CONFORMITY ASSESSMENT IN THE BRAZILIAN SPACE PROGRAM – A NECESSARY DISCUSSION

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Abstract. *The probable use of the Launching Center of Alcântara - CLA for commercial launching with the Ukraine places additional stress on the process for structuring a conformity assessment system within the national space program. The first efforts toward achieving this goal has been made by the Brazilian Space Agency - AEB, for example, through the implementation of the National System for Compliance Evaluation in the Space Domain – SINACESPAÇO and through the elaboration of safety regulations for launching activities in the Brazilian territory. Although some concepts from aeronautics can be adapted directly, some peculiarities inherent to the space field, namely high reliability and safety requirements, limited number of similar products for comparative reference and limited access to the product during the operation in the space, introduce additional difficulties to the regular advance of the process. In the present work, some of these subsequent questions, as the level of reliability to be demanded and the level of width and depth to be adopted in the evaluations, will be pointed out and discussed, taking into account the domestic situation and the experience of advanced countries. It is expected that the results will be useful for several organizations, governmental, industrial and academics, to visualize the situation and, if possible, to identify eventual opportunities to take part in consolidating a conformity assessment system for the national space program.*

Keywords*: satellite launch vehicle, expendable launch vehicle, conformity assessment, safety regulation, mission assurance*

1. INTRODUCTION

According to the information made available recently, the Alcântara-Cyclone-Space Joint Venture for satellite launching activities, established by Brazil and Ukraine, should begin operating this year (SPACEMART, 2007). It means that the parties can start the practical works to create a required infrastructure for the company and construct a launching pad for Cyclone-4 launcher.

In parallel with this advance of commercial space launch activities, development of safety rules to ensure public protection are also required. A first effort toward achieving this goal has been made by the Brazilian Space Agency - AEB through the implementation of the SINACESPAÇO - National System for Compliance Evaluation in the Space Domain (AEB, 2005) and through the elaboration of safety regulations for commercial launching activities in the Brazilian territory. Both initiatives are just in the beginning and, therefore, throughout understanding of their applicability certainly is not complete for the public indirect or even directly affected by the new rules.

With the purpose of providing some useful findings for supporting these on-going regulation development and conformity assessment implementation activities in the Brazilian space program, related activities conducted by United States Air Force - USAF and National Aeronautics and Space Administration - NASA, two well known advanced organizations are reviewed, summarized, and discussed. For the sake of clarity, basic concept of conformity assessment is presented initially and conditions for its implementation in the national space program are presented subsequently.

2. CONFORMITY ASSESSMENT

According to the ABNT (2005) standard, conformity assessment is defined as activity that provides demonstration that specified requirements relating to a product, process, system, person or body person (hereinafter referred to as product for sake of brevity) are fulfilled. Definitions are provided for first-party, second-party and third-party conformity assessment, based on supporting definitions for “supplier” and “user”:

- First party: conformity assessment performed by a supplier;
- Second party: confomity assessment performed by a person or body which has some interest in the supplied product, as a user; and
- Third party: confomity assessment performed by an independent party that has no interest in the transaction between the first and second party.

Supplier’s declaration, as first-party “attestation”, therefore, is clearly distinguished from “certification”, which can be defined as a procedure by which a third party, i.e. person or body independent from supplier and user, gives written assurance that a product conforms to specified requirements.

2.1. Conformity Assessment in the National Space Program

Development of a conformity assessment system requires identification of several elements, typically the stakeholders, needs of the stakeholders, type of product to be evaluated, characteristics that need to be assessed and desired level of confidence in compliance. In the present work, specifically, launching activities within the national space program are focused as a main subject to discuss the conditions for implementing an indigenous conformity assessment system.

As far as comercial space launching activities at Alcântara Launch Center - CLA is concerned, the Alcântara-Cyclone-Space Joint Venture Company, AEB (regulatory agency), CLA, certification organisms, aerospace technology providers, and payload users, for instance, can be considered as stakeholders (Post et al., 2002). Accordingly, all of them are “the individuals and constituencies that contribute, either voluntarily or involuntarily, to the joint initiative wealth-creating capacity and activities, and that are therefore its potential beneficiaries and/or risk bearers”.

