IMPROVING SPACECRAFT OPERATIONS BY LEVERAGING WORLD WIDE WEB TECHNOLOGIES

N. Priborsky
M. Schmidhuber

LSE - Lancaster Software Entwicklung GmbH
Münchner Straße 20 D-82234 Oberpfaffenhofen GERMANY
Phone: +49 (8153) 28-2754

The last decade saw an Internet revolution that left few businesses untouched. In many companies that previously didn't think themselves as part of the IT industry, email and intranet are now a part of daily work. Spacecraft operations traditionally are a computer and network oriented trade. However more often than not the new technologies are slow take hold in the operation centres. Traditional concerns about security and safety didn't allow crossing the barrier between data on paper and the operational world, between offices and control rooms freely. At the German Space Operations Centre a project was undertaken to introduce a growing system of intranet services that started by assisting the mission preparation and is now strongly interweaved with actual day-to-day operations. After successfully supporting nine missions we present a variety of tools and applications made possible by using intranet technologies. It is pointed out how to manage content, observe security aspects, and make the system efficient and reliable. Finally the effect on people is shown.

Introduction

The German Space Operations Centre (GSOC) is the national institution of Germany to conduct space mission operations. It has operated several scientific and telecommunications satellites as well as manned missions to the SPACELAB and the MIR space station. In the future it will be the main base for European activities on the space station. Currently supported missions include the twin GRACE satellites, BIRD, CHAMP and two upcoming EUTELSAT geostationary positionings.

The daily work of spacecraft operations involves a multitude of documents such as handbooks, databases and flight procedures. They come in electronic or paper format. Also, most commonly, a loose collection of software tools is used for mission preparation and execution. Reporting is mostly done in paper form. Communication takes place in form of mailings (including email) or meetings. The electronically available documents are usually shared on a network drive. This file system together with email can be seen as the most rudimentary form of intranet that exists in virtually all control centres.

The most commonly encountered shortcoming of the conventional work-style is the insufficient accessibility of information and its bad actuality. This also includes the information flow to outside parties like scientific institutes or manufacturers. Usually tons of papers are distributed which in many cases remain unused and unread in bookshelves or archives. This is the main motive for the implementation of an intranet.

The second incentive is the possibility to interconnect the information in "value-added" services. The previously widely spread multitude of software tools, data products and processing instructions are combined in a central place. The documentation can be kept side-by-side with the data and the tools. This also leads to streamlined tools development that is more likely to be re-usable for multiple missions.

Finally there is the goal to provide formal communication channels for team interaction and communication. All work that requires documentation (and what type of work doesn't?) can be alleviated by interactive websites. This includes reporting, log keeping and documentation of decisions, recommendations and activities.

An important consideration is that an intranet allows to use an interface, a standard web browser, that is available on all modern computer systems, is free of cost and mostly needs no installation or update as the intranet is expanded (thin client). Also the existing network infrastructure can be used as long as bandwidth and security considerations are not violated.

General Structure

For each project an individual web site was generated. They all use a similar main menu as a starting page. The content of this menu is taken from a database and can be different depending on login status, user identity and client PC location. The web administrator sees more hyperlinks than a casual user, the Command Operations Team has special links that are not visible to guest users, etc.

