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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 ON WRC-23 AGENDA ITEM 1.6[SUBORBITAL VEHICLES studies]**Regulatory, 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

working document on wrc-23 agenda item 1.6
[suborbital vehicles 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."

# 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

ITU-R [M.1038](https://www.itu.int/rec/R-REC-M.1038/en) Efficient use of the geostationary-satellite orbit and spectrum in the 1-3 GHz frequency range by mobile-satellite systems

ITU-R[M.1184-3](https://www.itu.int/rec/R-REC-M.1184/en) Technical characteristics of mobile satellite systems in the frequency bands below 3 GHz for use in developing criteria for sharing between the mobile-satellite service and other services

ITU-R [M.1316-1](https://www.itu.int/rec/R-REC-M.1316/en) Principles and a methodology for frequency sharing in the 1 610.6‑1 613.8 MHz and 1 660-1 660.5 MHz bands between the mobile-satellite service (Earth-to-space) and the radio astronomy service

ITU-R [M.1471-1](https://www.itu.int/rec/R-REC-M.1471/en) Guide to the application of the methodologies to facilitate coordination and use of frequency bands shared between the mobile-satellite service and the fixed service in the frequency range 1-3 GHz

 This Recommendation references applicable methodologies to access interference to fixed service receivers contained in ITU-R [M.1472-1](https://www.itu.int/rec/R-REC-M.1472/en) and
ITU-R [M.1474-1](https://www.itu.int/rec/R-REC-M.1474/en)

ITU-R [M.1741](https://www.itu.int/rec/R-REC-M.1741/en) Methodology for deriving performance objectives and its optimization for IP packet applications in the mobile-satellite service

*Report*

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

ITU-R M.2413-0 Reception of automatic dependent surveillance broadcast via satellite and compatibility studies with incumbent systems in the frequency band 1 087.7-1 092.3 MHz

[Editor’s note: In addition to Recs and Reports for RNSS, there may be Recommendations and/or Reports for other services used in the bands proposed for use by suborbital vehicles that that will need to be added in this section.]

# 3 Suborbital vehicles

A) Definition of suborbital vehicles

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[[1]](#footnote-1) without completing a full orbit around the Earth before returning to the surface of the Earth.

B) Operational concepts

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. Figures 1 and 2 show examples of the operational concepts of a suborbital flight.

Figure 1

Examples of the operational concepts of suborbital flight



Figure 2

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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.

One example of an operational concept, related to tourism, consists of a flight carrying crewmembers to beyond the Karman Line (the unofficial boundary between the Earth’s atmosphere and space), using a reusable suborbital rocket. The suborbital flight achieves Mach 3 velocity during launch and will spend a few minutes in zero gravity before deploying parachutes to return to the surface of the Earth.

Another example of an operational concept consists in suborbital vehicle 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, uses rocket thrust to increase altitude beyond the Karman line and then return to the surface of the Earth like a glider.

More conventional space launch provider used a first-stage reusable booster in these missions, which falls under the definition of suborbital vehicles in its concept of operation.

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

## 4.1 Radiocommunication functional needs

There are functional 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 Telemetry, Tracking & Telecommand (TT&C).

### 4.1.1 Telemetry, tracking and command

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, some sub-orbital vehicles may require transmitting real-time high definition digital videos from multiple feeds carrying 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**. Radiocommunications for telecommand are used in order to initiate, modify or terminate functions of equipment on sub-orbital 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 adjustments of its trajectory by means of radiodetermination. Such tracking is expected to be performed through either ground station terminals or relay satellites or space stations.

Like the communications link mentioned in Section 4.1.2, a desired aspect of sub-orbital vehicles TT&C links 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.

### 4.1.2 Communications

It is expected that sub-orbital vehicles will establish and maintain bidirectional communications with ground-based mission control centres during the full duration of flight through either direct communication or through relay satellites or space stations. These communication links are like the communication commonly established by airplanes using internationally standardized systems. It is noted passenger communications, in comparison is only for entertainment purposes and would not be considered safety of life.

An important aspect of sub-orbital vehicle communication requirements is the desire to maintain the link throughout various phases of flight, including atmospheric re-entry where radio communication with the vehicle experiences significant attenuation due to plasma effects caused by extreme heating and ionization of air around the vehicle; Doppler effect; and the vehicle’s altitude.

### 4.1.3 Surveillance

A surveillance service provides the identification and position of users of the airspace and obstructions. For example, the automatic dependent surveillance – broadcast (ADS-B), using the frequencies 978 MHz and 1 090 MHz, is an ICAO-standardized aeronautical surveillance system. It provides airspace navigation service providers and other users of the airspace surveillance data for high-altitude, high-velocity vehicles (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, such as automatic dependent surveillance – contract (ADS-C). Like ADS-B, the principal surveillance application would be the same as that used for conventional aircraft.

### 4.1.4 Navigation

Navigation is the determination of the position and velocity of a moving vehicle. It is expected suborbital vehicles would utilize the same navigation systems currently in use for conventional aircraft. Several electronic aids currently available for navigation, including GNSS navigation systems, are operated under the RNSS allocation (space-to-Earth).

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.

## 4.2 Spectrum needs for sub-orbital vehicles

### 4.2.1 Operations in non-segregated airspace

[Editor’s note: This section requires additional attention]

[The purpose of the types of operational concepts of suborbital vehicle in non-segregated has to ensure its integration in airspaces under the relevant air traffic management system including the safety of the passengers of the suborbital vehicle as is done for the conventional aeronautical aircraft.