In this scenario, AEB, as a regulatory agency, has the primary role to protect persons, properties and the environment against potentially hazardous systems, from the ground operation phase through the launching and flight phase.

AEB’s safety regulation package recently submitted for public consultation was elaborated just to ensure safety operation for commercial launching missions. Under the point of view of a regulatory agency, as far as commercial space launches are involved, clearly mission loss is not the main concern of the requirements to be imposed through the safety regulations. Conformity assessment to be performed, in this case, is mandatory and must include this regulation package as the main base for certification.

When government space launching activities are concerned, for launching the Brazilian expendable launch vehicle - ELV, Satellite Launch Vehicle (VLS-1), for example, now AEB is the main sponsor for the project development, besides the regulatory agency. One of the questions which arises in this situation: Should AEB’s safety regulation package be applied to VLS-1 project?

Apparently, the answer seems to be yes, since submission of the vehicle to the safety regulation package could provide a minimum level of required safety for launching. However, AEB, as the main sponsor of the project, should expect not only safety operation but also mission success in the launching activities. Therefore, besides the requirements for safety, conditions for improving the likelihood of mission success should be included in the conformity assessment process.

To date, it is known that no open discussion has been made on conformity assessment policy, with involvement of all the stakeholders nominated within the framework of the National System for the Development of Space – SINDAE, defined in the PNAE (AEB, 2005). Moreover, PNAE's contents itself do not give any detail on the subject: certification activities, for example, are included only as one of the cross-cutting issue and no detail is given on their practical implementation.

With the purpose of providing some useful examples and findings, conformity assessment for mission assurance, conducted in the United States of America - USA, which have well known advanced space program, was reviewed and summarized in the sequence.

3. MISSION ASSURANCE - LEARNING FROM THE ADVANCED SPACE PROGRAMS

3.1. US Air Force and Aerospace Corporation

As a result of several space mission failures, Space and Missile Center - SMC of United States Air Force – USAF issued a high level Policies in 1972 (SMC, 1995). Their intent was to enhance mission success based on lessons learned in systems design, technical analysis, and in manufacturing and test processes. The Policies identified critical lessons learned which could impact mission success and allowed compilation of accumulated data to issue various complementary policies and regulations.

Among the policies concerned with systems engineering, following independent (or third party) conformity assessment procedures for mission critical elements and processes were defined (SMC, 1995).

- Independent Pedigree Reviews: establishes policy and procedures and assigns responsibilities for assessing the flightworthiness of critical SMC space system hardware elements by means of independent pedigree reviews.
- Independent Safety Assessment: establishes policies and procedures and assigns responsibilities for SMC program offices to obtain an independent assessment of mishap risk reduction activities.
- Independent Verification and Validation: establishes policy and procedures and assigns responsibilities for software independent verification and validation.
- Independent Mass Properties, Stability and Control Analyses of Spacecraft and Launch Vehicles: establishes policies, procedures and assigns responsibilities for SMC program offices to implement independent mass properties, stability and control analyses for spacecraft and launch vehicle acquisitions.
- Independent Structural Loads Analyses of Integrated Spacecraft, Launch Vehicles, and Transporter Systems: establishes policies and procedures and assigns responsibilities for SMC space programs to obtain independent structural dynamic loads analyses of integrated spacecraft/launch vehicle systems and of a limited class of integrated space vehicle/transporter systems.
- Independent Stability and Control Analyses of Spacecraft and Launch Vehicles: recommends practices and serves as a guide for implementing the "Independent Stability and Control Analyses of Spacecraft and Launch Vehicles".
- Guide for Independent Readiness Reviews: recommends practices and serves as a guide for implementing the regulation pertinent to Expendable Launch Vehicle Independent Readiness Reviews.

