Journal of Space Safety Engineering 000 (2017) 1–8

Contents lists available at ScienceDirect

Journal of Space Safety Engineering

journal homepage: www.elsevier.com/locate/jsse

A model for setting a regulatory framework for the development of suborbital operations in Italy

Giovanni Di Antonio[a,*], Marco Sandrucci[b], Alessandro Cardi[c], Francesco Santoro[d], Alberto Del Bianco[d], Cristoforo Romanelli[d]

[a] ENAC – Italian Civil Aviation Authority, Airworthiness Regulation Department, Via Gaeta 3, Rome 00185, Italy
[b] ENAC – Italian Civil Aviation Authority, Turin Operations Office, Via R. Montecuccoli 2, Turin 10121, Italy
[c] ENAC – Italian Civil Aviation Authority, Deputy Director General, Via Gaeta 8, Rome 00185, Italy
[d] ALTEC S.p.A., Corso Marche 79, Turin 10146, Italy

ARTICLE INFO

Article history:
Received 4 November 2017
Revised 19 November 2017
Accepted 21 November 2017
Available online xxx

ABSTRACT

This paper describes the model currently under discussion in Italy which has been developing for setting up a regulatory framework for commercial suborbital operations. This model is expected to accommodate in the near-midterm HOTOL (Horizontal Take-Off and Horizontal Landing) suborbital operations within the national aviation system, the national airspace and using existing facilities, taking into account the relevant international regulatory experience in the field. An adequate level of safety for uninvolved people on the ground, in the air, at sea and for critical infrastructures will be primarily sought along with due considerations for the safety of involved people onboard, in line with the state of the art and the technological development of the sector.

1. Introduction

The growing interest and development of novel technologies in commercial suborbital operations of a number of consolidated and innovative firms and stakeholders pushed ENAC, the Italian Civil Aviation Authority, since 2014, to study, evaluate and analyze this emerging field [3] with the aim to develop an effective and, as much as possible, flexible regulatory framework which can accommodate sub-orbital operations within the existing aviation and airspace system. Possible applications of suborbital operations include tourism, business, microgravity experimentations and astronauts' training. The goal is to enable the development of HOTOL suborbital operations from existing airports within the Italian territory, primarily assuring an adequate level of safety for third parties on ground, namely uninvolved people and properties, and other airspace and sea users. As far as commercial operations are concerned, the mandatory control of the hazards for involved people onboard shall be required as well to an extent in line with the state of the art and with the development of the sector.

* Corresponding author.
E-mail addresses: g.diantonio@enac.gov.it (G. Di Antonio), m.sandrucci@enac.gov.it (M. Sandrucci), a.cardi@enac.gov.it (A. Cardi), francesco.santoro@altecspace.it (F. Santoro), alberto.delbianco@altecspace.it (A. Del Bianco), cristoforo.romanelli@altecspace.it (C. Romanelli).

2. Legal framework

Whether or not suborbital operations has to be regulated under the air law or under the space law is currently debatable, hence each State has to clarify which is the entity in charge to regulate and oversight the nascent sector of the commercial suborbital flights. This aspect will be even more relevant on the long term, when suborbital flights will connect two different points of the Earth setting forth for the future generation transportation. From a functionalist point of view [19] it could be reasonably agreed that the Aviation Authority could regulate a suborbital operation, though by setting an *ad hoc* regulatory regime and this for a few reasons. Firstly, HOTOL vehicle (at least some of its stages) is, in most cases, a winged vehicle capable to derive (part of) its support by the atmosphere from the reaction of the air, at least in some phases of the trajectory, namely during the launch and the re-entry. In this regard the spaceplane could meet in some way the ICAO (International Civil Aviation Organization) definition of aircraft as any machine that can derive support in the atmosphere from the reactions of the air [15]. Secondly, any suborbital trajectory will intersect and share the airspace below FL650 (Flight Level 650) during the launch and re-entry phase, hopefully by means of a dynamic 4D segregation. One more important factor to be considered is the fact that, at least in Italy, the sites likely to be used as a spaceport for commercial launch and re-entry

https://doi.org/10.1016/j.jsse.2017.11.001
2468-8967/

operations will be selected among existing civil aerodrome approved under the EU (European Union) Regulation 139/2014. Most of these sites are State airports assigned to ENAC by law in accordance with Art. 693 of the Italian CoN (Code of Navigation) [1], in turn assigned by ENAC to the aerodrome operator through a public concession. Finally, the Article 687 of the CoN recognizes ENAC as the unique national regulatory Authority for civil aviation and the law n. 265/2004 recognizes ENAC as the unique authority for Air Navigation Services regulation. From an international perspective, in 2013 Italy and the US (United States of America) signed the Framework Agreement for Cooperation and Use of Outer Space for Peaceful Purposes [2] further transposed into law n. 197/2015. On the basis of this agreement, in 2014 ENAC signed with the US Office for Commercial Space Transportation of the Federal Aviation Administration (the FAA-AST Office) a Memorandum of Cooperation in the Development of Commercial Space Transportation [4] later renewed and extended to the Italian Space Agency (ASI) on 30 July 2016. Taking into account the above considerations, the Italian Ministry of Infrastructure and Transportation (MIT) issued its Decree n. 354 of 10 July 2017 [5] which identifies ENAC has the national entity in charge to develop the regulatory framework for the commercial suborbital transportation in Italy. The priorities highlighted by the MIT are: (i) to develop a three-year plan to define a regulatory framework for HOTOL suborbital flights; (ii) to identify the issues that can be directly regulated by ENAC and those which may need to be addressed by the primary legislation or other government acts; (iii) the regulatory framework shall be flexible enough to support the development of the sector, provided that the safety of third parties on ground, in the air and at sea must be primarily pursued along with the safety of occupants; (iv) the level of safety for the system and operations shall be established by ENAC and shall be updated, as necessary, in accordance with the state of the art and the advancement of the technology; (v) suborbital operations shall take place within the national border and shall not have a detrimental impact on the civil aviation development; (vi) security and cyber-security issues shall be taken into account; (vii) the criteria for the selection of candidate spaceport site(s) (subsequently described at Para. 5.) shall be defined giving priority to the existing infrastructures; and finally (viii) ENAC will coordinate with the MIT and will cooperate with the military and ASI.

