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# CONTROL COMMAND STRATEGY FOR THE THOMX ACCELERATOR

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## *Abstract*

ThomX is a compact Compton based X-ray source under construction at LAL laboratory [1] in Orsay (France). The ThomX facility is composed by a 50 MeV linac (with an upgrade option of 70 MeV), a transfer line and a 18 meters long Storage Ring (SR). The Compton scattering between the 50 MeV electron bunch of up to 1 nC and the 30 mJ laser pulses stacked in the Fabry-Perot cavity results in the production of photons with energies (from 40 to 90 keV). The final goal is to provide an X-rays average flux of $10 \times 10^{11}$–$10 \times 10^{13}$ photons/s. ThomX is under construction and the first commissioning electrons are expected at the end of 2018.

## INTRODUCTION

The LAL laboratory is in charge of Control System (CS). The ThomX CS group is made up of LAL CS group and is helped in its work by the IT group. Network infrastructure has been planned by control group while it is operated by network team from the LAL laboratory.

## DEVELOPMENT

The control system source code is versioned using Mercurial Decentralized Version Control System, these source codes are shared on a reference repository on a Gitlab instance supplied by IN2P3 [2]. The TANGO [3] control system and its dedicated tools have been chosen to control de hardware devices. TANGO has already been implemented at several laboratories in Europe in particular at Synchrotron-Soleil [4] which is involved in the ThomX collaboration.

Many tools are provided from the TANGO community, depending on the preferred programming language. For example Java tools include JDraw, and ATK, and Taurus, PyTango, Sardana are programmed under Python.

A centralized nomenclature naming convention inspired by SOLEIL [4] is used to identify the elements used in ThomX, cabling, localization, and responsible for each device. This nomenclature is used as a centralized document. It allows to identify each device and discuss the need to connect it to network or to control it through TANGO. Some development are currently still in progress since all devices are not chosen yet. Once a DS has been developed, it is tested if possible in the context it will be used to decrease the risk of incompatibility during integration.

## SYSTEM AND NETWORK

While development began with TANGO 8 installed on Debian 8, CS group moved DS(Device Server) on TANGO 9 under Debian 9. Specific CS computers have been installed for development with TANGO 8 and TANGO 9 databases, Archiving service, PLC development under Windows, and specific DS which only work under Windows. They are installed in a specific autonomous VLAN distinct from final planned networks.

ThomX computers and devices are interconnected by a physical independent network (see Figure 1). This formally allows ThomX to operate even when network is disconnected from Internet. However, this network is connected to the LAL one, which has connexion to InterNet. Several subnetworks will coexist into ThomX:

- a public network will allow operators to access Internet from some specific ports inside ThomX.
- an acquisition network will be dedicated to high-consuming bandwidth devices like CCD, oscilloscopes and acquisition cards. This network allow high-bandwidth communications without arrival insurance.
- a control-command network will be dedicated to device configuration and slow acquisition, to assure data integrity. These networks will be separated by VLANs and a gateway will filter communications between Internet and ThomX networks.

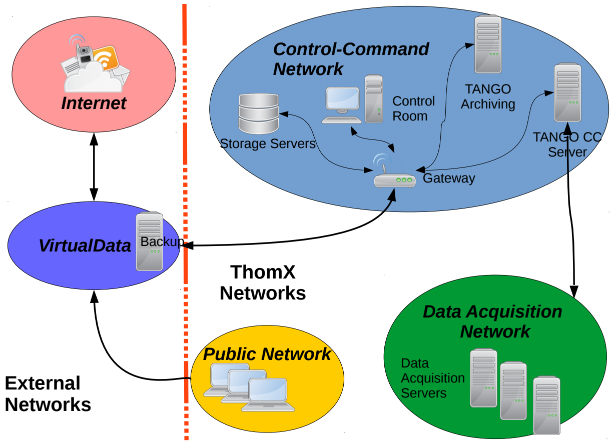
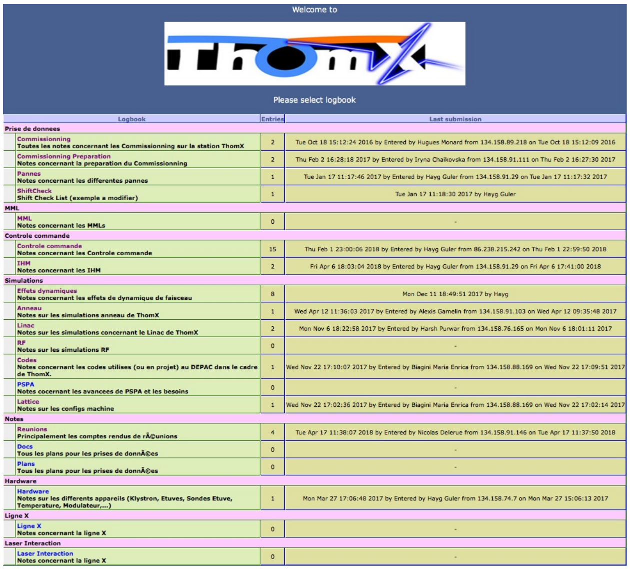


Figure 1: ThomX network scheme.

