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IChart: A Tool For Visualizing and Managing
Organizational and Force Structure Data

Architectures, Technologies, and Tools

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Abstract

The US Department of Defense (DoD) Joint Staff, Force Structure Directorate (J-8), along with the Office of Under Secretary of Defense for Personnel and Readiness (OUSD(P&R)) put forth the Global Force Management Data Initiative (GFM DI) with the goal of developing a reliable and maintainable data source capturing Organizational and Force Structure Construct (OFSC) information. The Global Force Management Information Exchange Data Model (GFMIEDM) was developed to enable disparate systems throughout the DoD to share force structure, manpower, and equipment data. However, merely exchanging this data is of limited utility without accompanying tools that improve the DoD's ability to manage, assess, and display the worldwide disposition of U.S. forces. This paper describes a graphical, Java-based tool to display, create, edit, manipulate, validate, and query an OFSC dataset. The IChart software architecture was intentionally built on a reusable foundation and divided into logical modules to allow it to be adapted for other uses such as command and control applications. This paper describes how IChart provides a visualization of OFSC data in a graphical tree structure to allow users to conceptualize snapshots of the force structure and chain of command hierarchies at a particular point in time.

Keywords: data modeling, SQL, XML

1. Introduction

The primary component of the Global Force Management Data Initiative (GFM DI) is the GFM Information Exchange Data Model (GFMIEDM) [8]. The purpose of this model is to define a common data dictionary to exchange force structure, manpower, and equipment data to disparate systems throughout the Department of Defense (DoD). The initial starting point of the model was the Joint Command Control Consultation Information Exchange Data Model (JC3IEDM) [7], a traditional SQL data dictionary, but over time the GFMIEDM was replaced by an XML Schema (XSD) [13].

In either form, GFM defines the components that constitute an Organizational and Force Structure Construct (OFSC) [2]. A basic tenet of GFM is that data is reused whenever possible to minimize duplication and the amount of data that must be exchanged when a change is made. An OFSC dataset contains current, past, and future data and tree structures, and a date of interest (DOI) must be supplied to produce a “snapshot” at a particular time.

There is a hierarchy of link types that represent various types of alignments and indirectly define different tree types. These link types are inherited down the tree to prevent duplication of subtrees for each tree type.

Finally, links and nodes may have the standard classification markings. A tool that constructs an OFSC tree from GFM data must be given the DOI, tree type (a set of link types), and the highest classification.

We designed a tool—IChart—to demonstrate the feasibility of the GFM data model and used it to construct actual DoD force structure data trees [4]. IChart has evolved from a proof of concept tool to become an application that is being used by all of the Services. It has grown from an SQL client to create, edit, and display OFSC data into a tool to validate XML data produced by the Organization Servers (OSs) maintained by each of the Services.

In this paper, we discuss how IChart provides a visualization of OFSC data in a graphical tree structure to allow users to conceptualize snapshots of the force structure and chain of command hierarchies at a particular point in time. IChart is work in progress. We limit our comments to the current version, Build 504, and mention future directions that IChart may explore.

2. Background

The GFMIEDM was developed, and continues to evolve, in response to the task of identifying and specifying high-resolution, operational force structure data and has resulted in a rigorously defined schema to document and communicate OFSC data. As part of the GFM DI, a single, authoritative data source (ADS, which is an OS) was created for each Service that integrates past, current, and future OFSC data in a comprehensive format accessible by all systems within the enterprise.

The overall dataflow of the GFM DI is shown in Figure 1. Raw data is received from a variety of sources (primarily legacy systems), manipulated as needed, and stored in the appropriate OS. Client systems obtain the authoritative data from the OSs using a combination of push and pull interfaces.

