Integration of STAMP thermal testing software with spacecraft checkout (EGSE) systems
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In this paper, we propose that software controlling the facility during vacuum tests (i.e. the STAMP software package) should exchange data with spacecraft checkout systems. We describe three main benefits: First, vacuum tests will run more efficiently and have a lower chance at human errors. Second, data from multiple sources can be presented on one screen therefore leading to a faster and more accurate interpretation of test results. Finally, EGSE systems can benefit from STAMP’s remote access client to monitor the test results from any off-site location. In short, a direct data link between STAMP and EGSE systems results in error reduction, improvement in test performance and increased productivity.

Nomenclature

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ASCII</td>
<td>American Standard Code for Information Interchange</td>
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<td>CCS</td>
<td>Central Checkout System</td>
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<td>DMZ</td>
<td>Demilitarized Zone</td>
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<td>DSP</td>
<td>Device Storage Process</td>
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<tr>
<td>EGSE</td>
<td>Electrical Ground Support Equipment</td>
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<tr>
<td>ESA?</td>
<td>European Space Agency</td>
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<tr>
<td>IABG</td>
<td>Industrieanlagen-Betriebsgesellschaft</td>
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<tr>
<td>MIB</td>
<td>Mission Information Base</td>
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<tr>
<td>OLE</td>
<td>Object Linking and Embedding</td>
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<tr>
<td>OPC</td>
<td>OLE for Process Control</td>
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<tr>
<td>PLC</td>
<td>Programmable Logic Controller</td>
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<tr>
<td>PSU</td>
<td>Power Supply Unit</td>
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<tr>
<td>SCADA</td>
<td>Supervisory Control And Data Acquisition</td>
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<td>STAMP</td>
<td>System for Thermal Analysis, Measurement, and Power supply control</td>
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<tr>
<td>TCP</td>
<td>Transmission Control Protocol</td>
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<tr>
<td>TSV</td>
<td>Tab Separated Values</td>
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<tr>
<td>XML</td>
<td>eXtensible Markup Language</td>
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I. Introduction

STAMP (System for Thermal, Analysis, Measurement, and Power Supply Control) is the software package¹ that is used to perform thermal tests by ESA and IABG in their large vacuum chambers. It is a powerful data acquisition, presentation, and control system that offers full control of the thermal test facility to an operator and presents test results to facility customers². Using STAMP, the operator can control from one location hundreds of devices (e.g. heaters, sensors, etc.), visualize thousands of sensors and other facility information, set alarms and monitor the spacecraft, all through an easy to use interface. STAMP can present the spacecraft test data to facility customers that are usually located elsewhere in the facility. Furthermore, STAMP has a secure remote application that allows real-time test monitoring from off-site locations.

Where STAMP is used to test and monitor the physical condition of the spacecraft during vacuum tests, all other aspects of the spacecraft (payload, the MIB database, power, etc.) are tested by means of Electrical Ground Support Equipment (EGSE) systems. An important part of the EGSE is the central checkout system (CCS) that facilitates the testing of the MIB, the platform and the payloads.

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In the current situation, STAMP and EGSE systems are running independently.Both collect their share of data and present the test results to test operators. These test operators will monitor the various systems and react to their specific alarms. In the case that EGSE systems need interaction with STAMP controlled devices, operators have to personally transfer the request from one system to the other. Also at the end of a test, the data from STAMP and from the EGSE are merged manually to obtain a complete picture of the spacecraft’s thermal test results. Every time a human intervention is required between two different systems, that are often located in different physical rooms, there is a risk of mistake, delay or data loss.

We propose to make a direct data exchange mechanism between both systems, as shown in Figure 1. We will show how a direct connection between STAMP and EGSE will result in an improved test performance. Another point of consideration for this direct data exchange is that STAMP is complementary to EGSE systems and in particular CCSs. By importing EGSE data directly into STAMP, test operators and spacecraft owners will benefit from the utilities provided by STAMP. Similarly, facility data, collected by STAMP will be immediately available in the EGSE results for a complete thermal test overview.

Most vacuum chamber facilities use in-house build software to control their facility and operate the chamber. We are not aware of any other software packages from thermal test facilities that have an option to export and import data from EGSE systems in realtime.

In this paper, we will first point out the most advantageous benefits from realtime automated data sharing between EGSE and STAMP, after which we will describe the implementation details of the data import and data export mechanism in STAMP. We will discuss some challenges that should be taken into account in the implementation design and finally, we give the status of which features are already implemented in STAMP.

II. Benefits of automated data exchange between STAMP and EGSE

In this section we will describe how direct data exchange between STAMP and EGSE software will result in better efficiency and performance of thermal tests.