## NOTES AND LOGBOOK

Dedicated electronic logbook [5] based on elog [6], shown on Figure 2, will be used for the commissioning and is already collecting simulations and control command notes. Automatic notes could also be parametrized either in GUIs or into dedicated scripts. Each section might have well defined category types because they will be used to search through logs.



Welcome to

Please select logbook

| Logbook | Entries | Last submission |
|---|---|---|
| Prise de donnees | | |
| Commissionning<br>Toutes les notes concernant les Commissionning sur la station ThomX | 2 | Tue Oct 18 15:12:24 2016 by Entered by Hugues Monard from 134.158.89.218 on Tue Oct 18 15:12:09 2016 |
| Commissionning Preparation<br>Notes concernant la preparation du Commissionning | 2 | Thu Feb 2 16:28:18 2017 by Entered by Iryna Chaikovska from 134.158.91.111 on Thu Feb 2 16:27:30 2017 |
| Pannes<br>Notes concernant les differentes pannes | 1 | Tue Jan 17 11:17:46 2017 by Entered by Hayg Guler from 134.158.91.29 on Tue Jan 17 11:17:32 2017 |
| ShiftCheck<br>Shift Check List (exemple a modifier) | 1 | Tue Jan 17 11:18:30 2017 by Hayg Guler |
| MML | | |
| MML<br>Notes concernant les MMLs | 0 | - |
| Controle commande | | |
| Controle commande<br>Notes concernant les Controle commande | 15 | Thu Feb 1 23:00:06 2018 by Entered by Hayg Guler from 86.238.215.242 on Thu Feb 1 22:59:50 2018 |
| IHM<br>Notes concernant les IHM | 2 | Fri Apr 6 18:03:04 2018 by Entered by Hayg Guler from 134.158.91.29 on Fri Apr 6 17:41:00 2018 |
| Simulations | | |
| Effets dynamiques<br>Notes concernant les effets de dynamique de faisceau | 8 | Mon Dec 11 18:49:51 2017 by Hayg |
| Anneau<br>Notes sur les simulations anneau de ThomX | 1 | Wed Apr 12 11:36:03 2017 by Entered by Alexis Gamelin from 134.158.91.103 on Wed Apr 12 09:35:48 2017 |
| Linac<br>Notes sur les simulations concernant le Linac de ThomX | 2 | Mon Nov 6 18:22:58 2017 by Entered by Harsh Purwar from 134.158.76.165 on Mon Nov 6 18:01:11 2017 |
| RF<br>Notes sur les simulations RF | 0 | - |
| Codes<br>Notes concernant les codes utilises (ou en projet) au DEPAC dans le cadre de ThomX. | 1 | Wed Nov 22 17:10:07 2017 by Entered by Biagini Maria Enrica from 134.158.88.169 on Wed Nov 22 17:09:51 2017 |
| PSPA<br>Notes cocernant les avancees de PSPA et les besoins | 0 | - |
| Lattice<br>Notes sur les configs machine | 1 | Wed Nov 22 17:02:36 2017 by Entered by Biagini Maria Enrica from 134.158.88.169 on Wed Nov 22 17:02:14 2017 |
| Notes | | |
| Reunions<br>Principalement les comptes rendus de rÃ©unions | 4 | Tue Apr 17 11:38:07 2018 by Entered by Nicolas Delerue from 134.158.91.146 on Tue Apr 17 11:37:50 2018 |
| Docs<br>Tous les plans pour les prises de donnÃ©es | 0 | - |
| Plans<br>Tous les plans pour les prises de donnÃ©es | 0 | - |
| Hardware | | |
| Hardware<br>Notes sur les differents appareils (Klystron, Etuves, Sondes Etuve, Temperature, Modulateur,...) | 1 | Mon Mar 27 17:06:48 2017 by Entered by Hayg Guler from 134.158.74.7 on Mon Mar 27 15:06:13 2017 |
| Ligne X | | |
| Ligne X<br>Notes concernant la ligne X | 0 | - |
| Laser Interaction | | |
| Laser Interaction<br>Notes concernant la ligne X | 0 | - |

Figure 2: ThomX LAL electronic logbook.

