Abstract

Space technology is today mature, spacecrafts and payload dimensions and weights have been reduced. Hence missions based on small satellites and constellation/formations of satellites can be conceived and realized at a reasonable cost. However, despite the consistent effort till today spent in studies, technology, equipments, two aspects remain still unsatisfactory in the space business: time to market and launch cost. Concerning the second point a substantial improvement shall be achieved only in the next decade by adopting the launcher reusable technology. Instead the time to market and the satellite development cost can be reduced applying modern design and manufacturing concepts.

Alenia Spazio is substantially participating into the development of Globalstar constellation being responsible for the satellite integration, test campaigns and launch campaigns. In particular all satellites (64 S/C + 128 active antennas) have been integrated and tested in a dedicated highly innovative facility located in Rome: the ‘Small Satellite Center’ where a new approach to satellite production has been successfully implemented.

This paper deals with new concepts for satellite manufacturing, AIV/AIT and pre-launch support activities suitable for reducing satellite cost and time-to-market. In this view Globalstar facility improvements are described such to propose the ‘Small Satellite Center’ as a national standard facility for small/medium size missions.

1. Introduction

In the last few years the space sector has dramatically changed from tradition. Several space applications became of commercial nature, Telecommunication and Navigation are mature, Earth Observation is on going. Globalization and Internationalization lead to the concentration of companies and the creation of new joint ventures for mass market exploitation. Coordination at Government and Science institution levels is increased. But the competition was also extending and growing. Old actors and new entrants search for new business opportunities fast exploitation while investors request higher ROI because of higher risk in the space activity environment.

The commercial space sector entered in the satellites constellation era by GLOBALSTAR and IRIIDIUM projects and therefore in the low cost space equipments and satellites intensive rate series production. This has changed the way to think at satellite design, manufacturing, integration and verification approaches. This paper deals with new ideas to further exploit the Globalstar experience and improve the ALS Small Satellite Center capabilities in order to cope with the on going projects.

2. The cost reduction exercise

In practice the only thing which really reduces substantially the cost of a product is the mass production. Unfortunately this is rarely applicable to the space business. Very often even when the same equipment or subsystem is reused in an other application customization is requested. Moreover a certain number of items are generally accounted as cost reduction factors:

- requirement trade
- standardization of components and equipment
- utilization of new equipment design (reduced number of parts, higher component integration , reduced interface,..)
- reduce component quality standards
- optimize AIV/AIT activity and Ground Support Equipment development
- new engineering processes and system design methodology (concurrent Eng., IPDT, IPT, lean manufacturing, etc.).
- good product management quality and application of lean manufacturing concepts
- weight reduction (mainly because of launch cost reduction)

In particular, the AIV/AIT optimization process has been detailed in this paper.

3. Design for producibility

The main objectives of an AIV/AIT campaign are well known:

- demonstrate system performance
- minimize time and cost
- improve heritage

In order to easily reach those objectives, especially for series production, it is important to start from the satellite design and the verification approach. The design for producibility concept implies a strong connection between spacecraft architectural design, equipment’s design and production requirements in order to guarantee during the manufacturing phase for easy handling, easy serviceability, easy access and integration and for easy testability.

In the spacecraft design and development phase, the design for producibility concept is devised by combing several elements:
Concerning the spacecraft architecture, the effort is mainly aimed at a simplification of the spacecraft lay-out so to minimize the AIT process at system level. To this purpose, the producible spacecraft design is addressed to the following guidelines:

- modular design for testability and easy troubleshooting;
- easy assembly/disassembly of equipment and modules;
- limited number of components to be integrated at spacecraft level;
- standardization of mechanical and electrical interfaces;
- easy operations at the launch base.

The definition of a suitable design and manufacturing philosophy is a fundamental step in the high rate satellites production process. The minimization of production lead time and the limited testing resources (especially necessary in case of limited production cost requirements) make it necessary to reduce the quantity of tests still maintaining the reliability requirements. In this view the application of Risk Management Approach, as described later, supports the test plan preparation and definition.

The high rate satellite production starts from the delivery of the already tested main sub-systems. This means that it applies the concept that acceptance tests shall be carried on just once and at as lower as possible integration level. Consequently the satellite production shall only include a certain set of test at satellite level and a reduced functional test for payload. The wise use of analysis to combine lower tiers and satellite measurements to get overall performance is well recommended too.

4. High Rate and Serial Production

The key words to reduce production time and cost are: minimize waste time, empower people and maintain the centrality of the customer/requirement (i.e. do what needed but nothing more). All should be pursued through a continuous improvement effort. The overall AIV/AIT cycle time should be reduced by using innovative methods and techniques in order to simplify flows, integrate processes, reduce set-up and movements of objects, use automation and simulation tools.