The GFMIEDM enables disparate systems throughout the DoD, including all of the Services, to share force structure, manpower, and equipment data. However, merely exchanging this data is of limited utility without accompanying tools that improve the DoD's ability to manage, assess, and display the worldwide disposition of U.S. forces. A necessary first task to support the GFM DI is to provide a tool with the ability to visualize, create, edit, validate, and query OFSC data. In response, the U.S. Army Research Laboratory has developed a graphical application—IChart—to manage and analyze force structure data obtained from each Service's authoritative data source. A graphical approach was taken because OFSC data describes a command structure, which itself is a hierarchy or tree (i.e., an organization chart).

The tool's feature set continues to be expanded based on feedback of end user requirements. The IChart software architecture was intentionally built on a reusable foundation

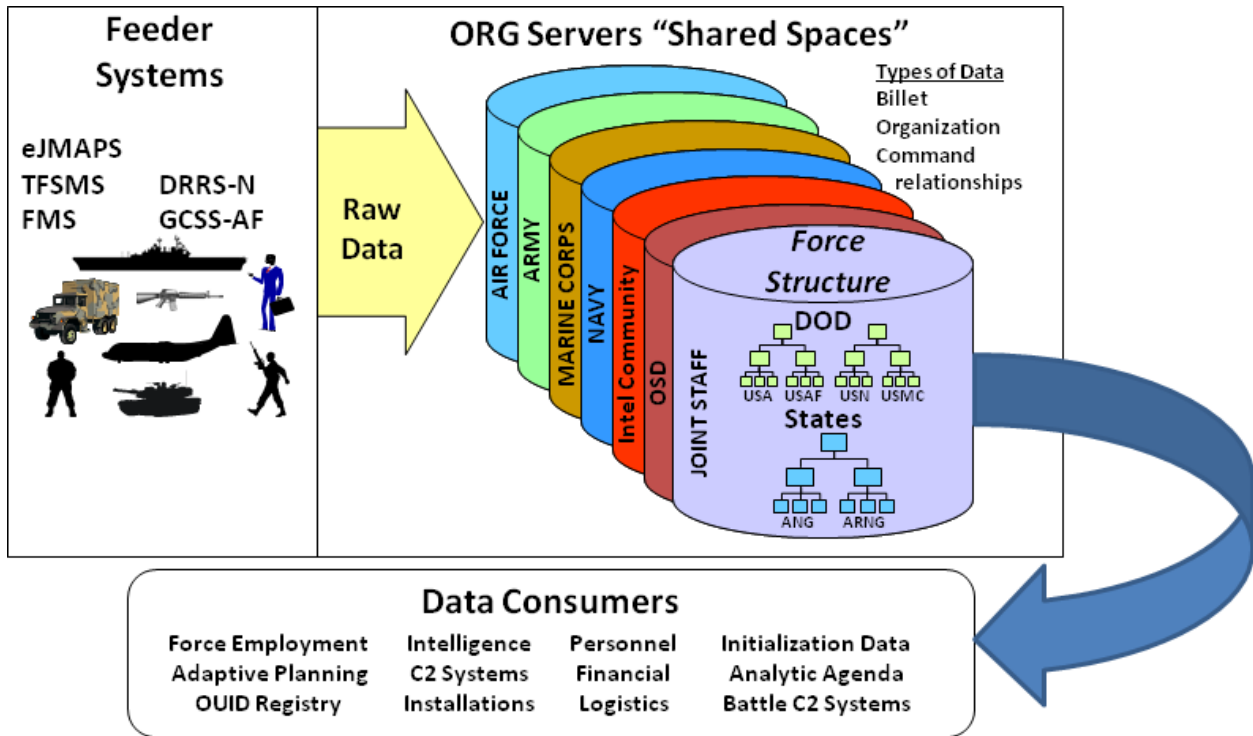


Figure 1: GFM DI data flow.

and divided into logical modules to allow it to be adapted for other uses such as command and control applications. The current feature set includes the following functions:

