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The new W7-X Logbook - A Software for Effective Experiment Documentation and Collaborative Research at Wendelstein 7-X

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Wendelstein 7-X (W7-X) completed its second operation phase (OP1.2a) in December 2017. A large number of diagnostics were operated in nearly 1000 experiment programs by an international research team. For the documentation of W7-X experiment programs, a new electronic logbook software was developed and eventually used for the first time in OP1.2a. The software was designed for the needs of W7-X researchers: a web-based logbook application for the whole team. For an effective documentation, greater part of the logbook content comes from automatically generated logs, complemented by users via web browser. The W7-X control software generates log entries for experiment programs during the program execution. This includes an automatic extraction of configuration information from the planned program, which is later represented as searchable tags within the logbook. The logbook allows full-text search and range queries for numeric values: both with response times within milliseconds. Separate component logs are created in the same way for W7-X diagnostics and machine subsystems for different use cases, e.g. experiment programs, standalone tests, or calibrations. The logbook allows adding rich-text comments to all logs, which also includes links and images. The web page of each experiment program log contains overview plots from measurement data, generated on the fly from data from the W7-X archive. For each W7-X component, the logbook also provides a separate web page, which is editable by the responsible officer. The pages contain descriptions, log overviews, and links to measurement data. Next to the website interface, the logbook provides a RESTful web service, which allows reading and writing of logbook data in any programming language.

1. Introduction

Wendelstein 7-X (W7-X) [1] completed the first part of its second operation phase (OP1.2a) in December 2017. Even in these early phases, a remarkable number of nearly 40 diagnostic systems were operated by the W7-X team. In the first operational phases with limited discharge durations of currently up to 60 seconds, the number of experiment programs per day are up to 50. Operating in a typical week with two or three experiment days, the number of programs sums up to 1000 – 1500 programs per operational phase. These activities are supported by the CoDaC software chain [2]. For the documentation of W7-X experiment programs, a new electronic logbook software was developed and used for the first time in OP1.2a.

2. Electronic logbooks

Electronic logbooks play an important role in many engineering and scientific fields. Different implementations of electronic logbooks were already used at other fusion experiments, e.g. at the tokamaks Alcator C-Mod [3] and TEXTOR [4]. In contrast to these implementations, the W-X logbook is designed as full-featured web service and is not limited to experiment logs and comments by the device operator. Logs in the W7-X logbook can be created for discharges, but also for all sub-components and diagnostics; for W7-X experiments or any other events like commissioning or calibrations. All members of the W7-X team can add rich-text comments with images. In this way, the logbook helps with the documentation of W7-X experiments and enables fast information exchange; by connecting experiment data and team comments on an interactive website.

3. Basic concepts

The implementation of the W7-X logbook was focused on a good usability for all team members and on the automatic creation of content in a standardized form, together with advanced search options and a seamless integration in the CoDaC software stack

3.1 Central logbook for the W7-X team

Research at W7-X is done in collaboration with a large international team of engineers and physics. The W7-X logbook provides dedicated views for different user roles, e.g., engineer in charge, session leader, diagnostic team and component operators.

3.2 Automatic data enrichment

The data acquisition systems of the W7-X subsystems and diagnostics produce a large amount of data for each discharge and in the final setup petabytes per year. For an effective analysis, an experiment journal and high-level description of this mass data is needed. As manually input tent to be time consuming and error-prone, large parts of this information should preferably generated automatically and the additional user input should be supported by the graphical user interface.

For the main content of the logbook, the W7-X experiment planning and control software (Xedit & Xcontrol) automatically creates logs. Meta data of an experiment program is obtained from its determining

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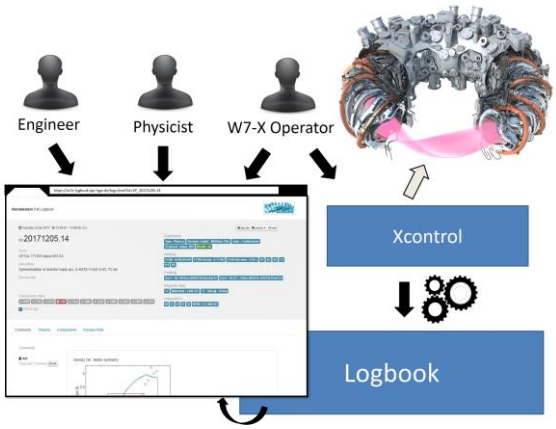

Fig. 1 – Logbook content is created by the W-X control software or manually by the W-X team members.