The execution of these policies has been the core activities of the Aerospace Corporation. Aerospace operates as a federally funded research and development center for the Air Force, and as such, is directly accountable to the SMC for the independent verification of launch readiness and other assessments. The notification on launch-readiness verification that Aerospace delivers to the Air Force provides assurance that all known technical issues have been assessed and resolved and that all residual launch risks have been assessed in a satisfactory manner. Thus, the mission can proceed with an acceptable level of confidence in launch mission success (Johnson, 2002).

To accomplish the entire spectrum of launch-verification activities, Aerospace keeps a cadre of engineers with expertise in a wide variety of disciplines. The specialists provide input through all phases of launch vehicle development and operations. This provides the basis for Aerospace's certification of each mission.

3.2. National Aeronautics and Space Administration

In 1995 NASA conducted an Agency-wide review to reassess all NASA Headquarters and Centers roles and responsibilities (NASA, 1999). One result of this review was the decision to transition ELV management from multiple Centers to a single Center. In January of 1998 a transition plan that established Kennedy Space Center - KSC as the lead Center for acquisition and management of Expendable Launch Vehicle - ELV launch services was officialized. The plan identified specific lead and performing Center roles and responsibilities. This included an implementation schedule for a staged transfer of intermediate expendable launch vehicle launch services from Glenn Research Center - GRC and medium, medium-lite, small, and ultra-lite class launch services from Goddard Space Flight Center - GSFC.

An important part of this transition involved the creation of strategic partnerships to take full advantage of the existing expertise at GSFC (Orbital Launch Services and Office of Flight Assurance), the Marshall Space Flight Center - MSFC (Upper-Stages Project Office), and GRC (Launch Vehicle Project Office). The support and expertise embodied in these strategic partnerships include such critical mission assurance functions as independent review and assessment, mission integration, engineering analysis, and anomaly resolution.

In parallel with these transitions, and in response to the series of expendable launch vehicle failures (August 1998 to May 1999), NASA's Office of Safety and Mission Assurance - OSMA initiated an independent assessment to identify and evaluate processes employed by NASA ELV program management and the NASA Safety and Mission Assurance - SMA community to assure safety, manage risk, and maximize the likelihood of mission success.

The independent team examined 25 ELV failure case studies to subjectively assess whether or not NASA KSC in-place assurance processes would have prevented the mishap from occurring. The conclusion was that the existing level of NASA core vehicle insight would not detect subtle errors in contractor execution of critical processes.

In the final report (NASA, 1999), delivered in August 1999, the team pointed out that possibilities to maintain excellent success rate exist, since the ELV launch service contracts are structured to provide NASA the opportunity to detect potential failure modes in design analysis, design verification and verification testing areas. In this case, in order for the KSC ELV organization to seize upon the contractually provided failure mitigation opportunities the workforce should be provided with:

- clear policy guidance (how deep and how wide),
- clarification of roles and responsibilities,
- clear mission specific assurance expectations, and
- necessary staffing, and contractor support.

Subsequent publications from NASA clearly reflect these recommendations, in accordance with the structure of documents presented in Fig. 1 (NASA, 2001a).