Project management is done with the Redmine tracking tool. It allows users to manage multiple projects and associated subprojects. It features per project wikis and forums, time tracking, and flexible, role-based access control. It includes a calendar and Gantt charts to aid visual representation of projects and their deadlines.

## COMMISSIONNING & GUI CONCEPTION

CS has created a virtual machine (VM) accessible to operators and experts. This VM is based on LAL openstack infrastructure maintained by the IT group. It is installed as a TANGO server to allow testing TANGO behavior and services, expert GUIs and high-level MML GUI. A TangoTest DS was first installed and launched to access random TANGO device attributes of each existing TANGO type. Simulated DS are currently configured using SimulatorDS [7] to allow mimic the ThomX device behavior in order to test them. This especially will help experts and operators to test high-level software with real attributes and command names.

Software development will continue even during the commissioning period, because tools should always be adapted to real-life data taking, and reality could be different from expectations. For this reason, development methodology should be very strict to prevent any data or software losses. In this purpose, dedicated server with simulated DS will be provided for development. Each developed tool must go through repository pipe, and approval by other developers or team members.

## CHOICE FOR TAURUS ENVIRONMENT FOR GUI DEVELOPMENT

Taurus is a popular solution for rapid creation of Graphical User Interfaces (both GUIs and command-line based) for experiment control and data acquisition (even by non-programmers) [8]. Taurus is a free, open source, multi-platform pure Python module (it uses PyQt for the GUI). It uses a Model-View approach to building the GUIs where the complexities of lower-level access to the data sources or control libraries is abstracted away by a set of plugins that provide Taurus model objects. The graphical components of a GUI just need to be provided with one or more model names in order to display and/or control the data represented by the model(s), allowing the creation of fully functional GUIs in a few minutes without programming.

At ThomX, different GUI levels should be specific each action:

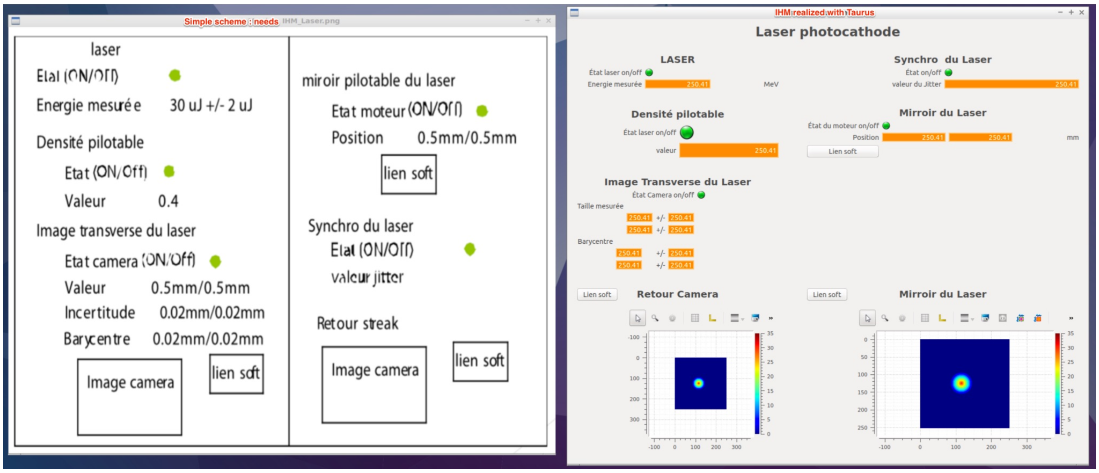
- Start equipments
- Control the equipments (Trends, histograms, ...)
- Start GUIs during operation
- Scans (charge phase, ...)

On top of Tango low level system, our control tools are developed under Taurus / Python environment for low level controls like start of equipments, machine controls, etc. High level operations, like for the ring, are done under the Matlab-Middle-Layer. Indeed MML contains all the tools to tune the machine since optics functions, beta and matching methods, are already implemented.

In order to be as close to the operator and machine expert needs, as possible, special development methods have been implemented. The methodology for GUI development is to follow the following steps:

- meet with each ThomX subgroups for the needed informations: which information would provide the GUI and which parameters we want act on
- Names and types of the DS to be accessed through the GUI
- simple scheme which shows GUI locations and associated functions (buttons, switch, labels, etc )
- some ergonomic rules to unify the GUI
- possibilities to call external program to calculate some variables
- high level Tango variables (beam size, Twiss parameters) should be necessary

Each GUI creator should have all the information to properly develop the application and test it with testing devices filled with random variables when the hardware is not yet ready. On Taurus based GUI example is shown on Figure 3 and compared to its designed scheme.