3. Safety considerations

In a very general form *safety* can be defined as the minimum level of risk deemed acceptable by the society for a specific situation. This minimum level of risk can be specified either in a qualitative or quantitative manner. The risk associated to a specific event that can lead to unwanted consequences can be expressed as the product (or the combination) of the probability that the event occurs and the measure (or severity) of its consequences. Two types of risk can be considered [21]: the collective (or societal) risks expressed in terms of costs or sacrifice suffered by the society as an all (such as the *number* of casualties or fatalities) and the individual risks expressed in terms of *probability* that a person suffer a casualty or a fatality. These two types of risk lead to the definition of two different types of safety objectives: a collective safety objective (expressed in terms of maximum admissible societal cost), and an individual safety objective (expressed e.g. as the maximum probability of having a casualty for a person exposed to the hazard). Another distinction has to be done in terms of the people exposed to the hazard. In that respect for suborbital operations we will distinguish two groups:

- The uninvolved people on ground, in the air and at sea, along with critical infrastructures (which are referred to as *third parties*), and
- The involved people onboard the spaceplane vehicle, either the crew or the other (possibly paying) participants (which are referred to as *occupants*).

For suborbital flights, the US regulation [8] addresses third parties' safety by the collective safety objective *Ec*, expressed as the maximum average number of casualties[1] per launch or re-entry mission and by an individual safety objective expressed as the maximum allowed probability for an individual of suffering a casualty during a mission. Three types of hazards are supposed to produce third parties casualties [8]: (i) the direct impact with a vehicle debris, (ii) the overpressure blast due to the explosion of a falling debris, and (iii) toxic release. In addition to that, the regulator should also pursue the minimization of the risk for the occupants (which is referred to as *occupant safety*) as an essential pillar to allow – even from a legal point of view – manned suborbital flights. The safety for the third parties in the air, i.e. the other airspace or outer space users, can be addressed in the near-midterm by segregation of the airspace below Fight Level 650 (FL650) and by limiting the maximum apogee altitude (e.g. well below the parking circular orbit of 186 km altitude). In the future this hazard is expected to be controlled by an STM (Traffic Management) system fully integrated with the existing ATM (Air Traffic Management) system [20].

3.1. Third parties safety

Let P_C be the probability that a debris from a suborbital vehicle crashes on a populated area on the ground during a launch or re-entry mission, and let N_C be the number of people that would be directly hit by a debris or by a harmful blast overpressure caused by the explosion of the debris. Defining the debris casualty area A_C as the harmful ground footprint of the debris [10], the number N_C of people exposed to the risk can be worked out as the product of the casualty area A_C times the average population density D of the region where the debris is expected to fall, i.e. $N_C = A_C \cdot D$. Assuming that everyone who is hit suffers a casualty (i.e. the conditional probability of suffering a casualty, given a person is struck, is assumed equal to 1), then the mean number of casualties per mission (or the risk R_C) can be worked out and it may not be greater than a pre-established value E_C:

$$R_C = P_C \cdot N_C \leq E_C \tag{1}$$

Hence, it is necessary to define the above acceptable upper limit E_C for the risk R_C. This upper limit is the *safety objective* that has to be met for assuring the safety of third parties on the ground. A possible value for E_C was originally set by the US regulation equal to 30 casualties per million of missions, i.e.: $E_C = 30 \cdot 10^{-6} = 3 \cdot 10^{-5}$ casualties per mission (see [8] Requirement 431.35). Recently this requirement has been relaxed based on a more accurate review carried out by NASA (National Aviation and Space Administration) and USAF (US Air Force) on the launch data available in the US since 1989 [9]. As a result of this review, the E_C value was increased up to 10^{-4} casualties per each launch and re-entry phase of a RLV (Reusable Launch Vehicle). In conjunction with the collective safety objective $E_C = 10^{-4}$ casualties per each launch or re-entry, the US regulation also mandates an individual safety objective in terms of a maximum probability $P_I = 10^{-6}$ for an individual of suffering a casualty during a mission.[2] If N is the

[1] According to the US regulation [8], Part 401, Para. 401.5, a *casualty* is defined as a fatality (i.e. a death) or a serious injury.

[2] A recent French low for launch activities [14] requires a "collective" (sic) safety objectives of $2 \cdot 10^{-5}$ expressed in terms of maximum admissible probability to