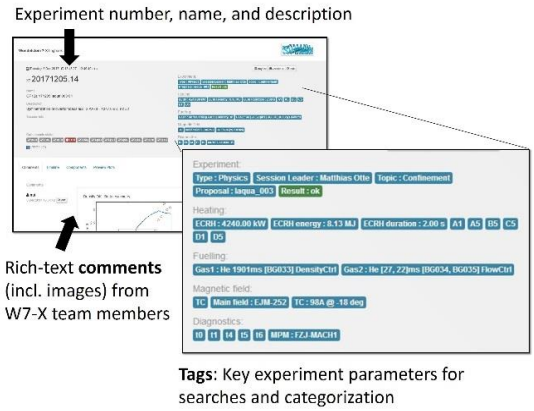

Fig. 2 – Key parameters and physics objectives are represented as tags on the experiment website.

parameters at planning time using the Component Model framework [5] as part of the experiment program editor [6]. This includes key parameters such as the intended plasma heating, fueling, magnetic field configuration and main diagnostic settings. During the experiment run, this meta data is logged to the archive together with the experiment sequence and more planning information retrieved from proposals database.

These automatic logs provide the basis for each experiment entry in the logbook. The W7-X team members complete these logs by adding additional information, like a result flag. This can happen manually in a web browser or programmatically via a script or software. Most of this information is added in a structured way in the form of annotations or tags (Fig. 2).

3.3 Tags for standardized input

The logbook supports different kinds of input for notes, remarks, and comments. Next to images and free-form text, key parameters are included as annotation objects, which are represented on the website as labels or tags in the form of key/value pairs for program meta data (Fig. 2). The standardized information input leads to better search results and is crucial if logbook data is used for an automatic analyze of W7-X experiment data on a larger scale. The different tags are defined and managed in an extendable tag catalog within the logbook. The value of a tag can be a string or a numeric value. For numeric tags an attribute for the unit can be set. In addition, a list with possible values can be defined, e.g. different gas types for gas injection. In the catalog, tags are divided into different categories: experiment (containing tags like session leader, proposal number, and program type), heating, fuelling, magnetic field, and diagnostics. The tag catalog is used on the website for creating a form, from which the user can select one or more tags and add them to a log.

3.4 Fast search index

The logbook uses a multi-tier architecture with presentation layer (a web interface), middle tier, and persistence layer. In the backend, the logbook data is eventually stored in the W7-X archive. The middle tier implementation includes a fast search index based on elasticsearch [5], which is used for providing full-text search for the complete logbook content with a near real time response time. In addition, the standardized tags allow searches in numeric ranges using a simple syntax, e.g. searches for all programs with a heating duration between 20 and 60 seconds. The flexible data model of the search index leads to a high extensibility of the software. The extensibility is an important factor for working with scientific data models, as requirements can change rather quickly and disruptive, e.g. caused by new results or research approaches.

3.5 RESTful web service

The logbook allows an easy integration of logbook content into other CoDaC tools, as well as the usage for automatic data analysis. Therefore, it was implemented as a RESTful web service [6], using standard protocols: HTTP (hypertext transport protocol), JSON (JavaScript object notation) and HTML (hypertext markup language). In a RESTful interface, the data is represented as resources on a server, which can be addressed by a web address or URL (uniform resource locator). A small number of HTTP operations are used to interact with these resources: typically, a “GET” request on a URL is used for reading the resource in a specific format, while “POST” is used for creating new resources on the server. Connections between resources are represented via hyperlinks.

4. Application

Implemented as a central collaboration tool, the logbook provides dedicated views to meet the different use cases: experiment overview, component and diagnostic specific documentation, physicists’ and engineers’ view.

4.1 Overview listing

The overview listing provides a streamlined interface and is the starting point for most use cases of the logbook. Next to the single input field for all kinds of search requests, a calendar widget and quick links to the last experiment days provides fast access to experiment logs sorted by date. The logbook search index based on elasticsearch delivers fast results within milliseconds

response time. Classifying tags and user comments are included in the overview list.

4.2. Experiment log website

The log of every program conducted by the W7-X segment control gets its own webpage with a unique web address at the start of the experiment. The logbook provides a version control for the log entries, so users can see the history of a log with all changes. A second version of the log is written on the end of the program, updating the log. The website contains the central information of an experiment, for example the experiment program (XP) number, the start and end time, name, and description.

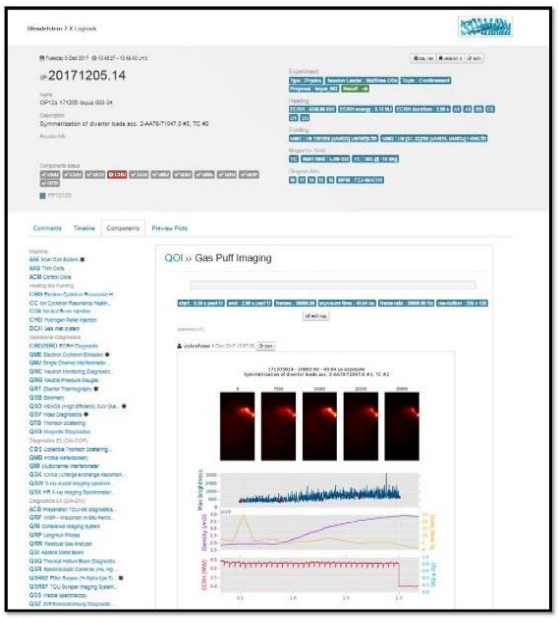

Fig. 3 – Component logs are listed on the experiment log site. Components which do have a log or comment for this discharge are marked with an asterisk.