- Provide a visualization of OFSC data in a graphical tree structure for a given date of interest (past, current or future) to allow users to conceptualize time snapshots of the force structure and chain of command hierarchies. This was achieved by recording a start and termination date for each datum, then constructing the tree from the top down, choosing nodes and links that are active at the date of interest.
- Manage data (create, edit) with a point and click interface. Data elements may be created and modified with text dialogs that limit allowed field values via pull-down lists where applicable. When data is available from electronic sources, much of the OFSC creation process may be automated. However, the GFM schema is far too complex for data to be constructed or modified entirely by hand.
- Generate reports such as roll-ups (or aggregations) of materiel and personnel to calculate requirements. Data elements may also be saved into text files suitable for import into spreadsheet applications for additional processing.
- Exchange data with a relational database management system (RDBMS), both incrementally and in bulk. Dynamically loading data as needed allows the desired portion of a tree to be extracted interactively with minimal overhead.

- Read, write and validate GFM data in Extensible Markup Language (XML) in accordance with the GFMIEDM. The original database schema was replaced by an XML schema because XML has become the *de facto* standard for data exchange.
- Analyze data for correctness and adherence to business rules.

3. Application Details

3.1 Overview

ICChart is written in Java 6 for portability. While most users run ICChart in Windows, the initial development and testing is performed on a Linux workstation. A third party GOTS library, Graphical Situation Display (GSD),* is used to display MIL-STD-2525B symbols[1]. It is written in C++ and is not available for OS X, so ICChart was modified to allow a limited set of symbols to be displayed without requiring GSD, thus permitting ICChart to be run on Apple Macs.†

MySQL was chosen as the RDBMS because it is free, popular, and portable [9]. JDBC is the mechanism used to connect ICChart to a MySQL server, allowing ICChart to perform all standard SQL operations from queries to creating new databases [10]. The SQL code is compartmented and does not use any unique MySQL features, which allows ICChart to be used with the Oracle RDBMS [11]. However, developers who are using Oracle are currently limited to running ICChart on existing databases and may not create new ones.

The Document Object Model (DOM) parser used by ICChart is part of the Xerces package [6, 14]. Because it has considerable memory overhead, the DOM parser is being replaced in ICChart with StAX, an incremental parser [5]. Normal print statements are used to generate XML output. While this works, there is no error-checking, and eventually XML classes will be used to create and output XML elements.

To facilitate maintenance and allow ICChart components to be reused in other applications, the ICChart Java classes are grouped into packages. Work has begun to refactor ICChart to reduce the close coupling between the various packages. The goal is to be able to plug packages written for ICChart into other applications such as command and control systems.

ICChart does not directly implement the GFM schema in SQL because of the hierarchical structure of the data tables. The GFMIEDM is a *data exchange* schema, not a database schema. However, the closer the database matches the GFMIEDM, the easier it is to convert the data between the SQL and XML formats. ICChart flattens the generalization hierarchy, trading table complexity for a smaller number of wide tables with many empty fields.‡

*This Northrop-Grumman project has been terminated.

†The GSD library is also incompatible with 64-bit Java virtual machines.

‡SQL scripts have been written to convert the data tables from one schema to the other.

3.2 General Design

Figure 2 shows the main IChart window.* The major areas are the graphical tree panel (displaying part of a company headquarters) and the detail panel which contains summary and rollup information. The display panel may be displayed separately as shown in figure 3.