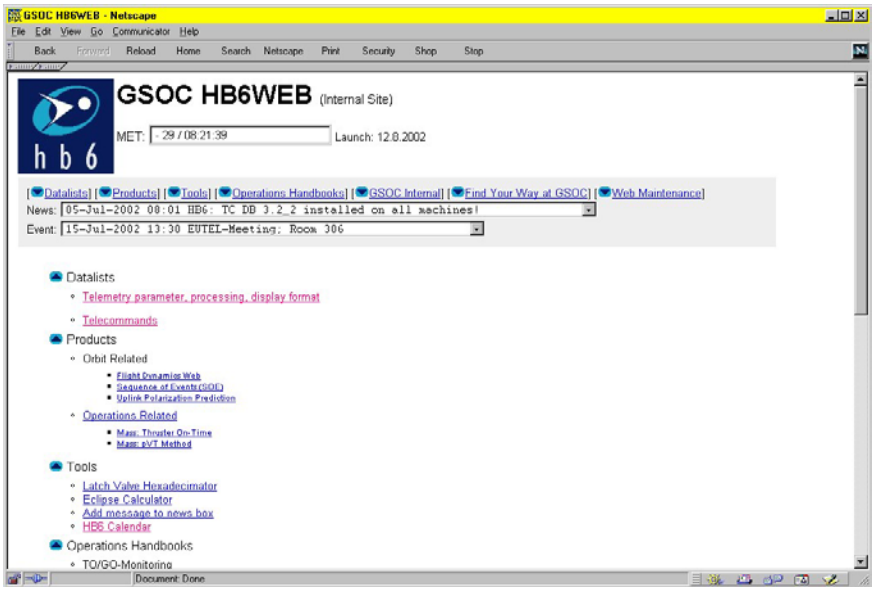

Figure 1: A typical starting page for a project intranet. It contains links to all the intranet services that are applicable to the current user. Logged-in users might see more entries. The news and event lines inform about current topics and upcoming events. There is also a mission countdown clock. The coloring and the mission logo together with similar layout of all pages make for a "corporate design" feeling.

Most of the provided services pages have a similar design including font-type, header, mission logo and a backward link to the main menu. The page header also includes a "jump station" that links to the most important intranet services for this project. This provides the user with a familiar environment and a good orientation. Linked Off-site pages will usually look different, of course.

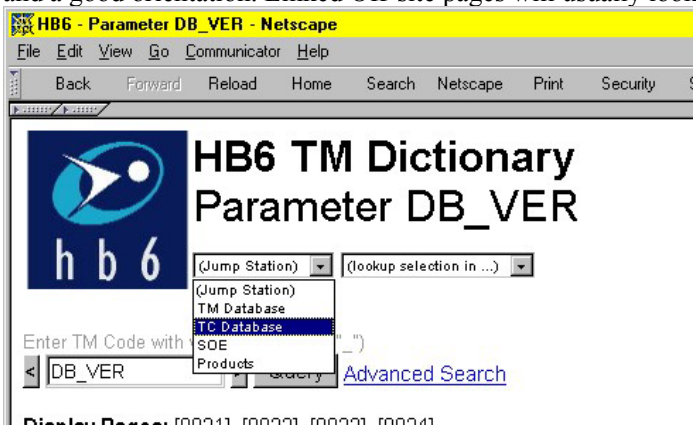

Figure 2: The page header is similar on each page. It shows the mission logo that also serves as a backward link to the main menu. There are always first and second level headlines clarifying the context of the current page. The jump station is a shortcut to the most frequently used intranet services.

Currently only the administrator can add or change links in the main menu. A tool allows to include (or modify) a link in the menu along with the information for which user accounts it shall become visible. On request it also generates a template file or uploads a plain text document and adds the page header.

Intranet Services

During the evolution of the GSOC intranet a couple of intranet services were established that are usable for all types of missions. Other features are applicable only to one mission. Shared features generally are individually adapted to mission peculiarities.

The most used service is the database query. The operational telecommand and telemetry databases are accessible along with complex search functions. All-important properties of the database entries are displayed e.g. processing of telemetry parameters, validity conditions, their implemented calibrations and limits along with descriptive information. From the display database a list of all display pages that show this parameter is taken. If the acronym of a parameter is unknown it may found by using wildcards or by searching for the description text. This service is available for all GSOC missions since they use a similar database structure.

Other types of databases are the Sequence of Events (SOE) database or the Flight Procedure database. The GRACE project uses completely intranet-based flight procedures while most other projects just provide hyperlinks to the list of procedure documents that are conventionally stored on a network file system.

This also applies to documentation. The vast majority of documents are still provided as conventional office document files. They are put on a network drive. To view them the corresponding office application has to be installed locally. By clicking on a link the application is started and the document loaded. An exception is the PDF format that allows opening the document in the web browser. A disadvantage is that office documents are usually large and have long loading times even over a LAN (local area network) connection. For special purposes these documents can be processed by the web server and distributed as common HTML web pages.

Short manuals, produced in-house, on the other hand are usually manually converted to HTML and published on the web.