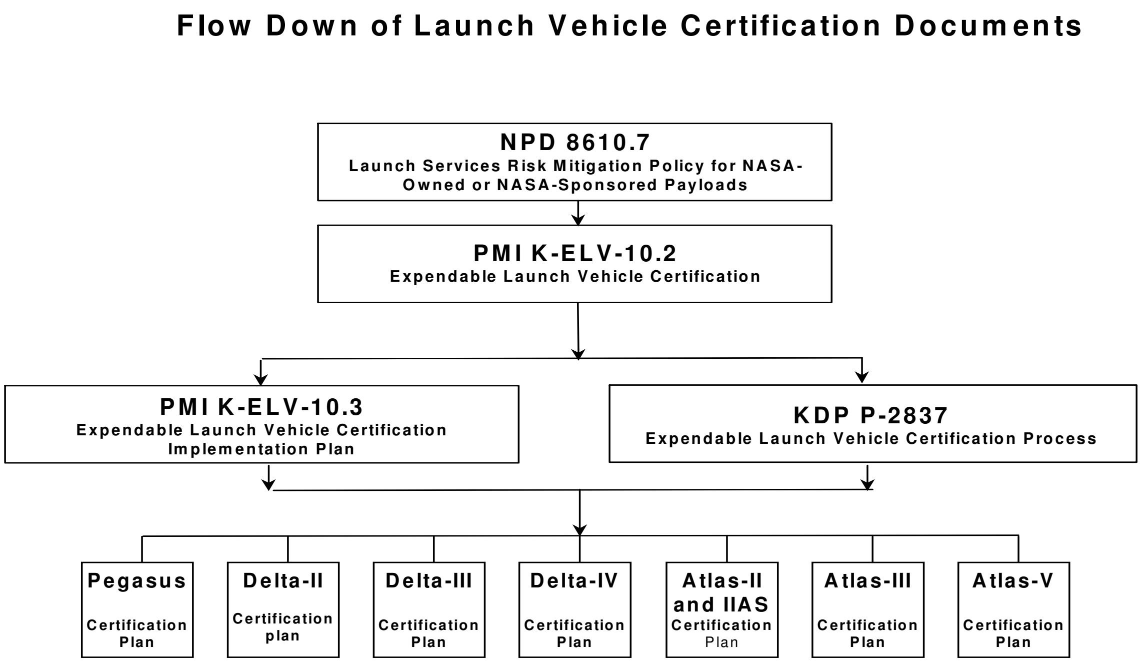

Figure 1. Certification documents for Expendable Launch Vehicle under contract for NASA's mission.

In fact, the main document NPD 8610.7 - Launch Services Risk Mitigation Policy for NASA-Owned and/or NASA-Sponsored Payloads/Missions (NASA, 2005) defined the required mandatory instructions and reviewed launch vehicle mission risk classification and launch vehicle certification strategy.

The policy addressed three levels of launch vehicle risk, namely high, medium, and low, and defined the certification approach, in accordance with the documents K-ELV-10.2 (NASA, 2001b), K-ELV-10.3 (NASA, 2001a) and KDP-P-2837 (NASA, 2001c), to mitigate these launch vehicle risks.

For consistency in definition, four risk levels or classifications were characterized for payloads (NASA, 2004a). The classification levels defined a hierarchy of risk combinations for NASA payloads by considering such factors as criticality to the Agency strategic plan, national significance, availability of alternative research opportunities, success criteria, magnitude of investment, and other relevant factors.

As it can be seen in Tab. 1 (NASA, 2004b), payloads which are classified as Class D payloads may be launched on Risk Category 1 launch vehicles i.e., a new common launch vehicle configuration with no prior demonstrated flight history. Payloads which are classified as Class C payloads and in some cases Class B payloads, may be launched on Risk Category 2 launch vehicles that have demonstrated a limited history of successful flights. Payloads which are classified as Class A, and in some cases Class B payloads, must be launched on Risk Category 3 launch vehicles that have a more robust demonstrated consecutive successful flight history. A "common launch vehicle configuration" referenced in Tab. 1 is defined as a unique combination of core propulsive stages, excluding strap-on rocket motors and stages explicitly for orbit escape or trim.

Table 1 NASA Launch Vehicle Certification Requirements Matrix (NASA, 2004b).