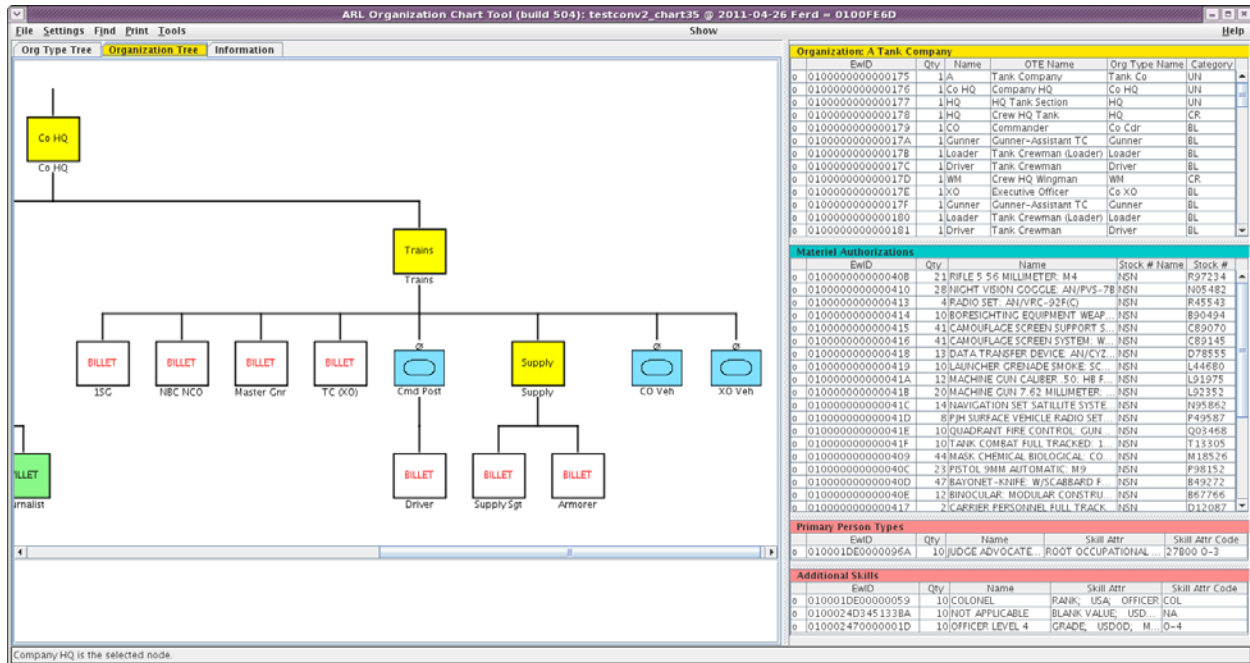


Figure 2: IChart Window.

The main window is divided into 6 areas:

- **Title Bar** Contains tool version, name of current dataset, and date of interest.
- **Menu Bar** Drop-down menus with items to load and save datasets, select tree display options, search for items, and provide debugging information.
- **Tabs** Allows the user to select which tabbed panel should be displayed. The Organization Tree is selected in Figure 2.
- **Tree Panel** Displays a tree panel or the information panel.
- **Sandbox** Holding area for new nodes until they are added to the tree.
- **Status Line** Shows progress messages to the user.

The detail panel in Figure 3 is a prototype for future summary information. This example contains a rollup starting at the Company HQ node. The panel is divided into four sortable, resizable tables:

*These are placeholder images until new ones are created for the final paper.

- **Organization** Lists the nodes in the subtree.
- **Authorized Materiel** Materiel aligned with the nodes.
- **Person Types** Personnel skill sets required by billets.
- **Additional Skills** Extra skills that are not part of standard job descriptions in the Person Type table.

The screenshot shows a window titled "Rollup" with a yellow header bar. Below the header, there are four distinct sections, each with a colored header bar and a table of data.

Organization: A Tank Company						
	EwID	Qty	Name	OTE Name	Org Type Name	Category
o	0100000000000175	1	A	Tank Company	Tank Co	UN
o	0100000000000176	1	Co HQ	Company HQ	Co HQ	UN
o	0100000000000177	1	HQ	HQ Tank Section	HQ	UN
o	0100000000000178	1	HQ	Crew HQ Tank	HQ	CR
o	0100000000000179	1	CO	Commander	Co Cdr	BL