Tools range from simple calculation aids to complex applications like the time-tag-buffer tool used in the CHAMP and GRACE projects. They were custom developed for these projects and allow modelling of the on-board time-tag buffer of these satellites and checking new time-tagged commands for consistency before they are uploaded. Other examples would be the EUTELSAT Eclipse Calculator that will be discussed later on or the fuel mass calculation software. There are also automated tools that function without the knowledge of the users. This is for example used to extract the log files from the telecommand machines in the BIRD and CHAMP projects. Whenever a log file is generated it is automatically copied to the web server, reformatted and made available internally and externally.

The GRACE project went the long way and even implemented a complete online reporting system where all control room users can write anomalies observation reports and pass them on to the responsible persons. This feature will also be discussed later on.

Distribution of data products is also made easier by using intranet methods. It might not be desired to give guests access to the file network. To provide them with the necessary data, it can simply be put on the intranet.

Finally the GRACE and CHAMP command operators use the Pass Report Tool. They fill out web forms after each pass and submit it into a database. All project participants have read access to this data.

Publishing Models and Content Management

Depending on the task at hand a variety of publishing models is used. All work started out by a single person being in charge for the web server system management, the authoring of tools and for keeping the content up-to-date.

At present most publishing is done "one-way" or asymmetrically. That means that there is one person, who takes a piece of information and puts in onto the web. All others are recipients of this information. This applies e.g. to linked documents and interactive database queries. The task of updating databases or documents is in some cases delegated to dedicated persons who use an online form to start the update process. This greatly reduces the workload of prime publisher and ensures up-to-date content.

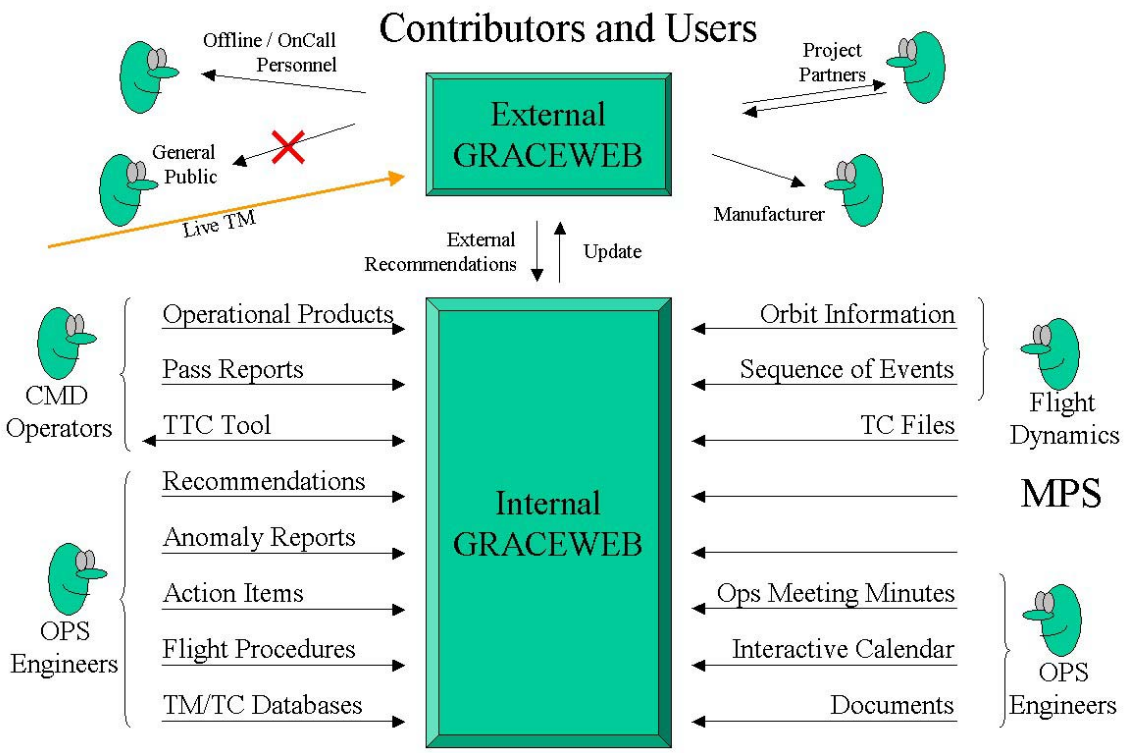

Figure 3: Overview of all participants of the GRACEWEB. Everyone is a user; some parties are also contributors to the intranet.

