Designing a ground support equipment for sattelite subsystem based on a product development reference model

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Abstract. This work presents an application of a reference model for product development: a ground support equipment for an environmental monitoring imager. MUX-EGSE is a product designed on demand to INPE (Brasilian National Institute of Spatial Researches). It is an equipment of electronic tests of a camera which will equip the CBERS3&4 satellite. This reference model was adapted to manage the development of this product, which is quite diferent from the products commercialized in other lines of the researched company.

Keywords. New product development, mechatronic reference model, aerospace industry, ground support equipment.

1 Introduction

In [11] is defined AIT: activities of assembly, integration and tests of an artificial satellite to be launched in the Earth's orbit. It corresponds to a set of procedures and the execution of logically inter-related events with the purpose of reaching a high level of reliability and robustness in the satellite performance. The multispectral imager (MUX) of CBERS3&4 satellite, which is being developed in a Brazilian company, ought to be submitted to a set of acceptance, calibration and functional tests in its design and AIT phases. Hence, it demands a specific electronic system which makes viable the satellite interface and the execution of this complex analysis. This system is called MUX-EGSE – ground support equipment of MUX subsystem.

For the design of this equipment it was necessary a process model of product development that comprehended the best practices in a mechatronic design context. The inexistence of such a model was observed in [1], that works in this gap and

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developed the mechatronic reference model (MRM). MRM is also utilized in other products commercialized by this company.

2 Reference models in New Product Development

This section presents some NPD reference models as chronologically available in the literature.

In [10] is presented the total design model. The author makes differences between total and partial design. He argues that Universities have taught partial design and this practice has created some troubles in company environments. [10] describes NPD as a phased process in which product specifications are continually refined. [9] develop a systematic approach to product design. They present design steps organized by phases too. Each phase is carrying out throughout a problem solving method. At the final, phase outputs are compared with a requirement list.

In [2], NPD is discussed as a map of information assets. Their proposal is a phased structure in which some deliverables are identified. The authors focused in performance measures that allow managers to look at results of development effort. [13] illustrate NPD as a development funnel. Authors stated in the beginning of NPD there are so many opportunities and along the time this number decrease because many ideas are realized to be unviable. At the end only few opportunities are transformed in new products.

In [3], NPD is studied as a process that needs to be performed in concurrency with the technology stream. He states that phases need to be monitored and controlled by check points and describes mandatory activities in NPD projects. A simultaneous engineering background is clear in [3] proposal when he describes the organization by which a new product must be designed. Author relies strongly in product development teams at several organizational levels. [12] rely in activity description and form utilization to present how to develop a new product. Authors identify different roles to each organizational unit in accord to the company organizational structure. For example, a functional manager has different functions if the company structure is functional or projectized.

In [8], NPD is studied to build a knowledge creating theory. All information generated by a new product is classified as a explicit knowledge and the company role is to allow knowledge conversions, especially from tacit to explicit. Some organizational structure and skills are more appropriated to enable conversions. [4] started to call NPD as a stage-gate process. He shows that is necessary to manage NPD to balance different kinds of development efforts. The author models the decision making process in NPD. He describes two situations in which important decisions are made to prioritize projects and allocate resources: gates performed inside each project and portfolio reviews performed by product line as a whole.

In [6] is built a design for six sigma proposal. Authors integrate several of previous approaches into a consistent framework. The main structure of their reference model is a stage-gate process. Each phase is detailedly described to allow activity scheduling and tracking. Another core concept in [6] is critical parameter design. Authors state product requirements must be prioritized and when a product concept is generated it is necessary to identify critical parameters of the product.

To each parameter a critical functional response in technological solutions to monitor it must be chosen. Tolerances must be designed to build capability indexes to each critical response.

In [5] is proposed the capability maturity model integration (CMMI). CMMI consists of best practices organized in process areas that address the development and maintenance of products and services covering the product life cycle from conception through delivery and maintenance. It is a new form of understanding product development, since other authors traditionally describe this process as a stage-gate intercalation, as above described. In CMMI NPD must be evaluated according to a maturity (or capability) level scale and a targeted profile should be used to improve it.