Materiel Authorizations					
	EwID	Qty	Name	Stock # Name	Stock #
o	010000000000040B	2	RIFLE 5 56 MILLIMETER: M4	NSN	R97234
o	0100000000000410	28	NIGHT VISION GOGGLE: A..	NSN	N05482
o	0100000000000413	4	RADIO SET: AN/VRC-92F(C)	NSN	R45543
o	0100000000000414	10	BORESIGHTING EQUIPMEN...	NSN	B90494
o	0100000000000415	4	CAMOUFLAGE SCREEN SUP...	NSN	C89070

Primary Person Types					
	EwID	Qty	Name	Skill Attr	Skill Attr Code
o	010001DE0000096A	10	JUDGE ADVOC...	ROOT OCCUPATION...	27B00 0-3

Additional Skills					
	EwID	Qty	Name	Skill Attr	Skill Attr Code
o	010001DE00000059	10	COLONEL	RANK; USA; OFFI...	COL
o	0100024D345133BA	10	NOT APPLICABLE	BLANK VALUE; US...	NA
o	010002470000001D	10	OFFICER LEVEL 4	GRADE; USDOD; ...	0-4

Figure 3: Detail Window.

Every item in a dataset may be examined in detail. Figure 4 shows the fields and related elements that comprise an Organization. The tabs along the top may be used to display related information. In this example, the Organization has four aliases, a superior, two subordinates, and is led by another organization. The Organization Type is this item's template, and a MIL-STD-2525B symbol has been supplied.

The dialogs contain low-level information and explicitly display fields from the schema because IChart was intended to be a research and validation tool. Options have been added to suppress certain fields (such as the numeric identifiers), and the partially implemented "production mode" will decouple the displays from the underlying schema.