A special form of asymmetrical publishing is of passive or continuous type. This means that nobody of the project needs to care about updating. This can be a link to another website where people from a different project or even another company maintain a separate web service. One example would be the link to the flight dynamics section web page where the newest orbit information can be found. The continuous type is used for pure file system reflection. For example in GRACEWEB the operators produce data and log files and put them on an internal file server. These files are automatically detected and copied to the web server where even personnel that have no access to the file server may view them. r. The original sub-directory structure can either be preserved or filtered in the process. The most advanced and complex type of publishing is the collaborative approach. Several persons communicate over an intranet service. This is realized e.g. in the Recommendation and Anomaly Reporting tool. One person opens a new report. Other persons can make contributions and give approval.

User Identification

Several principles are applied to identify users and to control the information they have access to. The CHAMP project uses a session principle that allows a login for command operators. This gives them access to special features like the time-tag tool. In some cases like the pass report tool all users have read access, while logged-in users can add new reports and modify existing ones. The login option can be limited to certain workstations. In the GRACE project users have to be individually identified in order to provide signatures to recommendations. Each user has an account here. No session state is used, since in the crowded and hectic control room during a LEOP (launch and early orbit phase) one person might use several stations and even share a terminal with another person. To make a submission or signature or to make modifications the password has to be given every time. Most projects also maintain an external website with similar content. In that case the complete external website is additionally password protected since project data is generally considered confidential.

Applicability

The intranets come into use during all mission phases. During the preparation it serves as document access facility. During mission execution it allows quick referencing and provides communication channels and tools. After a mission it can serve as an archive.

Employed web technologies

The continuing evolution of the World Wide Web and distributed computing technologies such as HTML, HTTP, XML, CORBA, RDBMS, Javascript and Java technologies (applets, JDBC, RMI, Java IDL) provide a powerful and inexpensive framework for the development of distributed applications. By combining some of these technologies the development time and thus the cost may be greatly reduced. Selection of the simplest technology to implement the desired functionality has a great impact on the complexity of the development.

Three approaches were used to develop web based software tools

- Generation of dynamic HTML pages and access to database with ASP scripts executed by the web server
- Java applets for more complex applications that require graphics, database access provided by JDBC
- Java applets accessing CORBA servants on the server for applications requiring near real-time processing, event and/or message handling capabilities

For example it may suffice to visualize information obtained from a database by generating a dynamic HTML page with the use of a scripting language such as ASP. Information is retrieved from the database via ODBC.
If a more complex visualization is required it may be more appropriate to implement the client as a Java applet thus using the Java graphics library and accessing the database via JDBC.
If an even more complex visualization is required, such as the display of real-time data, the client may be implemented as a java applet connecting to CORBA servants residing on the server via the IIOP protocol.
By selecting the simplest approach to fulfil the software requirement, development time may be significantly reduced.