In the case of a serial production approach carried on in conventional facilities, the production time is too much compared with the time needed to the deployment of the space infrastructure. Furthermore, as already mentioned, the classic verification approach based on the complete qualification of Flight Hardware is too expensive and inessential. So, a new integration approach foresees the availability of dedicated facilities with highly skilled personnel and integrated assembling, testing and handling facilities. Among different concepts ALS selected the “technological islands” approach being it considered the most effective. Each island is associated with a specific manufacturing or testing activity and for this reason is provided with dedicated personnel, facilities and temporary material storage. The whole facility is therefore organized in several dedicated islands. The satellite shall be rolled along each island until its completion. In figure 1. the conceptual layout of the high production rate facility is provided introducing same concepts derived by the lean manufacturing approach.

Such approach allows to have in the facility several satellites (up to 18!) at the same time (resources optimization), and to get better human performances thanks to the personnel training in their specific activity (shorter lead time). Basis is: the spacecraft is the only moveable item along the production line

- no movement of test equipment and skilled personnel (to optimize learning curve)
- each island is devoted to a specific testing activity
- isolation and management of failures in specific out of line islands

The main concepts and advantages related to the proposed production approach are afterwards summarized.

Each island can be sized autonomously in terms of human and equipment resources. It is able, through parallel use of resources, to ensure the correct production flow without forming bottlenecks and keeping production on schedule. Some islands can work in parallel with each other thereby reducing product lead-times.

As each island always carries out the same operations, there is a greater effect of the learning curve and a reduction in the margin of error. (effective from 8-10 system’s production)

However the flexibility of the island arrangement makes it possible to minimize disruptions in the production flow caused by possible malfunctions in the
product or the test equipment. The island approach is well suitable to introduce lean manufacturing concepts. It should be noted that in a space factory can be processed at same time customized (one of a kind) and standard serial products. Therefore the work/facility organization shall support:

- continuous flow (no variation)
- synchronization (no waste time)
- flexibility:
  - multisatellite capability
  - production rate and flow adaptation
  - measurement shop service (perform measurement over s/c externally integrated)
- standardization (particularly regarding interfaces)
- automation (testing, test report, NCR mgmt, activity planning, etc.)

In case of production series the overall spacecraft test program is generally composed of a Qualification Campaign phase and of a Flight Model Production phase.

One spacecraft qualification model (QM) will be subjected to a thorough qualification test campaign in order to:

- verify the performance requirements;
- verify design margins;
- validate handling, integration and test procedures and processes for the subsequent flight production phase.

Flight Models (FM's) will be integrated and acceptance tested to verify:

- the absence of workmanship defects after integration and acceptance tests;
- go-on-go performance

5. One kind sat: the pre-launch support plan

In this section is discussed some preliminary concepts related to the implementation of a Pre-launch Logistic Support Plan (PLSP). This aims at ensuring a minimum delay to the program from the period of satellite integration up to the launch, if a unit failure would occur which necessitates repair or replacement. Indeed not all the spacecrafts produced are based on a serial production and for those cases ALS proposes a specific approach.

The philosophy of the proposed approach is shown in figure 2. In the ordinate risk value is represented while in the abscissa there is the cost value. The behavior for a certain project design is clearly hyperbolic leading a reduction of risk in a cost increment. Now, first the situation is improved and the curve moved down by properly acting on the requirement and therefore reducing the system complexity. Then spare parts are procured increasing the cost and finally by a smart mixing of procedures and action plans the risk is still reduced.

Radarsat-2 development, for instance, is based on a Protoflight approach with maximum reuse of COTS and already qualified equipment and technologies (from PRIMA). In order to reduce cost a complete spare policy at equipment level shall not be adopted but suitable measures shall be identified to minimize the program risks. The Pre-launch support plan shall be based on the results of the system design analysis, FMECA, AIV/AIT approach and risk management results.

The Pre-launch Support Plan shall be established basing on the following documentation:

- transport plans and procedures
- launch support plan
- contingency plan and procedures (including AIT procedures, penalty test philosophy, spare parts application and repair procedures)

The spare philosophy needs to be assessed minimizing the manufacturing of additional equipment. However the following approaches can be pursued on a case by case base, according to the criticality of the equipment under consideration and applied to all the H/W procurement:

- request to all sub-contractors to order and maintain for all the program duration a spare set of flight components.
- the above concept could be extended to mechanical parts whenever considered necessary;
- for critical units can be envisaged the realization of additional printed boards or MW substrates with flight component mounted but no testing performed;
- long lead item spares shall be bought or leased for the program time critical intervals. This can include ASICs and MIC/MMICs;
- for COTS with large market it is possible to establish same sort of agreements with the suppliers where equipment stocks are maintained ready for immediate delivery during program critical times (a sort of time limited leasing);
- whenever EQM or QM shall be developed, they shall be refurbished and used as Spare parts. Those shall follow the flight H/W locations;
- the capability to repair spacecraft equipments within the predefined maximum time frame. Generally 2-3 weeks;
- as far as the EGSE is concerned, a set of spare boards shall be identified for non COTS H/W. Special agreement shall be defined with standard H/W Manufacturer.
- Suitable containers for flight H/W equipments shall be delivered together with the flight bus to be promptly reused in case of failures.
- Adequate spare parts shall be acquired for consumables including pyro’s.

