PROPOSAL OF SYSTEM ARCHITECTURE TO AUTOMATE TESTS OF SOUNDING ROCKETS ELECTRO-ELECTRONIC MODULES

Francisco Carlos Parquet Bizarria, fcpb@iae.cta.br
Instituto de Aeronáutica e Espaço - Praça Mal. Eduardo Gomes, 50 - CEP: 12228-904 – São José dos Campos – SP/Brasil

José Walter Parquet Bizarria, jwpb@inf.unitau.br
Universidade de Taubaté - Rua Visconde do Rio Branco, 210 - CEP: 12020-040 – Taubaté – SP/Brasil

Jairo Ferreira dos Santos Filho, jairo@iae.cta.br
Instituto de Aeronáutica e Espaço - Praça Mal. Eduardo Gomes, 50 - CEP: 12228-904 – São José dos Campos – SP/Brasil

Abstract. *The foreseen specifications for determined equipment can be proved by the results provided in accomplishment of specific tests. The tests accomplishment is a task that follows development cycle of systems applied to space segment. The eletro-electronic equipments that are part of sounding rockets electrical networks and satellite launcher vehicles, currently developed by Space and Aeronautical Institute, are typically submitted to qualification and / or acceptance and / or revalidation tests. Those tests are carried out by specialized technical team that performs a long sequence of activities. Those activities require, from the team members, constant visual evaluations, annotations and interventions in parts that compound the assembled sets to support any type of test. With a goal of minimizing time and the human efforts, in the accomplishment of those activities, it was opted to automate part of aforementioned tests. Within that context, this work presents a system architecture proposal to automate the tests of modules, which perform safety and switching tasks, inserted in the electrical networks of those sounding rockets electrical and satellite launcher vehicles. That system architecture was idealized to be applied in a specific family of satellite launcher vehicles, based on supervision system, programmable logic controller, sensors and actuators, available in national market, with a goal of taking advantage of, mainly, utilization of standard hardware and software that have capability to accomplish modifications in integrated development environment. The satisfactory results observed in the operational tests, performed with the first representative prototype version of that architecture, indicated that such proposal presented in this work is feasible and it is able to comply with proposed target.*

Keywords*: sounding rockets, electrical networks, tests automation.*

1. INTRODUCTION

The foreseen specifications for determined equipment can be proved by the results provided in accomplishment of specific tests. The tests accomplishment is a task that follows development cycle of systems applied to space segment. The electro-electronic equipments that are part of sounding rockets electrical networks and satellite launcher vehicles, currently developed by Space and Aeronautical Institute, are typically submitted to qualification and / or acceptance and / or revalidation tests (Palmério, 2005). Those tests are carried out by specialized technical team that performs a long sequence of activities. Those activities require, from the team members, constant visual evaluations, annotations and interventions in parts that compound the assembled sets to support any type of test. With a goal of minimizing time and the human efforts, in the accomplishment of those activities, it was opted to automate part of aforementioned tests.

2. WORK GOALS

The main goal of this work is concentrated in presenting a system architecture proposal to automate tests of modules, which perform actuation and safety tasks, incorporated into the sounding rockets and satellite launcher vehicles electrical networks.

To present preliminary results obtained from tests accomplished with the first prototype version, that was developed with the architecture proposed in this work.

3. PROPOSED ARCHITECTURE

The main representative components of proposed architecture to automate tests in electro electronic equipments, incorporated into the on board sounding rockets and satellite launcher vehicles electrical networks are showed in the Fig. 1.

The CONTROLLER block function, presented on that figure, which is able to be performed by mean of Programmable Logic Controller (PLC), because on that mentioned architecture that block must have resources to handle with digital and/or analog inputs and outputs, which support a vast electrical signals ranges (MIYAGI, 1996). On that controller must be foreseen installation of program that will run activities management of that proposed architecture, related to operational and/or functional characteristics required by the equipments to be submitted to the tests.