Simple scheme : needs IHM_Laser.png

laser
Etat (ON/Off) ●
Energie mesurée 30 uJ +/- 2 uJ
Densité pilotable
Etat (ON/Off) ●
Valeur 0.4
Image transverse du laser
Etat camera (ON/Off) ●
Valeur 0.5mm/0.5mm
Incertitude 0.02mm/0.02mm
Barycentre 0.02mm/0.02mm
Image camera
lien soft

miroir pilotable du laser
Etat moteur (ON/Off) ●
Position 0.5mm/0.5mm
lien soft
Synchro du laser
Etat (ON/Off) ●
valeur jitter
Retour streak
Image camera
lien soft

IHM realized with Taurus

Laser photocathode

LASER
État laser on/off ●
Energie mesurée 250.41 MeV

Synchro du Laser
État on/off ●
valeur du Jitter 250.41

Densité pilotable
État laser on/off ●
valeur 250.41

Mirroir du Laser
État du moteur on/off ●
Position 250.41 250.41 mm
Lien soft

Image Transverse du Laser
État Camera on/off ●
Taille mesurée
250.41 +/- 250.41
250.41 +/- 250.41
Barycentre
250.41 +/- 250.41
250.41 +/- 250.41

Lien soft Retour Camera

Lien soft Mirroir du Laser

Figure 3: GUI example with model on left and Taurus GUI on the right plot.

## THOMX INTERLOCK SYSTEM

Because of the high beam power and energies in an accelerator, the risk of beam induced damage is significant. An interlock system is then used to protect the very sensitive and essential equipments of an accelerator (vacuum chambers, valves, magnets, etc.) during machine operation. ThomX interlock system is based on Programmable Logic Controller (PLC-Siemens S7-1500); it collects default signals from the different subsystems of the machine, up to the master PLC, which kills the beam, by stopping the RF, in case of problem (bad vacuum, magnets overheating, etc.). The interlock system consists of two levels. The first one is a local process, whose role is to monitor the variations of different parameters of the machine subsystems, and generates default signal in case of operation problem. The second level is the master PLC, which gathers and process all the default signals from subsystems, and stops the RF power in a quicker reaction (less than 1 ms). Figure 4 presents an overview of all the devices linked to the interlock system.

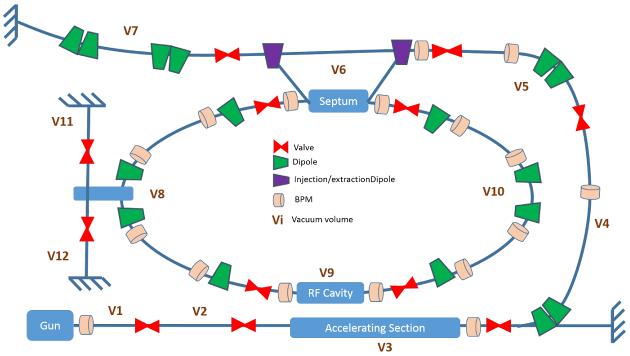


Figure 4: Overview of the ThomX subsystems linked to the machine interlock system.

## CHALLENGES

As it is typical for such a complicated setups, issues and bugs are expected and special methodology should be setup to properly debug. Long term bug and issue analysis might help to take into control weak parts of the command control and find where are the weak part in the hardware. Alarm management is one of the key point for the debugging, and controlling the machine. For this purpose, PANIC [9] seems a choice of Python-based alarm management system perfectly adapted to our software configuration. PANIC is a suite of Python applications focused on visualization, logging and notification of events occurring in ALBA Synchrotron Control System. Build on top of the PyAlarm Tango Device Server it provides an API and a set of graphic tools to visualize the status of the declared alarms, create new alarm processes and enable notification services like SMS, email, data recording, sound or execution of Tango commands. One could also link PyAlarm to the electronic logbook with dedicated keywords. For each interlock, we need to recover the full path of responsible devices which are at the origin of the interlock. This needs to connect the ThomX interlock system to a proper alarm management with precise timing.

## CONCLUSION

ThomX commissioning will start this year, which puts lot of challenging efforts both on the hardware and software installations teams. At some point, dedicated period for testing equipments together with the Tango-system will be necessary. The strength of the Tango-Taurus couple solution will be benchmarked through ThomX equipment and should be proposed as control system for all the foreseen machines at Orsay.

## AKNOWLEDGEMENTS

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[9] S. Rubio-Manrique et al., "Extending Alarm Handling in Tango", in *Proc. ICALEPCS'11*, Grenoble, France, Oct. 2011, paper MOMMU001.