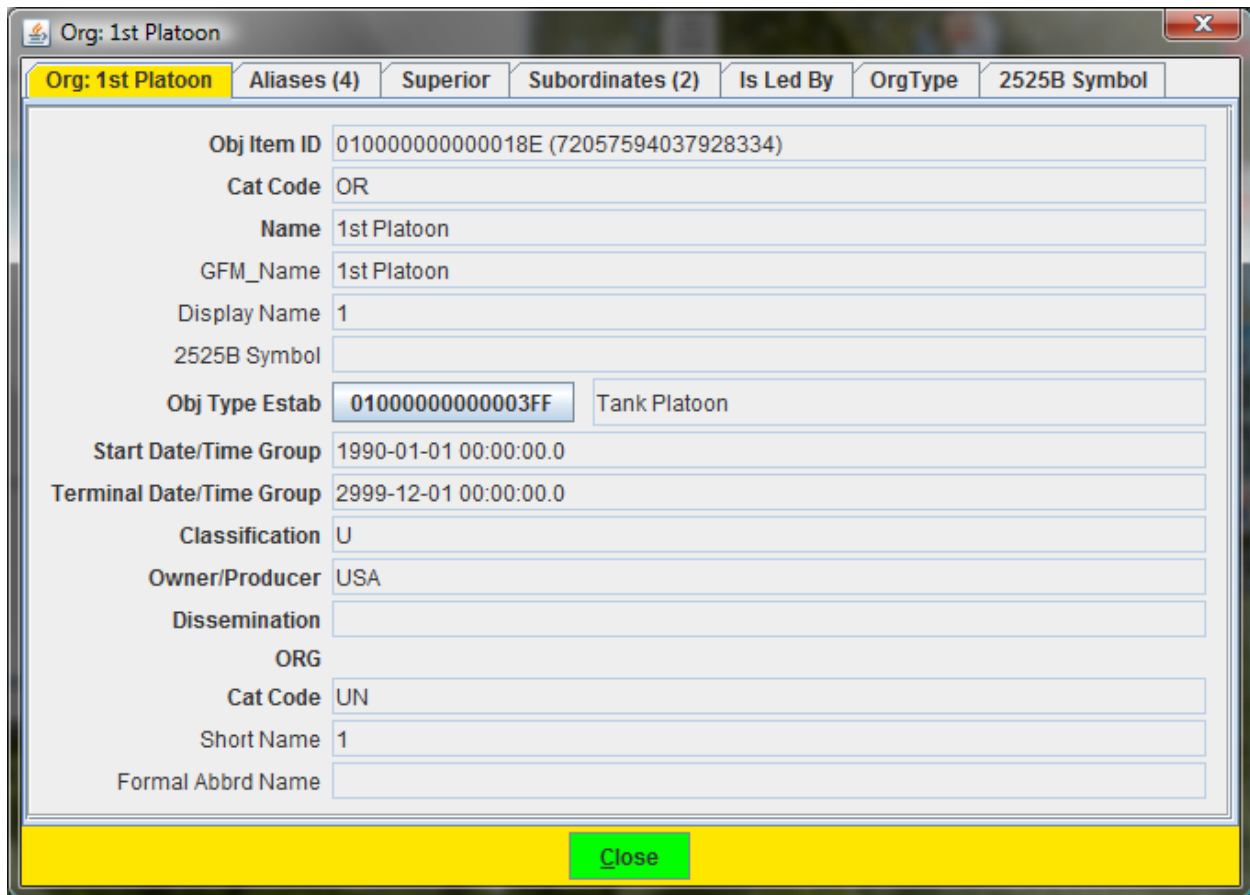


Figure 4: Organization Dialog.

3.3 Operation

An SQL database or XML data file may be loaded when IChart starts via a simple configuration file. This file may also be used to change colors and styles, define initial display settings, and manipulate XML schema details. Drop-down menus allow the user to load other datasets, save datasets as SQL, XML, or comma separated variables (CSV), and toggle display settings on or off. Tree parameters—date of interest, tree type, and classification level—may be set in the configuration file or changed in the Settings menu.

The tree panel provides left and right button context menus. The user may left click on a node to open a menu of display options that are applied to the node, while a right click opens a similar menu of editing options. The display menu options include:

- **Show Node** Open a detailed dialog for the node such as the one in Figure 4.
- **Show Link** Open a detailed dialog containing the link to the node's parent.
- **Expand** Draw the node's immediate children or a subtree.
- **Collapse** Visually remove the node's subtree.

This menu allows the user to manually traverse the tree, examining areas of interest. It also has options to show a node's details or generate a rollup of the subtree and display the results as shown in Figure 3.

The edit menu is used to modify existing items, create new nodes, and modify a tree's structure. To edit a node or link, a dialog similar to the one in Figure 4 is shown. Fields are editable where appropriate (some values may not be changed) and mandatory fields are highlighted in red. When a node is created or de-assigned from the tree, it is placed in the "sandbox" area below the tree. The user then clicks on the node, right-clicks on its parent in the tree, selects "Assign", and chooses the desired link type.

3.4 Dynamic and Remote Data

Data is "bulk loaded" into IChart, which means the entire dataset is cached in memory. While this is currently required by XML and when items are created or edited, it is impractical for very large datasets. An option called "display on demand" (DOD) fetches data from an SQL database only as needed as the user traverses a tree.

An added benefit of this approach is that IChart may access distributed data. When the child node of a link does not exist, IChart examines the link to see if it contains information about an external database and server. If so, it connects to the other database for that subtree until another external link is found.* As an example, when a user expands the Department of Defense node, each of the child nodes resides on a server maintained by a particular Service. This functionality has been demonstrated using MySQL servers running on three different machines.

A goal of the GFM DI is to use web services to remove the dependency on MySQL or other implementation-specific features. Portions of the IChart code were used to build a simple server; IChart is then run in DOD mode as a client of this server. When IChart requires more data, it sends a data request to the server and receives an XML payload in return.

3.5 Rollups and Other Aggregations

The user may click on a node and request that the alignment details for that node or a rollup of its subtree be displayed. This feature may be used for validation purposes or to provide summary information in a planning system. Each column may be sorted to aid in locating desired information. The first column indicates if the item has been modified or newly created, while clicking on the column causes a dialog like Figure 4 to be displayed.

