COMMERCIAL HUMAN SPACEFLIGHT: WHAT REGULATION?

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1. INTRODUCTION

The ever increasing number of international actors involved in civil, commercial and military launch, re-entry and on-orbit operations; the envisaged expansion of human access to space for tourism, commerce and point-to-point hypersonic transportation; and the placement on-orbit of global utilities, raises the central question of how to ensure the safety of public, flight participants, crew, ground personnel, and assets on orbit, and the protection of the environment. There is growing awareness that a harmonised framework of international policies and rules is needed. First they must be established, and then continuously monitored for proper implementation, by an accountable international body having the power to enforce compliance. There is, in other words, growing awareness that international governance of space operations is needed. Of all space operations? including exploration and scientific missions in deep space?

We have to separate environmental issues, which are in principle a global concern, like space debris or planetary contamination, from hazards that are of international nature, like launch, re-entry or space traffic, and from hazards that are convenient to address internationally to help commerce. We must also pragmatically consider that currently and for the foreseeable future there is little commercial (and military) interest beyond geostationary orbits (36,000 km), but growing interest for the so-called near-space region, defined as the region above the controlled airspace (i.e.18 km) up to 160-200 km of altitude. Therefore, the international governance discussed in this document is limited to commercial space systems taking place anywhere between 18 km above sea and 36,000 km.

It should be noted that the safety of a space system depends on its design, construction, and operations. Design and constructions are very much “in the hands” of industry, but operations safety cannot be treated neither “unilaterally” nor outside the wider scope of all space operations, manned, unmanned, commercial and non-commercial that take place in the region. Operational procedures have to take into account all possible interactions, multiple parties and sometimes conflicting interests, a variety of operating systems and environment, and also potential impacts on foreign countries. Thus, while in principle space systems safety design and construction rules could be left to industry to decide by means of industrial standards, with compliance certified by a third-part that is not necessarily a government organization, the definition of rules for space operations and the control of their implementation is a responsibility that always belongs to government regulatory bodies, and which needs to be internationally agreed and coordinated.

2. COMMERCIAL SPACEFLIGHT SYSTEMS

For the past half century humans have flown to space on suborbital or orbital space systems developed by governments. Within the next couple of years privately owned and operated systems should begin suborbital and orbital operations with human on-board. In the coming decades trans-atmospheric point-to-point transport may also become a reality. The missions of suborbital, orbital and trans-atmospheric space vehicles are aimed essentially to achieve three different goals: high altitudes (space tourism), prolonged periods of microgravity (research), and cross-range capabilities (fast mode of transportation) respectively.

2.1 SUBORBITAL SPACEFLIGHT

A suborbital flight is defined as a flight up to a very high altitude which does not involve sending the vehicle into orbit (i.e. speed below 11.2 km/s). A *‘suborbital trajectory’* is defined as : *“The intentional flight path of a launch vehicle, re-entry vehicle, or any portion thereof, whose vacuum instantaneous impact point does not leave the surface of the Earth.”* (US Code of Federal Regulations, 14 CFR 401.5 – Definitions). A typical suborbital trajectory is narrow parabolic trajectory (launch almost vertical).

Unmanned suborbital spaceflight has been common since the dawn of space-age by using sounding rockets for various science and technology research. Suborbital spaceflight is a matter of limits on speed not on altitude. A suborbital rocket can reach 700 km or even more, well above the orbit of the international space station, but without achieving orbital speed.

In the last decade suborbital spaceflight enjoyed new popularity because of the rise of commercial human spaceflight, leisure rather than true transportation, aimed around 100 km of altitude. An experience, sometimes referred to as *experiential spaceflight*, comprising view of Earth from the edge of space and few minutes of microgravity. Commercial suborbital spaceflight is opening the new frontier of the near-space region above Earth that's too high for airplanes but too low for satellites. The exploitation of the near-space region will gain importance in future by adding new commercial applications like stratospheric balloons and high altitude drones for space tourism and Internet services.

2.2 ORBITAL SPACEFLIGHT AND MICROGRAVITY

Any spacecraft in low Earth orbit must reach speeds of about 28,000 kilometers per hour to remain in orbit. The exact speed depends on the actual spacecraft orbital altitude, which for human spaceflight ranges from about 300 kilometers to 500 kilometers depending on the mission.

It is important to understand the link between orbital spaceflight and microgravity. The pull of gravity gets weaker the farther apart two objects are, but this is not why things float on an orbital spaceflight. For example, the force of gravity at the altitude of the international space station is actually rather high: 89% of sea level. So why astronauts on-board experience almost zero gravity (microgravity)? Astronauts float in space experiencing what we call microgravity because they are in "free fall". In fact, a spacecraft in orbit moves at a speed such that the curve of its fall matches the curve of Earth. That speed is on average the 28,000 km/h mentioned above.

In the 1950s, aviation scientists discovered that they could simulate microgravity by flying in parabolic arcs. When a plane flies upward at an angle of 45 degrees, its passengers experience first hypergravity (commonly about 2 G's) as the force of the climb combines with the pull of Earth's gravity. Then to create a weightless environment (microgravity), the airplane flies in long parabolic arc, first climbing, then entering a powered dive. During the arc, the propulsion and steering of the aircraft are controlled such that the drag (air resistance) on the plane is cancelled out, leaving the plane to behave as it would if it were free-falling in a vacuum. A similar mechanism works during a suborbital spaceflight.

Therefore microgravity is not linked to being in space, but to being inside a spacecraft on "free fall" on orbit, or inside an airplane or suborbital vehicle on a parabolic trajectory, or inside a (space tourism) capsule released from a stratospheric balloon, before opening of the parachute.

2.3 TRANS-ATMOSPHERIC SPACEFLIGHT

Point-to-point hypersonic spaceflight is often presented as the next step of suborbital spaceflight, and even called suborbital point-to-point flight, thus somehow stretching too far the definition of suborbital spaceflight.

As a matter of fact, orbital winged vehicles have already the capability to be used on a trans-atmospheric point-to-point flight path. Instead current suborbital vehicles do not have such capability. When a sub-orbital space vehicle of current design reaches its maximum altitude at the vertex of the parabola the horizontal speed is almost zero.

It may be possible to adapt a current sub-orbital design to cover few hundred kilometers, but for true intercontinental or "hemispheric" point-to-point space travel a new class of vehicle is needed: a hypersonic trans-atmospheric spaceplane, or in other words a crewed winged version of an ICBM. Compared with suborbital vehicles, it would be much more complex and technologically advanced, and orders of magnitude more expensive to develop and operate. The German space agency DLR is currently developing at conceptual level a trans-atmospheric hypersonic vehicle, the Spaceliner, as part of a research program funded by the European Union.

As mentioned, orbital winged vehicles have point-to-point transportation capability. The Space Shuttle was designed to satisfy a cross-range capability requirement, levied by the US military/reconnaissance community, of 1,100 nautical miles. Until its cancellation in 1963, the Boeing Dyna-Soar project of the USAF, a small lifting body vehicle to be launched on top of a Titan rocket, had a cross-range capability upon its re-entry in the atmosphere of 1,400 nautical miles. The current USAF X-37, and private Dream Chaser for cargo transportation to ISS, could have comparable point-to-point transportation capabilities.

3. REGULATING COMMERCIAL HUMAN SPACEFLIGHT

The commercial human spaceflight vehicles currently in development, and in particular sub-orbital vehicles, will be operated locally in the country of development but also in foreign countries. Furthermore, a substantial por-

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