The development of parallel programs could lead to a joint spare philosophy with important cost savings. This is an additional service/ assurance that can be salied when Company’s standard product is used. In addition to the preventive actions undertaken for repairing and maintaining the H/W, the following actions can be performed during AIT:
- Preparation of mounting and dismounting test procedures.
- Promptly test evaluation and validation by collocated concurrent engineering.
- Troubleshooting by immediate availability of system and AIV engineers both via multimedia and local attendance. During the program critical phase, subcontractors representatives shall be requested to attend in order to improve the reaction capability at unpredictable situations.
- The development model of satellite and its subassemblies, if existing, shall be transported to the test sites to improve troubleshooting capability and S/W modification and testing
- S/W specialists shall participate at bus-payload initial integration and testing and shall be available up to Satellite test completion.

Pre-launch support plan at least contains:
- PLS (pre-launch support approach)
- PFM requirement
- GSE requirement
- spare parts philosophy and description
- repairing approach and facility
- contingency plan
- critical operations
- schedule
- responsibility and personnel

6. Risk management aspects

Risk Management is: "a systematic approach to support the program management and the optimization of resources with the purpose to identify, assess, reduce, prioritize, control, document and communicate the risks involved in a program with reference to cost, schedule and performance”.

Therefore risk management is very well suitable to be applied in AIT/AIV activity and in the evaluation of test effectiveness vs. cost and risk. The large number of produced satellite (more than 70 for Globalstar only) can provide very interesting information to be extracted from historical testing data.

The Risk mgmt activity in this context supports:
- manufacturing, integration and testing risk assessment (global and for each phase)
- selection of suitable design, development and verification approach
- selection of the model philosophy
- establishment of appropriate integration and testing planning
- identification of areas of risk
- define specific (early) testing for new technologies, equipments, subsystems
- monitoring activities and early problem recognition

7. Electronic Product Management System (ePMS)

In support to the production facility, a local electronic Product Management System (ePMS) has been implemented and it is part of the Small Satellite Center ePMS, linking together Alenia Spazio with external stakeholders (Prime contractor and suppliers).

The local ePMS is an integrated information system, inside the production plant, providing the AIT facility with the capability to electronically receive, catalog, store, retrieve and distribute data.

All data regarding satellite, design, integration and test are stored and made continuously available and accessible from all authorized remote nodes. In particular, the distributed and acquired information foreseen during spacecraft production includes drawings, parts list, materials list, processes list, AIT procedures and data (integration & test results, logbooks), QA & PA reports and non-conformance documentation.

Under ePMS, every island of the AIT plant are connected to the system with input/output data exchange capability.

8. Additional improvements

In this section new ideas are discussed to further improve the Small Satellite Center capabilities.

A first interesting idea might be to transform each island and his contour team in a “Measurement Shop” which provides independently his specific services. Than the schedule is managed according to the rules applied in the multitasking computers where programs are competing for resources or left completely under the Shop team responsibility. Of course synchronization is requested for the overall flow optimization inside the facility particularly when satellite series are produced.

The shop approach is useful when there are under production spacecrafts with similar but not identical characteristics. Of course the test plan should allow a consistent degree of freedom.

Special care is spent in personnel management and training, searching for the best balance between specialization and multifunctional capabilities to rise motivation and reach better efficiency. The overall production strategy is inspired from Just In Time and bottleneck optimization with high level of reconfigurability and adaptation.

The supply chain, a key element to sustain high production rates, is powered by dedicated personnel assigned to the production section. Special relationships are then established with the suppliers by long term agreements and concurrency in business risk/benefits. See fig. 3 for an overall picture of the distribute lean organization.
The Information Technology is the heart and the tank for heritage conservation and skill management. The exploitation of such element is another objective for the future activities.

Of outmost importance is the data base accessible that contains all the test results, NCR, etc., of previous programs and in particular the Globalstar heritage.

The analysis of heritage and past experience comparing ground and in-flight failures shall provide the evaluation of test effectiveness and will be used for future projects development.

In summary the improvement to be applied are in the following areas:
- employee empowerment
- maintenance improvement
- improve material handling solutions
- introduce automation in activity planning and control
- automates processes
- introduce automation in verification, test results and analysis (also low tier) generation and mgmt

9. Conclusions

Time to market is a powerful weapon to counter the tough competition imposed by globalization.
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Reference

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