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| **Purpose/Objective:** This contribution provides regulatory, operational, and technical studies to respond to Resolution **772** (**WRC-19**). |
| **Abstract:** Resolution **772** (**WRC-19**), in preparation for Agenda Item 1.6 (WRC-23), invites the ITU-R to study the spectrum needs for stations on board sub-orbital vehicles, any appropriate modification to the Radio Regulations, excluding any new allocations or changes to the existing allocations in Article **5**, and to identify whether there is a need for access to additional spectrum that should be addressed after WRC-23 by a future competent conference. This contribution provides those studies to support the agenda item. |

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| **Radiocommunication Study Groups** |  |
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| working document towards a preliminary draft new report itu-r m.[SUBORBITAL studies]**[Regulatory, o]Operational, and technical studies of radiocommunications for suborbital vehicles** |
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**Introduction**

Resolution **772** (**WRC-19**), in preparation for Agenda Item 1.6 (**WRC-23**), invites the ITU-R to study the spectrum needs for stations on board sub-orbital vehicles, any appropriate modification to the Radio Regulations, excluding any new allocations or changes to the existing allocations in Article **5**, and to identify whether there is a need for access to additional spectrum that should be addressed after WRC-23 by a future competent conference. The United States offers this contribution to provide those studies to support the agenda item.

Attachment: 1

ATTACHMENT

[ELEments of a working document relating to wrc-23 agenda item 1.6 addressing operational and technical studies for suborbital vehicles]

working document towards a preliminary draft new report ITU-r m.[SUBORBITAL studies]

**Regulatory, Operational, and technical studies of radiocommunications for suborbital vehicles**

*[\*Editor’s Note: This document may be a candidate for a future ITU-R Report.]*

# 1 Introduction

Resolution **772** (**WRC-19**), in preparation for WRC-23 agenda item 1.6, invites the ITU-R:

 "1 to study spectrum needs for communications between stations on board sub-orbital vehicles and terrestrial/space stations providing functions such as, *inter alia*, voice/data communications, navigation, surveillance and TT&C;

 2 to study appropriate modification, if any, to the Radio Regulations, excluding any new allocations or changes to the existing allocations in Article **5**, to accommodate stations on board sub-orbital vehicles, whilst avoiding any impact on conventional space launch systems with the following objectives:

– to determine the status of stations on sub-orbital vehicles, and study corresponding regulatory provisions to determine which existing radiocommunication services can be used by stations on sub-orbital vehicles, if necessary;

– to determine the technical and regulatory conditions to allow some stations on board sub-orbital vehicles to operate under the aeronautical regulation and to be considered as earth stations or terrestrial stations even if a part of the flight occurs in space;

– to facilitate radiocommunications that support aviation to safely integrate sub-orbital vehicles into the airspace and be interoperable with international civil aviation;

– to define the relevant technical characteristics and protection criteria relevant for the studies to be undertaken in accordance with the bullet point below;

– to conduct sharing and compatibility studies with incumbent services that are allocated on a primary basis in the same and adjacent frequency bands in order to avoid harmful interference to other radiocommunication services and to existing applications of the same service in which stations on board sub-orbital vehicles operate, having regard to the sub-orbital flight application scenarios.

 3 to identify, as a result of the studies above, whether there is a need for access to additional spectrum that should be addressed after WRC-23 by a future competent conference."

**[**This Report will be organized into sections as outlining in Resolution **772 (WRC-19)** for WRC-23 agenda item 1.6:

Section 2: Relevant ITU-R Recommendations and Reports.

Section 3: To study spectrum needs for communications between stations on board sub‑orbital vehicles and terrestrial/space stations.

Section 4: To study appropriate modification, if any, to the Radio Regulations, excluding any new allocations or changes to the existing allocations in RR Article **5**, to accommodate stations on-board sub-orbital vehicles.

Section 5: Summary of studies.**]**

# 2 Relevant ITU-R Recommendations and Reports

**Recommendations:**

ITU-R [M.1787-3](https://www.itu.int/rec/R-REC-M.1787-3-201803-I/en) *General characteristics of the systems and networks of radionavigation-satellite services*

ITU-R [M.1903-1](https://www.itu.int/rec/R-REC-M.1903-1-201909-I/en) *Characteristics and protection criteria for receiving earth stations in the radionavigation-satellite service (space-to-Earth) and receivers in the aeronautical radionavigation service operating in the band 1 559-1 610 MHz*

ITU-R [M.1905-1](https://www.itu.int/rec/R-REC-M.1905-1-201909-I/en) *Characteristics for RNSS receivers in the frequency bands 1 164-1 215 MHz*

**Report:**

ITU-R [M.2477-0](https://www.itu.int/pub/R-REP-M.2477-2019) *Radiocommunications for suborbital vehicles*

# 3 Spectrum needs for communications between stations on-board sub‑orbital vehicles and terrestrial/space stations

According to Report ITU-R M.2477, a suborbital vehicle (SoV) is a vehicle executing suborbital flight and suborbital flight is defined as the intentional flight of a vehicle expected to reach the upper atmosphere with a portion of its flight path that may occur in space without completing a full orbit around the Earth before returning back to the surface of the Earth.