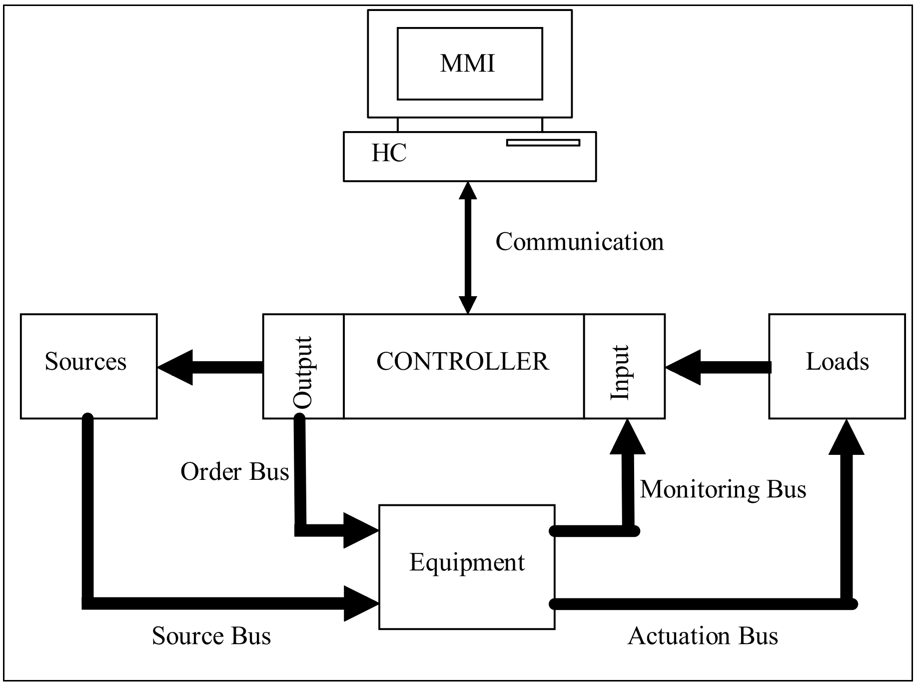

Figure 1. Main components of proposed architecture

As per operations sequence established for switching and supervision accomplishment of equipment state, that program will be able of executing actions to obtain information related to the tests sequence conceived by the designer that idealized the equipment.

In the Man Machine Interface (MMI), that is installed at applicative layer in the Host Computer (HC), which is foreseen a dedicated window provided with necessary resources for the operator actuates the equipments and supervises their states during the tests accomplishment (De Moraes and Castrucci, 2001). That switching could be performed by mean of either manual or automatic operation mode. The information concerning to the equipment current states are presented on that interface to system operator's monitoring. Also that information will be stored in database for subsequent specialist analysis. That interface shall be able of communicating with the Programmable Logic Controller by dedicated network.

The block named by Loads, represents the devices that shall be switched by on board electro-electronic equipments submitted to the mentioned tests.

The block named by Sources, represents the types of electrical energy supplies, direct current, which are necessary to support equipment working submitted to the tests.

3.1. Connections Diagram

The analytic diagram of connections adopted in the first prototype version developed to validate the architecture proposed in this work is presented in the Fig. 2. That diagram was created to support specifically the module named by Actuation and Safety Module (ASM), which is included in satellite launcher vehicles on board electrical networks (Pinheiro, 2005).

The components set presented in the Fig 2 are related to those indicated in the Fig 1 other than Signals Conditioning Interface (SCI). The main function of that interface is to provide suitable digital signals that were sent from the PLC to the components enclosed in equipment submitted to tests and vice-versa.