Launch Vehicle Risk Category	**Category 1 (High Risk)**	**Category 2 (Medium Risk)**		**Category 3 (Low Risk)**		
Vehicle Maturity	**No Flight History**	**Limited Flight History**		**Significant Flight History**		
Payload Class (per NPR 8705.4)	**D**	**C & D, sometimes B**		**A, B, C & D**		
Options		**1**	**2**	**1**	**2**	**3**
Flight Experience	No previous flights required, can use the first flight of a common launch vehicle configuration, instrumented to provide design verification & flight performance data	1 successful flight of a common launch vehicle configuration, instrumented to provide design verification & flight performance data	3 consecutive successful flights of a common launch vehicle configuration from an evolved vehicle family developed by an LSC with a previously certified launch vehicle for Risk Category 2 or 3, instrumented to provide design verification & flight performance data	14 consecutive successful flights (95% demonstrated reliability at 50% confidence) of a common launch vehicle configuration, instrumented to provide design verification and flight performance data	6 successful flights (minimum 3 consecutive) of a common launch vehicle configuration from an evolved vehicle family developed by an LSC with a previously certified launch vehicle for Risk Category 3, instrumented to provide design verification and flight performance data	3 consecutive successful flights of a common launch vehicle configuration from an evolved vehicle family developed by an LSC with a previously certified launch vehicle for Risk Category 3, instrumented to provide design verification & flight performance data

The establishment of the risk level early in the NASA's program/project provides the basis for program and project managers to develop and implement appropriate mission assurance and risk management strategies and requirements and to effectively define the acceptable level of risk.

4. DISCUSSION AND FINDINGS

In both space programs under consideration, conducted by USAF and NASA, a sequence of launching mission failures resulted in a decision to issue high level policies. These policies identified critical elements which could impact mission success and allowed compilation of several complementary instructions to organize the certification, or independent conformity assessment processes applicable throughout the life cycle of a space project. In both cases, systems concept was used, in accordance with the systems engineering approaches whose general guideline can be found, for instance, in the references provided by these two organizations, namely, NASA Systems Engineering Handbook (NASA, 1995) and SMC Systems Engineering Primer and Handbook (SMC, 2005).

4.1. Mission Assurance Approach

According to the systems engineering approach, the validity of a mission and its environmental requirements are analyzed and assessed for mission deficiencies and are revisited whenever they exhibit adverse impact on cost, schedule, performance, or risk, through the life cycle of a project. Safety, in this case, is one of the elements of specialty engineering which support the systems engineering process by applying specific knowledge and analytic methods from a variety of engineering specialty disciplines to ensure that the resulting system is actually able to perform its mission in its operational environment (SMC, 2005). Besides the safety, specialty engineering disciplines typically include reliability, maintainability, integrated logistics, test, fabrication/production, human factors, and quality assurance.

The Aerospace and USAF joint experience certainly can be considered as one of the extreme approach: to accomplish the entire spectrum of independent launch-verification activities, Aerospace keeps a cadre of engineers with expertise in a wide variety of disciplines, which include system engineering, mission integration, structures and mechanics, structural dynamics, guidance and control, power and electrical systems, avionics, telemetry, safety, flight mechanics, environmental testing, computers, software, product assurance, propulsion, fluid mechanics, aerodynamics, thermal engineering, ground systems, and facilities and operations (Johnson, 2002).

To conduct these activities, Aerospace employs about 3,450 people, of whom 2,400 are scientists and engineers with expertise in all aspects of space systems engineering and technology. The professional staff includes a large majority, 74%, with advanced degrees, with 29% holding Ph.Ds. The average experience of members of the technical staff is more than 25 years (Johnson, 2003).

The Aerospace approach to independent launch-readiness verification, for example, can be considered unparalleled in its breadth and depth. The end-to-end process extends from concept and requirements definition through flight operations: It draws upon independently derived system and subsystem models to validate contractor data; it provides review through firsthand involvement in all aspects of the launch campaign; and it concludes with a thorough post-flight assessment using independent analytical tools and independently acquired telemetry data to generate useful feedback and monitor performance trends (Tomei, 2002).

Clearly, this approach is completely unrealistic for current Brazilian space program. Nonetheless, the basic concepts of independent conformity assessment system should be evaluated for selecting the best practices usable in the domestic program.

The NASA's approach, on the other hand, seems to be more feasible than previous one. According to the ranking presented in Tab. 1, VLS-1 can be classified as Category 1, a launch vehicle with no previous successful flight. In this context, the content of the report "Independent Assessment of NASA Expendable Launch Vehicle Safety & Mission Assurance Processes" (NASA, 1999) and aforementioned subsequent publications, could be a good starting point to make a parallel, to evaluate the situation of the Brazilian space program, to define the required policy guidance, and to consolidate a conformity assessment system.