Currently, there are a variety of technical solutions to achieve suborbital flight. Launch modes include horizontal and vertical, landing modes include horizontal landing and vertical landing, recovery modes include self-controlled return and parachute recovery, and thrust modes include rocket power and combined power. Suborbital flights can be implemented by different combinations of the above modes. Figure 1 shows examples of the operational concepts of a suborbital flight.

Figure 1

Examples of the operational concepts of suborbital flight



With the rapid development of the various suborbital flight concepts in recent years, such as hypersonic flight and reusable carrier rocket technology, suborbital flight has become an operational reality, which supports a wide range of fields including education, transportation, tourism, and scientific research. Current research and development aim to enable suborbital vehicles to be capable of carrying several thousand kilograms of cargo and passengers by 2035 and up to 6 000 flights per year by 2045.

There are use-cases for suborbital flight that are much sooner than 2035. One commercial space transportation operator is currently testing a launch vehicle with plans to launch its first operational flight carrying up to six passengers to beyond the Karman line (the unofficial boundary between the Earth’s atmosphere and space), using a reusable suborbital rocket, in early 2021. The suborbital flight is planned to achieve a Mach 3 velocity during launch and will spend a few minutes in zero gravity before deploying parachutes to return back to the surface of the Earth. Another commercial space transportation operator expects to take its first passengers into space late 2021. This suborbital vehicle will be ferried by a special airplane and then released at a high altitude for conventional aircraft. This suborbital vehicle, which is part airplane and part rocket, will use rocket thrust to increase altitude beyond the Karman line and then return to the surface of the Earth like a glider. A more conventional space launch provider with over 100 successful mission in the past decade used a first-stage reusable booster in these missions, which falls under the category of suborbital vehicles in its concept of operation. Further, the same company is planning a flight around the moon in 2023, which is expected to carry up to ten people on-board the spacecraft stage. The first stage of this reusable booster currently falls under the category of suborbital vehicles; however a second stage is also planned global point to point passenger and payload delivery in near future.

# 4 Spectrum needs for communications between stations on-board sub‑orbital vehicles and terrestrial/space stations

There are spectrum needs for radiocommunications between stations on-board sub-orbital vehicles and terrestrial/space stations providing functions such as, *inter alia*, voice/data communications, navigation, surveillance, and TT&C.

## 4.1 Communications

It is envisioned that the crewed sub-orbital vehicles to establish and maintain bidirectional audio communications with their ground-based mission control center during full duration of their flight through either direct communication with Earth or through relay satellites or space stations. Such audio communication is considered critical for crews commanding the vehicle with ability to perform manual controls and piloting of the vehicle. These communication links are similar to the communication commonly established by airplanes using Internationally Standardized systems. It is noted that the passenger communication, if on-board these sub-orbital vehicles, may not be considered safety of life.

A unique aspect of sub-orbital vehicles communication requirement is the ability to maintain the link throughout various phases of flight including atmospheric re-entry where radio communication with vehicle experiences significant attenuation due to plasma effects caused by extreme heating and ionization of air around the vehicle.

## 4.2 Telemetry, tracking and command (TT&C)

Telemetry, Radio telemetry and Space telemetry are defined in RR Nos. **1.131**, **1.132**, and **1.133**.Radio telemetry for sub-orbital vehicles provide information about the status of vehicle and its subsystems. It is envisioned that the real-time telemetry is transmitted to ground stations, relay satellites, or space stations over radio frequency links. Additionally, crewed and un-crewed sub-orbital vehicles will require transmitting real-time high definition digital videos from multiple feeds carrying critical visual information about the vehicle status to ground terminals directly or through relay satellites or space stations.

Telecommand and Space telecommand are defined in RR Nos. **1.134** and **1.135**. The use of radiocommunication for telecommand in order to initiate, modify or terminate functions of equipment on sub-orbital vehicles is required for safe operation of these vehicles.

Space tracking is defined in RR No. **1.136**. It is envisioned that sub-orbital vehicle will rely on dedicated radio frequency links to perform necessary navigation throughout its trajectory by means of radiodetermination. Such tracking is expected to be performed through either ground station terminals or relay satellites or space stations.

Similar to the communications link mentioned in Section 3.1, a unique aspect of sub-orbital vehicles TT&C links requirement is the ability to maintain the link throughout various phases of flight including atmospheric re-entry where radio communication with vehicle experiences significant attenuation due to plasma effects caused by extreme heating and ionization of air around the vehicle.

## 4.3 Surveillance

 A surveillance service is necessary to determine the identification and position of users of the airspace and obstructions. The automatic dependent surveillance - broadcast (ADS-B) on 978 MHz and 1090 MHz is an ICAO-standardized aeronautical surveillance system envisioned to provide airspace navigation service providers and other users of the airspace surveillance data for high-altitude, high-velocity vehicles (as compared to conventional aircraft), including suborbital vehicles. One of the use-cases for this system includes equipping the suborbital vehicle to report ADS-B messages in all phases of flight for the purpose of aeronautical surveillance and collision avoidance from other airspace users, such as conventional aircraft operating in the airspace at lower altitudes and at much lower comparative velocities. Other surveillance technologies exist for use by suborbital vehicles, but like ADS-B, the principle surveillance application is the same as that used for conventional aircraft.