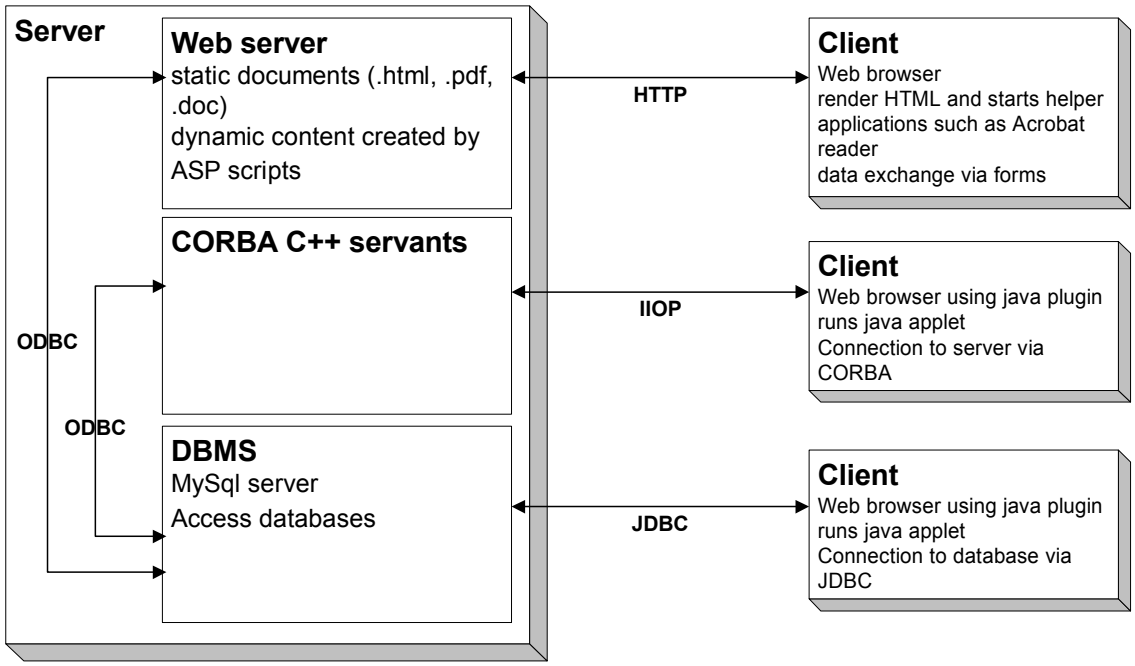

Figure 4: Employed web-technologies for web-based software tools.

Examples of services

These examples shall demonstrate the functionality of some of the tools.

Recommendation Tool

Recommendations are used in the GRACE project to report contingencies and discrepancies of any kind. The users can be divided into two groups. The mission operations team consists of the GSOC project personnel, the Satellite Assistance Team is provided by the manufacturer and project scientists. Additionally there is an Overall Mission Manager.
The recommendation tool starts with an overview page. Here all existing recommendations are listed. This list may be sorted and filtered. There is also a full-text search facility.

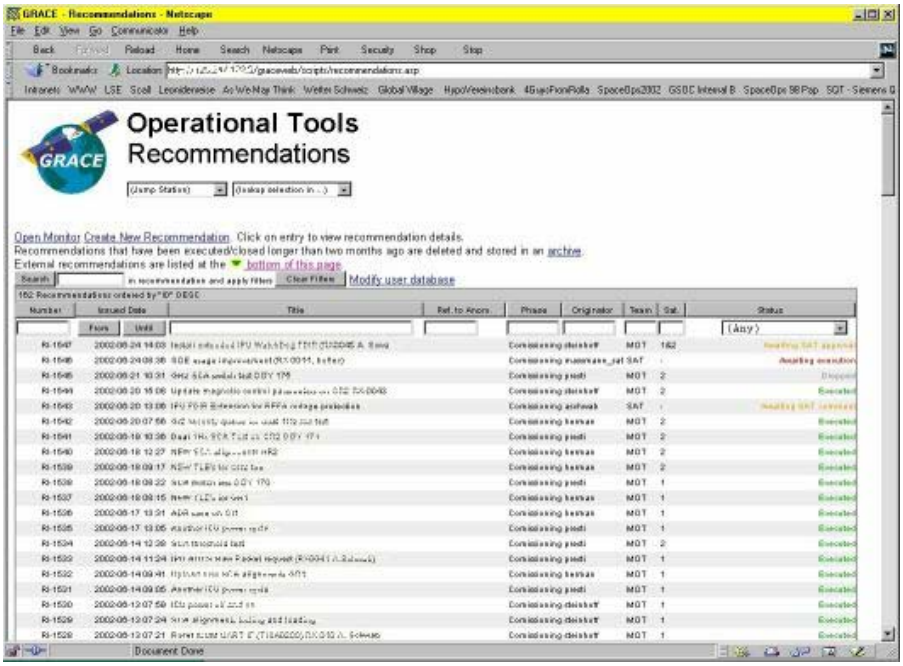

Figure 5: The starting page of the Recommendation Tool shows an overview of all existing entries. Color-coding indicates the processing status of the reports. The list allows be sorting and filtering.