3 Mechatronic reference model

The reference model, used to develop new product in the company, utilizes a framework that represents NPD as a phased process.

The model reflects best practices in mechatronic product development, and a mechatronic reference model (MRM) has been dubbed because, from the technical standpoint, it involves products that integrate electronics, mechanics and software.

Figure 1 gives an overall view of the process of the proposed reference model. The phases of the MRM are defined as a function of the results they generate. Results are documents and represent the concept of “information of value” discussed by [2].

The phases of the MRM can be described as follows:

- Strategy: definition of the strategic objectives to be pursued in each product line (PL);
- Portfolio: definition of the portfolio of each PL;
- Specifications: definition of the specifications of each product;
- Project Planning: definition of the project plan for each product;
- Conception: definition of the main components and solution principles for the main functions of the mechatronic product;
- Technical planning: detailing of the project plan based on the previous defined conception;
- Technical design: technical solutions for the main functions of the product;
- Optimization: detailing and testing of solutions for the product’s secondary functions and analyses required to increase the product’s robustness and reliability;
- Homologation: homologation (approval) of the product’s manufacturing and assembly process;
- Validation: product validation and certification;
- Launch: launching of the product in the market;
- Monitoring: monitoring of the results attained with the product and management of the modifications made in the initial production configuration.

Each phase is separated by a decision point and four different types of gates were developed. The gates, illustrated by (◆),represent moments but the decisions are made for a given set of products. In the strategy phase, the set comprises all the products of the company, while in the portfolio phase, all the products belong to a given PL.

Gates ( )are business-oriented decisions made on the basis of design performance indicators. These gates ( ) are technical decisions made through peer review meetings, and a gate ( ) represents the closing of a given development project after ramp-up of the product.

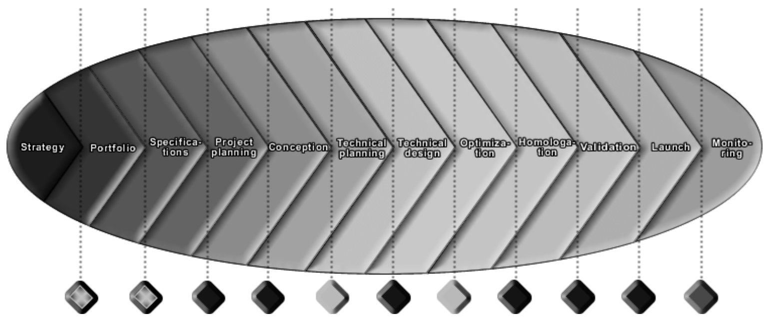

Figure 1. Phases and decisions of the MRM

4 Development of a ground support equipment

The application of the MRM started in the specification phase because strategy and portfolio phases are related to business decisions. In the aerospace industry the specification phase of a new product project is performed by contractor. The company role is to understand functional, constructional and safety requirements and to deploy design specifications in a verification matrix associating the proper types of verification (analysis, similarity, inspection or test).

In the project planning phase the product architecture suggested by contractor was written as a work breakdown structure (WBS). Some designers were allocated to each element of WBS and a schedule was built to comply with contractor milestones. This schedule was used to develop equipment conception. In this phase the ground support equipment was the larger risk of the project as a whole because its timetable was shorter than other project parts and its complexity was almost so larger than the main equipment.

In the conception phase, the main technologies, components and facilities of the project were chosen. As demanded by the requirements, the electronic system should be composed by two racks with industrial computers that automate the control of all equipments and the tests to be executed. Real and virtual measurement instruments were chosen and an own electronic system based in boards settled in slots of a main board was developed to process hundreds of telemetries, telecomands, video, high-frequency and other necessary signals between MUX-EGSE and MUX subsystem.

Before technical planning phase all technologies were known. A product tree was structured (Figura 2) and a detailed schedule was built and refreshed every month.