Activities related with domestic sounding rockets and VLS-1 projects, being a governmental initiative, should be, in principle, mission-oriented. It is worthwhile to note that when the mission assurance approach is adopted as a comparative reference, the conformity assessment process on the way in the domestic launcher program, currently in its early stage, can be considered as a safety-oriented approach, since adverse impact of cost, schedule, performance, or risk (other than safety-related risk) on the project are scarcely evaluated through its life cycle.

Among several factors contributing to the current situation, lack of certification culture and tradition and lack of a clear policy can be considered as the main initial hurdles to be overcome. Subsequent definitions, namely, the sizing of the assessment specialist cadre and the breadth and depth to be adopted in the assessment, among others, can not be concluded realistically.

4.2. Safety

According to the previous discussion, safety can be considered as one of the main elements of specialty engineering which supports the systems engineering process to ensure that the resulting system is actually able to perform the proposed mission in its operational environment. Under the point of view of a regulatory agency, therefore, it would be enough to evaluate the conformity with safety requirements, necessary to protect basically the public and properties, and to regulate the launching activities to the extent necessary to ensure compliance with international obligations as a launching state.

In fact, the Federal Aviation Administration - FAA's responsibility to regulate the commercial ELV industry of the USA, for example, is applied only to the extent necessary to ensure compliance with safety, but not mission success. This is the ELV safety concept defined by FAA. A speech of the Associate Administrator of FAA's Office of Commercial Space Transportation - AST (Smith, 1999) well illustrates this concept application: "if a mission failed, but failed safely, we would certainly share in the disappointment, but feel we had done our primary job... That's why there are flight termination systems on ELVs, so they can be safely destroyed if necessary to assure safety to persons and property".

When compared with mission assurance requirements, therefore, safety requirements demand less expertise, variety of disciplines and specialists, however, the responsibility for safety is not lessened at all. As aforementioned, it must be present a system safety program that identifies and controls hazards to the public and properties, which include facilities, support equipment, and the flight system during all stages of the mission development, launch, and flight operation.

The subject, safety requirements, is still polemic even in the USA since commercial space launch companies must obtain a license for their ELVs from the FAA and meet safety regulations set by the USAF, which operates government launch pads and associated facilities. The primary range safety document issued by the USAF's Eastern Western Range, EWR 127-1 (SMC, 1997), for example, is pointed out as a huge document that is focused much more on methods and solutions than on basic, performance-based safety requirements (NRC, 2000).

Only recently, in the end of August 2006, FAA, after a broad public consultation started in 2000, issued the new common rules that ensure the same safety standards for launching activities applicable to both federal and non-federal launch sites (FAA, 2006).

Knowing that the AEB's safety regulation package takes no account of this new FAA's regulations, knowing the worldwide FAA's leadership in safety regulation, and knowing that international customers can be requiring Brazilian launching services, it is suggested that the next review of the AEB's safety regulation package should include an evaluation process to check the existence of eventual critical differences between the two regulations.

5. CONCLUSION

With the purpose of providing some useful findings for supporting the on-going implementation of conformity assessment system in the Brazilian space program, conformitiy assessment activities conducted by two well known advanced organizations were reviewed, summarized and discussed. Some of the main conclusions can be summarized as follows:

- Current domestic conformity assessment process should evolve from safety-oriented to mission and safety-oriented approach. For this purpose, the national space program needs a clear policy defining applicable primary certification basis, as well as definition of roles and responsibilities of each stakeholder.
- A clear policy will allow stakeholders to define how deep and how wide should be the conformity assessment to be implemented. The experiences of both organizations under consideration, notably NASA's experience and technical documentations, can be a good starting point.
- The next review of the AEB's safety regulation package should include an evaluation process to check the consistency with the FAA new safety regulation.

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