Each project member can open a new recommendation and note his observation. He then has to give his name and password in order to submit this report. Immediately afterwards the report can be viewed by everyone. Additionally a small report monitor window can be opened where newly arrived reports are indicated. Other members of the originator's team can now make additions and corrections. Before a recommendation becomes official however, a team responsible person has to give a signature to finalize or drop the report. Now the report becomes available to the lead person of the other team and the Mission Manager. They also have to give their signatures. If the recommendation is approved the mission operations team or the command operators can execute the recommendation and add an execution note. At all points during the processing other persons can view the report progress.
The Recommendation tool was extensively used during mission preparation, several full-scale rehearsals and all the time since launch. Similar applications are the Anomaly Reporting Tool and the Action Item Tool.

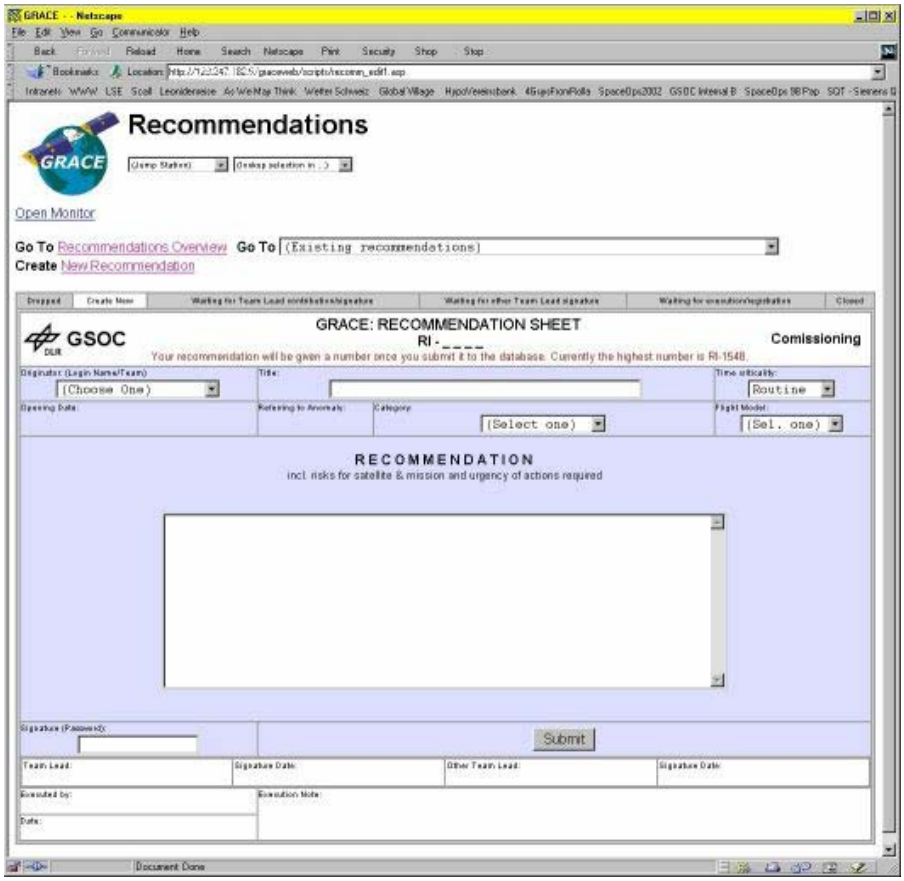

Figure 6: A new Recommendation sheet. At this point all project participants can enter text and submit it with their name and password.

Eclipse Calculator

During geostationary transfer orbit phases a satellite like EUTELSAT HB6 frequently crosses the earth's shadow. The spacecraft has to be configured for these events. Unfortunately eclipses happen also in times when the prime mission staff is off-shift. To give an aid to the staff on duty the eclipse calculator was included as a web service.

On opening the web page it automatically parses the newest orbit event file supplied by GSOC's flight dynamics section. It extracts all eclipses of the next few days and presents a selectable list. The responsible person has just to select the upcoming eclipse that is to be prepared and all flight procedure timing information is calculated. Alternatively the eclipse times can be entered manually if the current orbit file is not available. After entering the times all spacecraft commands are displayed in a syntax that can directly be loaded into the Command System. The commands are written into a command file and automatically distributed to the telecommand machines.