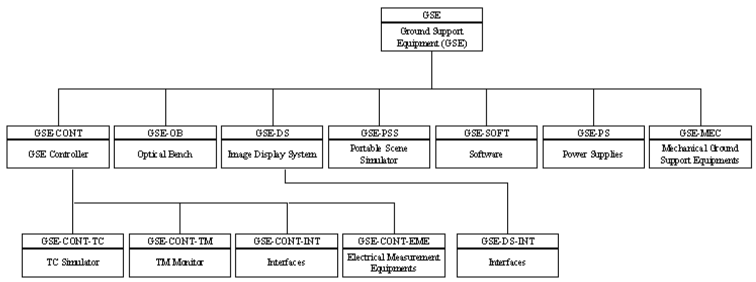

Figura 2. Product tree

The product architecture and interfaces were detailed consisting in:

- GSE-LAN interface: integrated local network with D-Link router that utilizes Gigabit Ethernet, Fast Ethernet (IEEE 802.3) and Wi-Fi (IEEE 802.11) standards to communicate among the controller rack, the images exhibition rack, printer and remote client computers.
- High speed I/O interface: acquisition PCI board of high speed low voltage differential signaling (LVDS information can be found in [7]) of National Instruments which receives the image data from the MUX camera.
- TM/TC simulator: PCI boards of analog and digital data I/O with developed circuits to multiplex, demultiplex, conditionate and distribute signals simulating the MUX interface with the on-board data handling (OBDH) subsystem of the satellite.
- Energy source supply interface: Agilent's source supply controlled by GPIB with developed circuits to distribution, in-rush current measurements, power switching and closed loop to supply precision simulating the interface of electrical power source supply (EPSS) subsystem of the satellite.
- Measurement electrical equipments: virtual instrumentation PCI boards that emulate millimeter, scope, logic analyzer and waveform generator for electronic tests.
- Optical equipments control: equipments acquired of specialized companies (Omega, Labsphere, Newport) controlled by interfaces RS232, GPIB and Ethernet: temperature and pressure sensors, radiometric light source, filter wheel, precision motorized motion controllers and integrating sphere.

Critical parameters were identified in form to allow the team to search functional responses to manage them. In the project the following aspects were understood as critical:

- Real time camera images acquisition;
- High precision jitter signal measurements;
- Client remote computers system access;

Software requirements were identified using structured analysis. LabVIEW platform was chosen to the software development. It makes simple the implementation of communication routines between virtual or real measurement instruments and computers. Hence, the processing activities of telemetries, telecomands and image data decode were the only ones which demanded more work. Figure 3 presents a data flow diagram for the EGSE controller software.

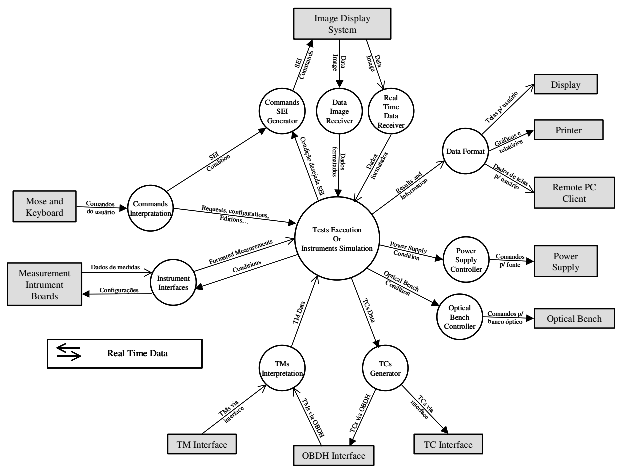

Figure 3. Data flow diagram for the EGSE controller software

In the technical design phase the reference model predicts some concurrent activities as illustrated in Figure 4.

The basic engineering of the product was basically the development and fabrication of mechanical parts to support the equipments.

The communication and control system was developed interconnecting all necessary connections as required by specification and setting all instruments controlled by Ethernet, GPIB or RS232 with proper options as in the router, in the software and in the operational system of EGSE controller.