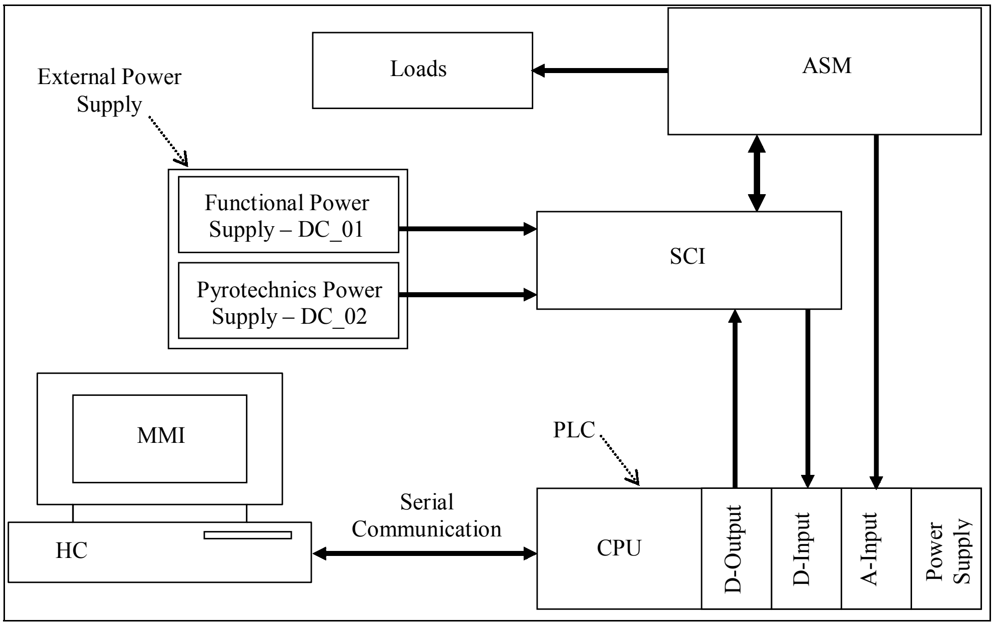

Figure 2. Prototype Connections Diagram

The Programmable Logic Controller (PLC) employed in the prototype assembly is composed mainly by the following components: i) Central Processing Unit (CPU), ii) digital input (D-Input), iii) digital output (D-Output), iv) analog input (A-Input), v) Power Supply, vi) Chassis and Programming Terminal (Costa, 2005).

That configuration associated to the Signals Conditioning Interface (SCI) and External Power Supply are necessary components to allow mainly: i) to supervise the functional battery voltage levels and pyrotechnics, ii) to supervise and switch the Safety Relay and supervision of events Passive Condition (PC) indication, iii) to supervise and switch the External Power Relay installed in the SCI.

The external power provides electrical energy with availability of +28, -28 and 18 voltages, direct current, to supply the signals conditioning interface and equipment that are included in the test.

A serial communication link is used to perform the information flow between the PLC and the host computer (HC), which incorporates the system Man Machine Interface (MMI). The used controller incorporates the communication protocols defined by Electronic Industry Association (EIA) standard.

The signals conditioning is composed by an interface that supports the PLC to send and receive digital signals properly. Those signals are related to the tasks of actuation and monitoring of circuits that are included in the Actuation and Safety Module (ASM). To have proper signals, that is necessary to use the electrical voltage levels available in the referenced external power. That interface is basically compounded by a circuit board, which performs the tasks of indication and command. The function of that board is concentrated in the task of: i) receiving signals and commands sent by the PLC, ii) adjusting those signals to the electrical voltage levels compatible with the components that are included into the modules that will be tested, iii) applying those signals in the electrical network modules, iv) receiving indication signals which come from the module, v) performing applicable adjusts at the signals electrical voltage levels, vi) becoming available signals for the PLC reading.

A components set view that integrates the first prototype version developed to perform tests in electro electronic equipments incorporated into the sounding rockets and satellite launcher vehicles is showed in the Fig. 3. On that prototype were accomplished tests to validate the architecture proposed in this work.