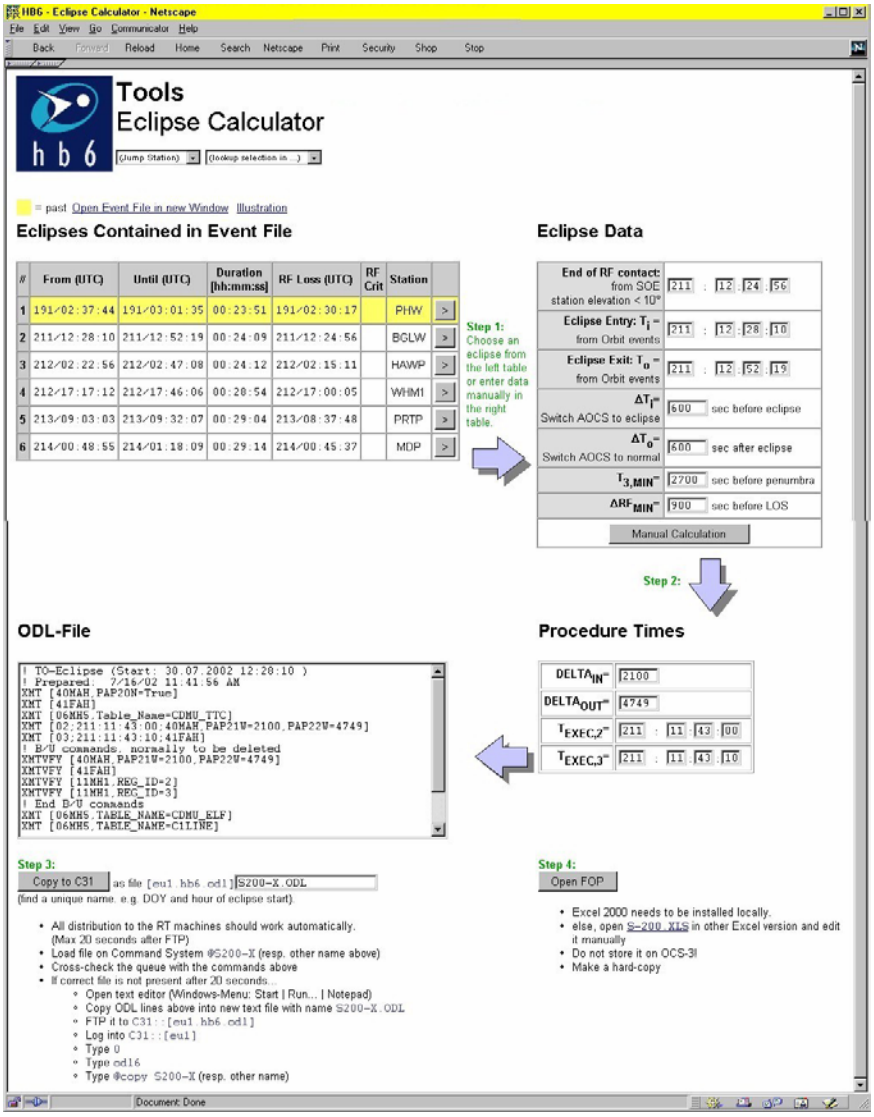

Figure 7: The top left corner of the eclipse tool web page shows the upcoming eclipses in the current sequence of events. The data can be copied to the Eclipse Data table on the right where also manual entries can be made. The Procedure Times show the relevant timing steps as they are used in the eclipse flight procedure. The box ODL-file shows the commands that have to be sent during the procedure. By clicking on a button they are written to a file that can be loaded into command system. Helping instructions and illustrations are given for all steps. They include also instructions for failure cases.

Conclusion

Since the introduction of the intranet a lot has changed in the daily work of mission operations at GSOC. Already meetings are centred on web based action item lists and recommendations. Flight procedures and other documents are read online, and web tools assist operations. The system has reached a critical mass where it can influence all future planning. Due to the ability to quickly adapt to the peculiarities of individual projects the acceptance is very high both on management and on engineering level. Future projects will from the beginning be based on an intranet foundation. Keeping the system close to accepted standards and permanent evolution will ensure that the possibilities will not come to a standstill and projects will find the intranet not a corset but a boost to their progress. The added responsibilities require increased efforts to boost the system's availability and performance.