For electronic design, the components were chosen considering already used ones in other company projects or the main manufacturers such as Texas Instruments, Analog Devices, among others. Circuit simulations, electrical schemes, lay-outs and gerber were developed using Altium Designer platform. After the boards were designed, they were manufactured, assembled, tested, revised and re-manufactured achieving theirs second fully operational version. For tracing purposes lots of documents had to be generated to each developed board: electrical scheme, lay-out, gerber, assembly map, assembly list, assembly checklist, assembly fluxogram, test procedures, inspection checklist, inspection procedures and test report.

Software develoment was divided in low and high level. In the first one, all communication among system components routines were designed and in the second one, using these routines, all necessary programs were designed to run all

MUX subsystem tests automatically, such as grounding and bounding, signal clock jitter, optical alignment, temperature control, among many others.

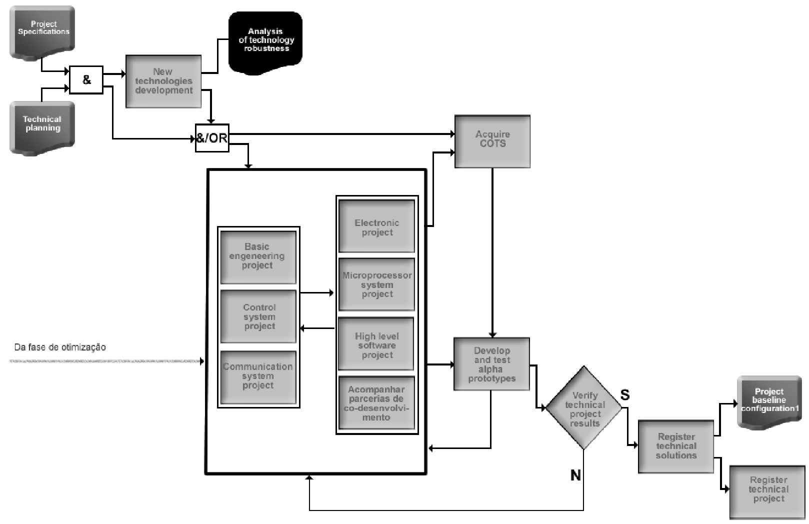

Figure 4. Technical design fase

The phases of optimization, homologation, validation, launch and monitoring were not yet implemented because the engineering model of satellite camera is still being developed, then optimization phase could not be finished. Figure 5 presents some photos of the built system: controller rack, part of its electronics and image acquisition test screen.

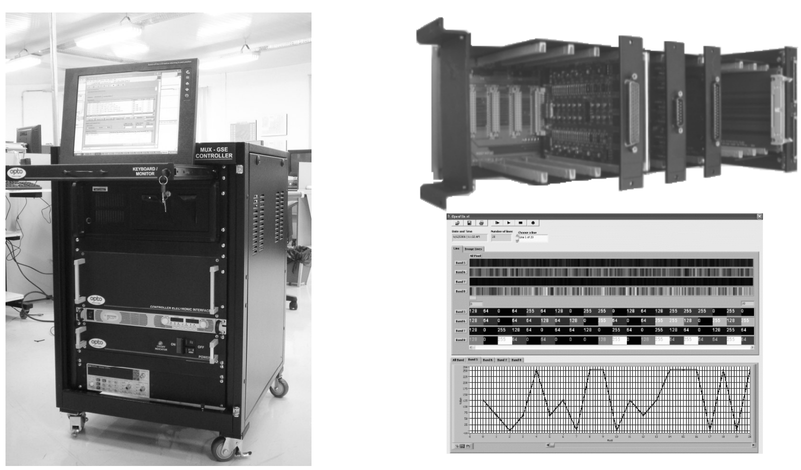

Figure 5. EGSE controller rack, electronic boards and image acquisition test screen

5 Final considerations

This work presents a well suceeded adaptation of MRM, a development reference model. Althought it has been designed to commercial products, its guidelines throught many phases helped designers in the consistent development of an equipment for aerospace industry and in the generation of its documents. The results obtained so far are totally satisfactory, since the developed electronic ground support equipment for CBERS multispectral camera is able to test all the satellite subsystem requirements, fulfilling all specifications.

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