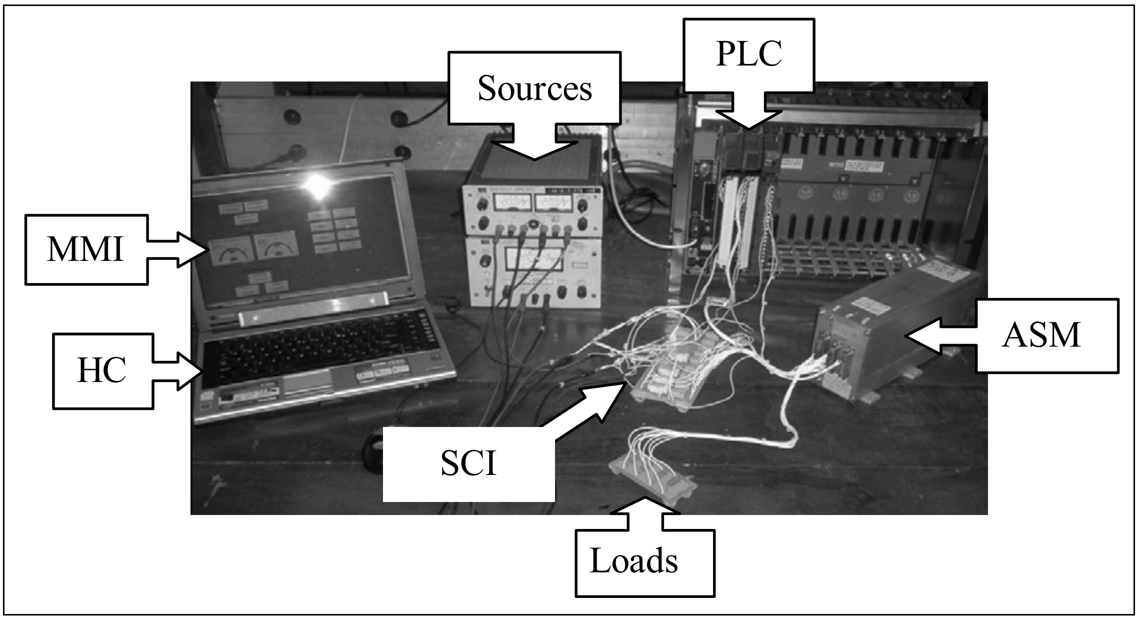

Figure 3. Prototype view

3.2. Management Program

The management program of information, which is foreseen to the architecture proposed in this work, which was prepared based on a document named by Dossier of Actuation and Safety Module Manufacturing. That document is prepared by the designer responsible for electronic module development and it describes the procedures that shall be complied with to the accomplishment of equipment functional tests, taking into account their electrical characteristics and operation.

That management program shall run in two split modes. In the first mode the system operator shall perform an individual switching of each test step. This will allow the evaluation of isolated events, aiming to purge possible equipment operation failures.

On that mode of operation that is possible to active and deactivate part of the equipment electronic circuit, as much as necessary. That action can be used as a resource to diagnose and / or to confirm non-conformities manifestation in parts of the equipment. This is possible because that equipment presents as operational characteristic the presence of state indication, that when it is sent to the supervision system, which is able of informing to the system operator how complete the system is, considering the signal under analysis.

The second mode is applied for global evaluation of the electro electronic equipment. That mode is able of identifying non-conformities in the equipment and this way it does not allow manually to active and deactivate part of the circuit, which is out of the sequence foreseen by the management program.

Independently of the operation mode that is chosen to be executed by the management program, that are always used the state signals, analog and/or digital, that are included in the modules to define if the performed switching were successful.

The management program algorithm of the architecture proposed in this work, it shall execute mainly the following tasks:

- To start the external power supplies, which must be within predefined voltage values.
- To turn on the functional power of the module.
- To turn on the Control Bench monitoring.
- To turn on the pyrotechnics power.
- To verify if that voltage value, related to the functional power is within the expected range.
- To position the safety relay in SAFETY mode.
- To verify if the relay was position in the referenced condition.
- To verify if that voltage value, related to the pyrotechnics power, that is within the expected range.
- To position the safety relay in ARMED mode.
- To verify if the relay was position in the referenced condition.
- To verify if that voltage value, related to the pyrotechnics power, that is within the expected range.
- To verify if the passive condition was activated.
- To generate the signal that refers to the ORDER 1.
- To verify if there was a response to the ORDER 1.

- To generate the signal that refers to the ORDER 2.
- To verify if there was a response to the ORDER 2.
- To generate the signal that refers to the ORDER 3.
- To verify if there was a response to the ORDER 3.
- To generate the signal that refers to the ORDER 4.
- To verify if there was a response to the ORDER 4.
- To position the safety relay in SAFETY mode.
- To verify if the relay was position in the referenced condition.
- To deactivate the pyrotechnics power.
- To deactivate the Control Bench monitoring.
- To deactivate the module functional power.
- To turn off the external power supplies.

If all evaluations performed by that algorithm are within the expected values, the equipment evaluated that will be considered complete to be used in on board electrical networks. Considering the hypothesis that one of those values is out of the expected value, that is triggered the maintenance of the non-conform equipment and in the next step to perform a new sequence of evaluations.

3.3. Graphics Interface

The Man Machine Interface (MMI) basic function described in this work that is concentrated in being the link to the operator commands and supervises the tests. The main window of that interface is showed in the Fig. 4.

The acronyms, buttons layout, switching modes, indications and colors, showed on that window, that were created with a goal of supporting the operator's necessities whom perform the tests and to facilitate the identification of states during the usage of that interface, becoming its usage more intuitive, easy and fast to the operator to obtain accurate information from the process.