There are spectrum needs 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.

The expectation for these operational concepts of suborbital vehicles in non-segregated is to use the same aeronautical services ensuring the safety of life of the conventional aeronautical aircraft. The status of the stations on board stations remains the same (e.g., terrestrial stations or/and Earth stations) during the whole flight.

Telemetry, tracking and telecommand would be used without ensuring any safety of life function.]

### 4.2.2 Operations in segregated airspace

The separation with other aircraft is provided by the segregated airspace ensuring the safety of life for the other aircraft. However, it is of the interest to limit as much as possible the time during which the segregated airspace is needed.

There are spectrum needs for radiocommunications between stations on-board sub-orbital vehicles and terrestrial/space stations providing functions in particular TT&C. TT&C would be the main radiocommunication application used.

Aeronautical services may also be used with the purpose to provide information to ATM that the suborbital vehicle has left an area and that the airspace could return to the status of non-segregated.

# 5 Summary of studies

[To be added]

[Editor’s note: to be used for the section on summary for studies in draft CPM text]

Annex 1

Technical studies on suborbital vehicles in non-segregated airspace

## A1.1 Frequency bands under consideration for technical studies

[To be completed]

## A1.2 Technical characteristics and protection criteria relevant for the following studies

[To be determined]

### A1.3 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.]

Annex 2

Technical studies on suborbital vehicles in segregated airspace

## A2.1 Frequency bands under consideration for technical studies

[To be completed]

## A2.2 Technical characteristics and protection criteria relevant for the following studies

[To be determined]

### A2.3 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.]

Annex 3

Regulatory considerations to facilitate operating stations
on board sub-orbital vehicles

Under this agenda item, it is recognized that the frequency accommodation for expendable space launch systems should not negatively impact current use of frequencies by conventional space launch systems. However, the solutions for suborbital vehicles may provide radiocommunication opportunities for the conventional space launch systems to limit as much as possible the time during which the segregated airspace is needed.

## A3.1 Examples of radiocommunications services and frequencies

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 1 518-1 544 & 1 545‑1 559 MHz (space-to-Earth), 1 610-1 626.5 MHz, and 1 626.5-1 645.5 & 1 646.5‑1 660.5 MHz (Earth-to-space), and 1 668-1 675 MHz (Earth-to-space) can be used for safety (AMS(R)S allocation in the 1 610-1 626.5 MHz band) and non-safety applications.

– [MS: in RR No. **5.394**, some Administrations expressed the view that, the use of the band 2 300-2 390 MHz by the aeronautical mobile service for telemetry has priority over other uses by the mobile services. Some other Administrations expressed the view that, use of the band 2 360-2 400 MHz by the aeronautical mobile service for telemetry has priority over other uses by the mobile services.

 TT&C applications in the Aeronautical Mobile Service (AMS) are currently using aeronautical mobile telemetry (AMT) in the 2 200-2 290 MHz for telemetry and 2 025-2 110 MHz for command shared with other services including SOS, EESS, and SRS and upper S-band 2 360‑2 395 MHz for telemetry. Therefore, there is no need for changes to the Article 5 of the Radio Regulations in these bands.~~]~~

## A.3.2 Application of existing mobile satellite service radio regulations

The operation of MSS systems providing aeronautical radiocommunications in the above-identified frequency bands are regulated under existing RR provisions. The existing RR Article **9** procedures are adequate to capture any new coordination requirements in the operation of MSS earth stations onboard sub-orbital vehicles in the 1.6/1.5 GHz bands that result with other MSS satellite systems and networks, and other space services operating in the 1.6/1.5 GHz bands.

This approach would permit the existing frequency coordination procedures identified under Section II of RR Article **9** to remain applicable in the coordination and operation of MSS communications to sub-orbital vehicles, during the intervals of time when a sub-orbital vehicle is in space.

For coordination and protection of terrestrial services, is noted that the operation of MSS earth stations on sub-orbital vehicles in space would result in less interference to terrestrial services, relative to the comparable case of an MSS earth station operating on the Earth’s surface or within the Earth’s atmosphere on an aircraft. This reduction in the potential for interference at the Earth’s surface results from the increased separation of the MSS earth station to the Earth when operating in regions of space.

Similarly, no changes are necessary for MSS satellite transmissions to support the operation of MSS earth stations on sub-orbital vehicles, since the required satellite transmissions powers, if anything, would be lower. When operating earth stations on sub-orbital vehicles, there would be a lower path-loss between the MSS earth station and associated MSS satellite, together with a reduction in the atmospheric impairment and multipath degradation.

Both above factors would ensure the protection of terrestrial services is maintained in the use of MSS communications, and that the existing regulatory provisions and coordination requirements in the use of MSS communication in the 1.6/1.5 GHz frequency bands remain effective. Additionally, it is noted that RR Nos. **5.208B** and **5.379C** would continue to apply to MSS earth stations operating on sub-orbital vehicles, to maintain the protection of radioastronomy operating in the frequency bands 1 660.0-1 660.5 MHz and 1 668-1 670 MHz.

## A3.3 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 existing 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.

1. The delimitation between atmosphere and outer space has not been legally defined at an international level by the competent organizations. [↑](#footnote-ref-1)