A. Improved hardware interfacing

During a test, EGSE systems need to communicate with facility equipment, such as sensors or power supplies. Every change of facility equipment requested during the thermal test involves interaction between the spacecraft test operators and the facility operators. This is acceptable when the frequency of parameter changes is low, but for higher-frequency operations, a direct data link would be preferable. For example, some payloads might still be missing during testing of the qualification model of the spacecraft. To compensate for the energy that is produced by the missing payload devices, heaters are used. These heaters, powered by power supplies (PSUs), are set to dissipate the same amount of thermal energy as the device. STAMP controls the power supply as part of the facility equipment. Now, every time the payload device (simulated by the heater) is switched on or off, the spacecraft test operator has to submit a paper request form to the facility operator with a new setpoint for the power supply controlling the heater. The facility operator will process this request in STAMP, where STAMP logs, verifies, and implements the setpoints on the controlled power supplies.
A direct data link would allow the EGSE to present setpoints directly to STAMP, which directly improves the performance of the test. There is no lost time when updating setpoints; the software directly controls the PSU (through STAMP). Traceability and verification of setpoints remain in place. These are and will still be handled by STAMP downstream from setpoint injection.

Besides the improved performance, also the reliability of the test will increase: There is no chance of STAMP misreading or misunderstanding a request. The spacecraft testing team doesn’t have to spend time on setpoint change requests and will therefore be able to better focus on the test.

Finally, using STAMP to control the facility, EGSE systems don’t have to invest into the development of hardware drivers, as they are already incorporated into STAMP. The only adjustment is the implementation of the communication protocol for STAMP, which is a simple and straightforward TCP connection.

B. Presentation of merged data

As discussed before, STAMP handles the thermal analysis of the facility and does the read-out from the thermal sensors that are placed on the outside of the spacecraft. Thermal data measured inside the spacecraft are sent through house-keeping telemetry to the EGSE systems. The only way to obtain a complete picture of the thermal behaviour of the spacecraft is to map these thermal test sensors to the thermal flight sensors. The manual analysis of data extracted from the different systems, either via side-by-side comparison or by merging the data by means of spreadsheets, is time consuming and error prone.

Using the automated data sharing between the EGSE system and STAMP, thermal test results can be merged much faster, even in real-time. Without any loss of precision or accuracy, test results can be analysed and visualised, for example, thermal data from inside the spacecraft can be shown in STAMP presentations, like in the 3D synoptic presentations as shown in Figure 2.

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Besides thermal data exchange, the EGSE will be also able to import test information into the STAMP logbook, such as which test step is run at what time. Logbook entries can be made visible in the graphs and other presentations, as shown in Figure 3. In this way a complete picture with the highest possible accuracy can be achieved, which will guide the test operator to a better understanding of the thermal test.
C. Availability of remote realtime data access

Using a direct data exchange between EGSE systems and STAMP, facility customers will benefit from the utilities provided both by STAMP or EGSE. Here, we focus on the Remote Client, a tool in STAMP that allows teams from distant locations to participate fully in the thermal test through a secure connection. The remote client allows realtime and offline monitoring of spacecraft and facility test results. When EGSE data are imported into STAMP, facility customers working offsite can use this remote client to follow the test as if they were present onsite. Furthermore, the Remote Client allows for realtime exporting of data to other systems, so test data can be processed in realtime at the customer site using the usual in-house tools. If needed, the results can be shown and discussed quickly with in-house experts, even while the test is still running. Any possible problem can therefore quickly be identified and interventions can be made when required. This process will reduce the cost of a thermal test and will increase efficiency in the case of problems.

1. Offline and realtime test monitoring

The STAMP remote client is given to the facility customer. The remote client makes a connection to the test server and the selected test database is downloaded into a local database. As long as the connection remains, the remote client receives realtime test data updates. The local copy of the test database also allows the facility customer to work offline during and after the thermal test at moments convenient for him. On reconnection to the test database, the local copy will be brought up to date, so the facility customer has access to the latest possible data.

2. Security Aspects

To send real-time test data over the internet, extra security measures should be taken into account. STAMP uses a range of techniques to address these concerns. The main components are shown in Figure 4. The Master server stores all test configuration and data in the test database. The firewall 1 blocks all incoming connections and allows only external connections that are created from inside the test center to the outside. An intermediate server, the so-

Figure 3. Example of merged data from EGSE and STAMP.

An example of the graph presentation in STAMP. The STAMP sensors represent sensors that are located on the outside of the spacecraft. The EGSE sensor represents thermal data from inside the spacecraft, which is extracted from the house-keeping data packets. The EGSE has exported the data together with test information to STAMP. STAMP merges the facility data with the test sensor data and displays all information on the screen. Note that the graph shows simulated data.
called teletest server, is set up in the Demilitarized Zone (DMZ). It contains a copy of the test configuration and test data. This teletest server distributes the data to connected Remote Clients and is protected by a second firewall. Firewall 2 only allows incoming connections from remote clients, if and only if, the client can present a trusted and valid client certificate that is signed by the test center. An encrypted username and password are requested to define which subset of the test and configuration (e.g. sensors, PSUs, synoptics, etc.) can be made visible to each particular remote client. Of course, all data are sent encrypted using a strong encryption, which makes it practically impossible to intercept or alter the data during its exchange.

III. STAMP import/export implementation details

There are several data sharing mechanisms in STAMP that allow for the export and import of both real-time and historical data. Here, we describe the two principle interfaces that can be used for the EGSE data sharing; the Socket interface and system specific import applications.