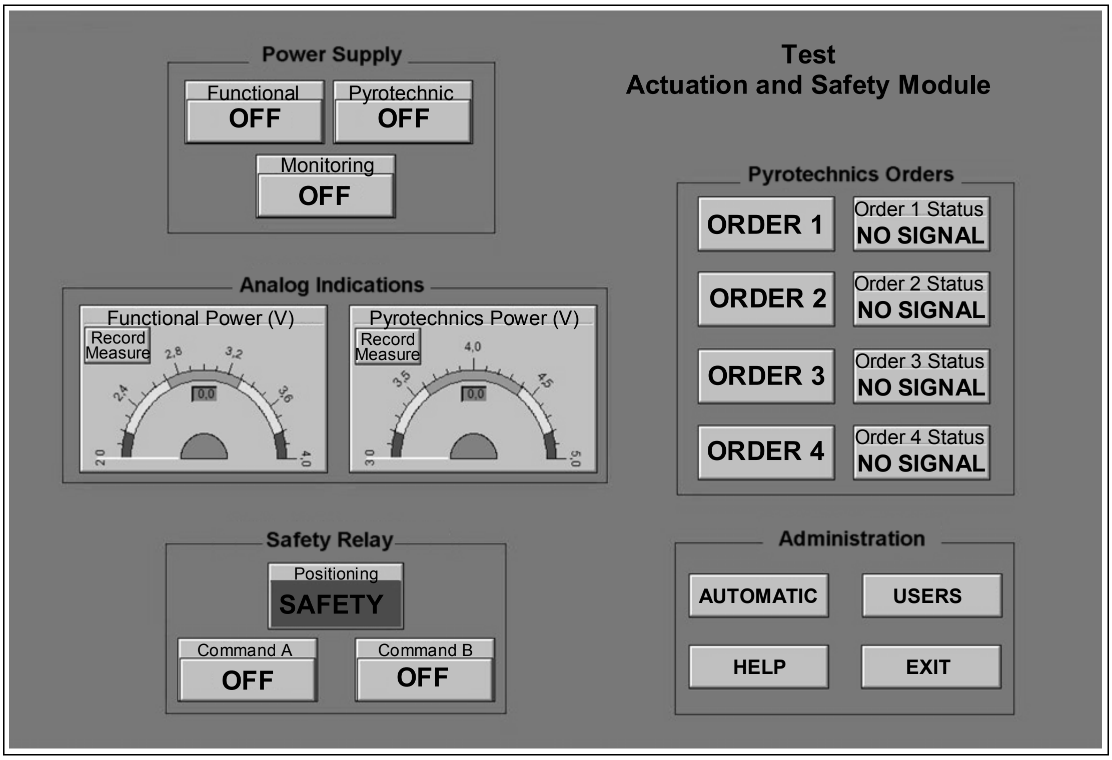

Figure 4. Graphics interface main window

The buttons usage, contained inside the interface showed on that figure, can be selected either directly by mouse, which is included into the Host Computer (HC), or by the functions keys contained on the mentioned computer keyboard.

The operator's graphics interface was developed in commercial software named by Elipse (Elipse Windows, 1999).

The keys meaning and indications included on that interface are described in this section.

3.3.1 Power Supply Group

"Functional" Power button – to turn on or off the external power provided to the ASM (Actuation and Safety Module). When that button is turned on shows indication in green color and "on". When turned off shows indication in gray and "off".

"Pyrotechnics" Power button - to turn on and off the external power provided to the pyrotechnics elements. When turned on shows indication in green color and "on". When turned off shows indication in gray color and "off".

Control Bench "Monitoring" button - to turn on or off the external power provided to the equipment monitoring circuit. When turned on shows indication in green color and "on". When turned off shows indication in gray color and "off".

3.3.2 Analog Indications Group

"Functional Power" Indication (V) – to indicate voltage values related to the functional power supply. That indicator still has the button "Record Measure" to register the indicated value on specific database.

"Pyrotechnics Power" Indication (V) – to indicate voltage values related to the pyrotechnics power supply. That button also has "Record Measure" to register the indicated value on specific database.

3.3.3 Safety Relay Group

"Command A" button – to position the safety relay in SAFETY mode. When that button is turned on shows "on". When that button is turned off shows "off".

"Command B" button – to position the safety relay in ARMED mode. When that button is turned on shows "on". When that button is turned off shows "off".

Safety Relay "Positioning" display – its function is to indicate the present position in which the safety relay is. The SAFETY condition, which is related to the open pyrotechnics line, is indicated in red color and "SAFETY". The ARMED condition, which is related to the connected pyrotechnics line, is indicated in green color and "ARMED".

3.3.4 Pyrotechnics Orders Group

"ORDER 1" button – generates signal to active the pyrotechnics elements, related to order 1. When that button is on shows "ORDER 1", in green color. When that button is off shows "ORDER 1", in gray color.

"ORDER 2" button – generates signal to active the pyrotechnics elements, related to order 2. When that button is on shows "ORDER 2", in green color. When that button is off shows "ORDER 2", in gray color.