*Otherwise a virtual node is created as a visual placeholder.

3.6 Working With Subtrees

There are times when the data from a particular subtree is required. The user may expand and collapse nodes to select the nodes that are of interest, then perform an operation starting with one of the nodes. The current operations include generating a rollup, displaying specified fields in a collection of nodes as a vertical text tree or saving it as a spreadsheet file, and saving the nodes along with related data as an XML file.

3.7 Validation

Early versions of IChart did very little error checking because GFM was still under development and rules specific to a particular Service were avoided. Once the GFM XML schema was codified, the schema and a set of scripts written in XML Stylesheet Language: Transformations (XSLT) became the primary means for validating GFM XML data [3, 12]. The main ways that IChart is used for data validation consist of requesting that the DOM parser validate XML data against the schema and by visual inspection of the trees. For example, business rules such as naming conventions may not be automated, command structure analysis requires human evaluation, and IChart provides additional on-screen debugging information such as node counts to the user.

Now that IChart has become the *de facto* tool to view GFM data, more sophisticated error checking and diagnostics are being added. Workbench-style error messages are no longer sufficient. IChart has always used the Java logging feature to record program execution at various levels of detail, and the user may now view the log file from within IChart while the application is running.

A related task has been the translation of structural and business rule tests into SQL procedures. Once a dataset has been loaded into IChart and saved as an SQL database, these new tests may be run. Because of query optimization and lower overhead, these tests run much more quickly than their XSLT counterparts.

4. Future Enhancements

4.1 IChart Features

The features in IChart fall into three major categories:

1. Basic capabilities to demonstrate the usefulness of GFM,
2. Features requested by users, and
3. Experimental options to broaden IChart's utility or test new GFM ideas.

Current projects include the construction of "Chain Of Command" trees from "Command Structure" trees. While a command structure or OFSC tree shows the relationships between

units, crew platforms, and billets, a chain of command tree contains only billets. This is demonstrated in Figure 5 where the company commander is the overall leader, his tank crew and a platoon leader serve directly under him, the platoon leader's tank crew and squad leaders report to him, etc. IChart is able to handle multi-hatted positions where the same billet may appear in multiple locations in the tree.