## 4.4 Navigation

The operator of the suborbital vehicle must know where the vehicle is located relative to the Earth to safely and efficiently navigate the planned mission. There are several electronic aids to air navigation currently available, however GNSS navigation systems using the RNSS allocation (space-to-Earth) are currently used on-board suborbital vehicles to provide a global navigation capability within Earth’s atmosphere and in the brief periods of time the suborbital vehicle operates in space. The navigation systems using the RNSS frequency bands 1 164-1 215 MHz and 1 559-1 610 MHz are currently most suitable for safety-of-life applications as these are currently used by conventional aircraft and the principle application is not different in the case of suborbital vehicles.

Since different technical requirements may be expected between the RNSS receivers, which will be operated under RNSS (space-to-Earth) allocations, and RNSS receivers, which will be operated under RNSS (space-to-space) allocations,, whether the same RNSS receivers can function may be investigated by receiver manufacturers and/or sub-orbital vehicle operators. However, this kind of investigation should be conducted outside of ITU-R studies.

[To be added]

# 5 Appropriate modification, if any, to the Radio Regulations, excluding any new allocations or changes to the existing allocations in Article 5, to accommodate stations on-board sub-orbital vehicles/Technical conditions to allow some stations on board sub-orbital vehicles to operate under the aeronautical regulation

## 5.1 The status of stations on sub-orbital vehicles

[This section will consider the status of stations on sub-orbital vehicles and study corresponding regulatory provisions to determine which existing radiocommunication services can be used by stations on sub-orbital vehicles.]

There are several existing radiocommunications services that can be used by stations on-board suborbital vehicles using existing coordination processes and procedures. These services\* include, but may not necessarily be limited to:

* AM(R)S: The Aeronautical Mobile (Route) Service, e.g. VHF voice and data communications and ADS-B, when permitted by ICAO SARPs.
* RNSS: The GNSS systems using 1 164-1 215 MHz and 1 559-1 610 MHz can be used for navigation.
* MSS: The Mobile Satellite Service in the frequency bands 1610-1626.5 MHz can be used for safety (AMS(R)S allocation in the 1610-1626.5 MHz band) and non-safety applications.
* AMS: TT&C applications in the Aeronautical Mobile Service (AMS) are currently using aeronautical mobile telemetry (AMT) in the lower S-band\* (2200-2290 MHz for telemetry and 2025-2110 MHz for command) shared with other services including SOS, EESS, and SRS and upper S-band\* (2360-2395 MHz for telemetry).

\* in some cases such as AMS S-band currently used for TT&C applications and other services, no modification of the RR will be required.

[To be completed]

## 5.2 Frequency bands under consideration for technical studies under this agenda item

[To be completed]

## 5.3 Technical and regulatory conditions that allow some stations on board sub-orbital vehicles to operate under the aeronautical regulation

[This section will study the technical and regulatory conditions to allow some stations on board sub‑orbital vehicles to operate under the aeronautical regulation and to be considered as earth stations or terrestrial stations even if a part of the flight occurs in space.]

5.3.1 Potential modifications to the Radio Regulations, in accordance with *invites* 2, Resolution **772** (**WRC-19**), that facilitate radiocommunications that support aviation to safely integrate sub-orbital vehicles into the airspace and be interoperable with international civil aviation

At this time sub-orbital flight radiocommunications has been carried out using the existing regulatory provisions of the Radio Regulations. These have been recognized in Report ITU-R M.2477. They include both terrestrial and space services as provided for in RR Article **5**. Further they have been carried out under the exiting definitions of these services in RR Article **1**.

Resolution **772 (WRC-19)** has indicated the need to study any appropriate modifications to the Radio Regulations that “facilitate radiocommunications that support aviation to safely integrate sub-orbital vehicles into the airspace”. There are several options for achieving this objective:

a) Make no changes to the RR – this option recognizes the exiting experience but provides no unique identification of sub-orbital use of spectrum.

b) A Resolution (WRC-23) – in this option a new Resolution would appropriately recognize the services used by sub-orbital vehicles.

c) Modify RR Article **4** – this Article, “Assignment and Use of Frequencies” contains statements relating to unique spectrum applications through description of their use of the RR.

d) Modification of other parts of the RR – in this option other Articles of the RR could be modified to accommodate sub-orbital vehicle use of spectrum.

## 5.[4] Sharing and compatibility studies

### 5.[4.1] Technical characteristics and protection criteria relevant for the following studies

[to be determined]

### 5.[4.2] Sharing and compatibility studies

[This section will contain sharing and compatibility studies with incumbent services that are allocated on a primary basis in the same and adjacent frequency bands in order to avoid harmful interference to other radiocommunication services and to existing applications of the same service in which stations on board sub-orbital vehicles operate, having regard to the sub-orbital flight application scenarios.]

# 6 Summary of [technical] studies

[To be added]