dissimilar system is possible and is not a difficult. Currently the Joint Module XML (JMX) is a defined set of XML tags that are common for both JWST and the JPL Mars missions.
- Some additional XML tags to XTCE are needed for it to be an exchange format for JPL and JWST.
- A common tool set for viewing and organizing the XML is useful but not required.
- Command XML is more complex than telemetry.
- The use of XML metadata to describe pages and scripts was needed due to the proprietary nature of current ground systems.

Systems that have used successfully the JWST XML database directly with no conversions is the PSS and Data Formatter (DF) that is used as a front-end for the JWST I&T system. The following ground systems have imported and used the JWST XML database using conversion scripts; EPOCH®, ASIST®, ITOS®, and Eclipse®. ITPS® is a GSFC developed engineering archive and data analysis system that has used the JWST XML database. Each of these systems took about one to two weeks to write and test the XML ingest script. Once the script was written, further JWST XML database releases needed no ingest script changes. On average it takes less than 10 minutes to convert the JWST XML to a usable format.

One of the biggest compatibility issues that JWST has, is for the XML database to maintain a level of backwards compatibility with previous databases and the systems being used. JWST XML has a release and CM controlled ICD describing the format and XML elements, but as the systems and data matures additions and changes to the JWST XML ICD are necessary. The JWST Project has already experienced a change that caused a direct backwards compatibility not to be possible. In this case the JWST Project has built a converter that will be provided to each user that will convert the databases to an acceptable format.

Another example is the science instrument computer loads are delivered to the Eclipse® ground system in XML. The XML elements used by Eclipse® are not changed, but additional XML elements are added for other systems to use for processing and analysis of the loads. This demonstrates the power of XML by allowing enhancements to be made without affecting other system.

7. References

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8. Biographies

Jonathan Gal-Edd has been working at NASA since 1994. His current assignment is the Ground System, System Engineer Lead for the James Webb Space Telescope (JWST). JWST is the follow on program to the Hubble Space Telescope (HST) and is now entering the design and development phase (Phase B). Jonathan was also the Ground System Manager for the JWST flight demonstrator called Nexus. Previous to these missions, Jonathan was a member of the GSFC development team for Earth Observing Science (EOS) information system (DIS). Prior to moving to GSFC from Johnson Space Center (JSC), Jonathan served as the Software Development and Integration Lab (SDIL) Manager, for the International Space Station (ISS) program.

Curtis Fatig is currently the James Webb Space Telescope Ground System, System Engineer. Previously he was the Hubble Space Telescope Servicing Mission Test and Integration Manager. His team of engineers set up remote Payload Operations Centers, tested the entire ground/space software and communication links used for each HST servicing mission, and tested NASA institutional upgrades affecting HST. He also supports long term development of new mission ground systems. He has received NASA's Spaceflight Awareness Award, Public Service Medal, and many Achievement Awards for these efforts from GSFC, KSC and JSC. He received a B.S. from Salisbury State College in 1978 and a M.Ed. from Rollins College in 1982.