"ORDER 3" button – generates signal to active the pyrotechnics elements, related to order 3. When that button is on shows "ORDER 3", in green color. When that button is off shows "ORDER 3", in gray color.

"ORDER 4" button – generates signal to active the pyrotechnics elements, related to order 4. When that button is on shows "ORDER 4", in green color. When that button is off shows "ORDER 4", in gray color.

"Order 1 Status" display – its function is to monitor the present position in which the pyrotechnics line relay is, that is related to the Order 1. "NO SIGNAL" condition, related to the relay in normal open condition, is indicated in gray color. "EXECUTED ORDER" condition, related to the pyrotechnics line relay connected, is indicated in green color.

"Order 2 Status" display – its function is to monitor the present position in which the pyrotechnics line relay is, that is related to the Order 2. "NO SIGNAL" condition, related to the relay in normal open condition, is indicated in gray color. "EXECUTED ORDER" condition, related to the pyrotechnics line relay connected, is indicated in green color.

"Order 3 Status" display – its function is to monitor the present position in which the pyrotechnics line relay is, that is related to the Order 3. "NO SIGNAL" condition, related to the relay in normal open condition, is indicated in gray color. "EXECUTED ORDER" condition, related to the pyrotechnics line relay connected, is indicated in green color.

"Order 4 Status" display – its function is to monitor the present position in which the pyrotechnics line relay is, that is related to the Order 4. "NO SIGNAL" condition, related to the relay in normal open condition, is indicated in gray color. "EXECUTED ORDER" condition, related to the pyrotechnics line relay connected, is indicated in green color.

3.3.5 Administration Group

"AUTOMATIC" button – it executes all test sequence automatically.

"USERS" AND PASSWORD button – it allows to the Administrator user to create, modify and exclude users, passwords and access levels.

"HELP" button – when that button is on shows a text with buttons and indications description foreseen in the interface contained in the Fig. 4.

"EXIT" button – when that button is on finishes user's activities with the interface.

In general terms that are applicable inform that:

All information about non-conformities and alarms detected in that system operation are presented on a specific display located in the right bottom corner of that window.

The colors, acronyms, buttons layout and indications, showed on that window, were created with a goal of supporting system user's requests and necessities and to facilitate components identification during the usage of that interface.

3.4. Practical Tests

During the practical tests accomplishment, that were necessary to validate the proposal presented in this work, it was implemented the connection diagram showed in the figure 3 and it was created a program for the PLC, in ladder language, that is able of executing the foreseen actions in the system management program algorithm.

On that tests were carried out several operations of switching and state supervision of those equipments, which are part of on board electrical networks, with usage of the program in normal and automatic mode. Taking into consideration that part of those operations were carried out with a presence of non-conformities, in known equipments, to observe how capable the system is and to identify those non-conformities.

4. RESULTS AND CONCLUSIONS

The satisfactory results observed on the practical tests, performed with the first prototype version that is representative about that architecture, indicated that the proposal presented in this work is feasible and can be performed for the application in which is dedicated.

The forecast goals in this work were fully reached, mainly concerning to the on board equipment tests.

During the prototype assembly it was specifically employed supervision system, programmable logic controller, actuators and sensors, available in the national market. That situation minimizes the implementation costs, facilitates maintenance and becomes the system modification easier.

5. REFERENCES

Palmério, A. F., 2002, "Introdução à Engenharia de Foguetes", Apostila de Curso realizado no Instituto de Aeronáutica e Espaço (IAE), S.Paulo, Brasil, 250 p.

Miyagi, P. E., 1996, "Controle Programável – Fundamentos do Controle de Sistemas a Eventos Discretos", Editora Edgard Blucher Ltda, S.Paulo, Brasil.

De Moraes, C. C. e Castrucci, P. L., 2001, "Engenharia de Automação Industrial", LTC, Rio de Janeiro, Brasil.

Pinheiro, A. P. M., 2005, "Sistemas Eletropirotécnicos", Apostila de Curso realizado no Instituto de Tecnológico de Aeronáutica (ITA), S.Paulo, Brasil, 150p.

Costa, C., 2005, "Controlador Baseado em Lógica Programável Estruturada". Dissertação de Mestrado – Departamento de Engenharia Mecânica, Universidade de Taubaté, S.Paulo, Brasil, 150p.

Elipse Windows, 1999, "Sistema de Supervisão, Controle e Aquisção de Dados". Manual do Usuário".

6. RESPONSIBILITY NOTICE