For a high-level overview, more-generic tags are added on the experiment level, while specific tags are added to associated component logs. Examples for the experiment tags are the configuration of the main coils system, including usage of trim coils and control coils. The power and duration of the main heating systems: electron cyclotron resonance heating and neural beam injection. For the fueling, gas type and timing are shown: for the gas injection and pellet injection systems, as well as tags for injective diagnostics, which are used for transport and impurity studies. Session information are also includes as tags, e.g. experiment leader, program type, corresponding proposals, and a result flag. The users can add new tags from the tag catalog directly on the website. In addition, the component team members add system specific tags on the corresponding component logs.

The components logs with user comments concerning the experiment program are listed on the experiment website (see Fig.4). In this way, users can share their components settings, notes and observations with the W7-X team.

4.3 Interactive preview plots

An important part of experiment execution is a fast evaluation of the experiment success, for example for planning the next steps of a session. The logbook supports this task with live plots from data of central systems and diagnostic measurements. The website of an experiment log provides a fast preview with overview plots showing the main plasma properties of the discharge (Fig 4). The preview plots are available right after, or even during, a discharge, as they are generated on the fly with JavaScript from the web service of the W7-X data archive [7]. The central W7-X archive contains the raw and analyzed data from the diagnostic systems, as well as machine operation data. By using a server side downscaling the data is loaded and displayed in a timely manner, even for data from high-resolution data acquisition systems. The configurable plots are able to show multiple data streams in a row. The user can freely configure the plots by selecting any data available from the archive, or use one of the predefined presets. The plots provide interactive features like zooming and panning using the mouse.

Fig. 4 – Preview plots are generated on the fly from archived experiment data. Many signals are already available during a discharge.

4.4 Component pages

Next to the central logs for W7-X experiment programs, the logbook provides dedicated areas for the machine sub-systems, heating and fuelling systems and diagnostics. The component overview page on the logbook website lists currently over 80 systems. The logbook provides special status overviews of different system groups e.g., machine subsystems, or profile / scrap-off layer diagnostics.

Every system has its own logbook area with a special website (see Fig.6). This includes a start site containing the most important information about the system e.g.,

hardware, team members, and data access links. The website shown all logs of the component: for W7-X experiments, as well as for other events e.g. tests, commissioning or calibration measurements. The logs can be accessed by selecting from a calendar or as a complete listing.

4.5 Engineer in charge logbook

The logbook provides a special area for the engineer in charge, which uses the logbook for shift logs and the documentation of planned activities and incidents concerning the commissioning and operation of the machine and all peripheral systems. All entries are available within the full-text search. For documentation of the operation of W7-X, the logbook provides the option to create daily reports with all experiment programs and machine operation events.

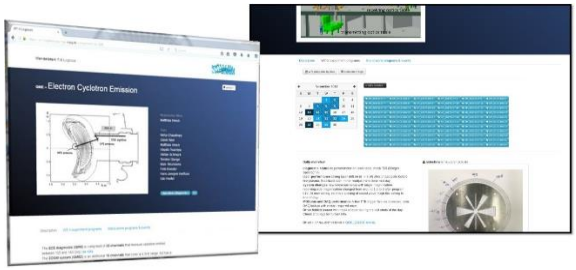

Fig. 6 – Each W7-X component has its own area on logbook website.

5. Implementation

The logbook was implemented iteratively in an agile software development process, starting from a small proof-of-principle prototype. For this prototype, the data from about 1000 experiments of the first operational phase was imported into the logbook search index, as well as stand-alone programs from many different W7-X components since 2015. The requirements are mainly based on the experience from the first campaigns. In addition further requirements were collected from W7-X team members, representing different roles in the project.

For the server part of the software, a RESTful web service was written in Java, providing the different resources as JSON or HTML. The logbook provides all features as interactive HTML5 websites for the human-readable user interface, which can be accessed by any modern web browser. In addition, the same resources are available in the same way as JSON for programmatic access. The website uses a single-sign-on mechanism, so the user is automatically logged in on a Windows machine. The users are managed within the central user database of the institute.

6. Conclusion

A central web based logbook software was implemented for the use by the whole W7-X team. The basis of the content are automatically generated logs by the W7-X control software. The logbook includes special areas for the logs of the diagnostics, heating- and subsystems of W7-X, as well as or the engineer in charge. Fast full-text search and range-based queries with tags are important for manually exploration of the results, as well as for automatic analysis. All functions are available as a website on web browsers or via RESTful web service for programmatic access and the integration in other software. The logbook allows HTML-based rich-text user comments which also includes images. Interactive website with plots from experiment data. The W7-X logbook was quickly adopted by the W7X-Team and appreciated as a crucial tool for W7-X experimentation.

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