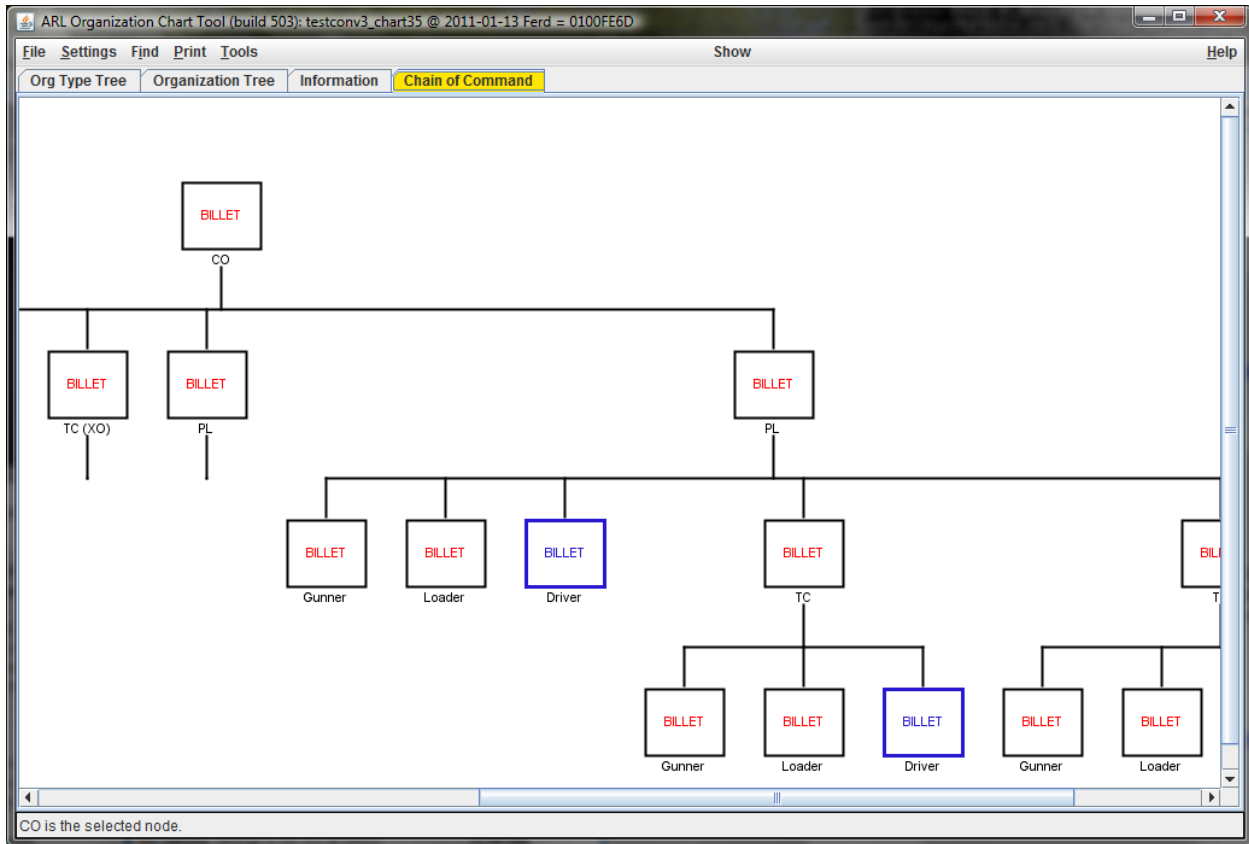


Figure 5: Chain Of Command Tree.

Over time, as more data has been created by the Services, the GFM business rules have been refined. For example, rules that were written for Army data may not be pertinent for Air Force data. These rules are gradually finding their way into IChart to assist the developers who are populating the initial databases.

More effort is being spent on IChart's user interface. While researchers and developers may be comfortable with IChart's low-level approach to data, people who are using the tool to view and query data demand a more sophisticated and abstract level of detail. One example would be the addition of drag and drop where appropriate.

4.2 Related Tools

The first IChart "spinoff" was a tool that compared two different OFSC trees. Because GFM reuses data when possible, it is important to be able to track incremental changes.

An outside agency chose to extend IChart to include actual personnel data. Together these tasks indicate a need to modify IChart to allow programmers to extend the existing Java classes or implement features using plugins.

A portion of IChart code was used to build a server to test the incremental loading of GFM data. This new tool acts as a client to a MySQL database and a server to the standard IChart tool. Instead of having IChart communicate directly with an XML file or MySQL database, it connects to this GFM server which emulates an OS.

A tool that is nearing completion incrementally reads a GFM XML file using StAX and stores each element in a MySQL database. This avoids the huge overhead required by the DOM parser and will allow very large XML datasets to be converted into SQL data for analysis by the new SQL-based data validation scripts. It will also permit users to browse OFSC trees in datasets that are too large to be bulk loaded by IChart.

The newest use for IChart modules has been by the Applied Research Laboratories at the University of Texas in Austin. They would like to decouple the graphical tree display portion of IChart and adapt it as a general purpose model that may be used by command and control systems.*

5. Conclusion

IChart has proven to be a valuable tool for manipulating GFM data. At the beginning of the GFM DI project, IChart was used by developers to create actual DoD data in GFM form. It has since evolved into a tool to analyze and validate GFM data. In its role as a briefing tool, it has introduced many people to the concepts espoused by the GFM methodology. Because of IChart, analysts in the personnel and logistics communities have expressed an interest in using GFM data in their own work.

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