A. Socket interface

To interact with the EGSE or any other software package, a socket interface is provided. STAMP communicates through a simple, well documented, ASCII based, communication protocol, which does not require any external libraries to be linked. The data can be imported in XML format and TSV format, which should contain a unique sensor name, time stamp and a value. This protocol has been successfully used for the MetOP program as well as the SMOS earth observation satellite to share data between STAMP and the Central Checkout Systems developed by Terma.¹⁵

1. Data export

STAMP considers the data export to be a presentation type, as it presents data to another software package. In the Remote Client, or the Common Presentation Client, there is a presentation available for this purpose, the so-called connector presentation. It exports a (subset of) sensors to the specified ip-address and socket. This exported data can be either real-time data or a block of data for a certain time-period.

2. Data import

STAMP considers imported data to be similar to an acquisition device, as it acquires data from another software package. A data
import from any EGSE system to STAMP is therefore configured in the exact same way as a scanner that is connected through a TCP socket interface. See Figure 5. To increase security, STAMP will only allow incoming connections from the ip-addresses and ports specified in the interface. Imported data will be shown as real sensors together with the acquired data by STAMP. See Figure 3. By treating imported data as normal sensors, STAMP allows the user to place alarms on these imported sensor values and present them in the exact same way as regular STAMP data.

B. Interface application

If the EGSE software package is not compatible with the STAMP communication protocol, a STAMP import application can be developed. This application will handle all communication to the EGSE system and will be added as a standalone extension to the STAMP software package. There are two possible ways to set up an interface in this case:

- Using the interface provided by the EGSE software. The provided communication protocol will be used by STAMP to import the thermal data into STAMP. For example, an OPC import/export application has been developed that is used to communicate with the SCADA software for the facility PLC.
- Directly querying the EGSE database to retrieve the telemetry packets and extract the thermal parameters. The STAMP import application will need the MIB and access to the EGSE database to perform these actions. During the test STAMP will query the database on regular basis for new packets that contain thermal data. These packets will be interpreted by the STAMP import application and the thermal data will be imported to the STAMP server. This particular approach has not yet been implemented, as no customer has shown interest in this feature. However Terma has the technical knowledge to develop the application, when requested.

IV. Foreseen challenges

A. Safety checks

When allowing the operators from the EGSE system to control power supplies, a manual check on the setpoint validity is lost. To ensure that the facility operator is aware of power supply setpoint changes, STAMP can be configured that a warning message is presented to the facility operator. These warning messages could be configured as warnings, alarms or even a digital setpoint change request form that pops-up on the screen of the facility operator. These warnings and the level of the warning could be set separately for each PSU.

B. Time differences

STAMP presents timestamps according to the configuration of the local machine it is running on. Telemetry usually has two time points, the on board time stating when the packet was generated and the ground time indicating when the packet was received. STAMP needs to correct these times to be able to correlate thermal data from flight sensors to the thermal data from the test sensors. Therefore, a time offset parameter is required when setting up the EGSE data import, see Figure 5. The time offset will indicate how much time difference there is between the on board time and the time used in STAMP. STAMP will correct any data value with this offset, thus presenting the timeline as accurate as possible.

Note that STAMP is capable of handling nonsequential data values and present them in sequential order to the customer. Therefore spacecraft thermal data can be merged with test data at any point during the test, either in realtime or in retrospect, without compromising the stored data or presentations.

C. Security

The facility network where STAMP is running is generally shielded from the EGSE network of the spacecraft owners, either through a firewall, VLAN tagging or sometimes the networks are completely physically separated. A direct data link between STAMP and the EGSE requires that a connection between the facility and EGSE network exists. Therefore, it is important that sufficient security measures are taken. This could be done by firewalls, proxy’s or some other mechanism. Which solution is chosen depends on the facility and the possibilities.

V. Current Implementation Status

Most of the features in this paper are available today, and have been in use for many years. Remote access using the Remote Client, in particular, is nowadays fully integrated in the tests at ESTEC. Controlling PSUs from an external (EGSE) system is also possible with today's software, although this has not yet been used in a practical
situation. Note that such control is only available within the testing network itself; the Remote Client is only for remote presentation, not for remote control.

Reading EGSE databases from STAMP is not yet implemented. The implementation of this feature would be a reasonably large amount of work, as the whole interpretation of the MIB and telemetry packets must be implemented and validated. Once the framework and telemetry interpretation is in place, it would be a small effort to add support to queries for the databases from the various EGSE systems.

**Conclusion**

STAMP is a mature solution for large scale thermal testing that has been refined and improved over a period of almost two decades. In this paper, we propose an automated data exchange between STAMP and EGSE systems. We describe how sharing data between STAMP and EGSE systems through an automated data exchange mechanism will result in error reduction, improvement in test performance and increased productivity. We are confident that in the near future this direct data link will become a standard requirement for every spacecraft thermal test.

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**References**

1. STAMP, System for Thermal, Analysis, Measurement, and Power Supply Control, software package v3.1.6, Terma BV, Schuttersveld 9, 2316 XG, Leiden, the Netherlands, 2015.
5. TSC, The Test Sequence Controller, software package, Terma BV, Schuttersveld 9, 2316 XG, Leiden, the Netherlands, 2015.