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| **Purpose/Objective:** This contribution provides further updates to WRC-23 AI 1.6 Report 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 updates to support the agenda item. |

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| **Radiocommunication Study Groups** |  |
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| WORKING DOCUMENT TOWARDS PRELIMINARY DRAFT NEW REPORT 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 further updates to support the agenda item.

Attachment: 1

ATTACHMENT

working document TOWARDS PRELIMINARY DRAFT NEW REPORT on wrc-23 agenda item 1.6
[suborbital vehicles studies]

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

# 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 Abbreviations/Glossary

ADS-B: Automatic dependant surveillance – broadcast

ADS-C: Automatic dependant surveillance – contract

AM(R)S: Aeronautical mobile (route) service

AMS(R)S: Aeronautical mobile satellite (route) service

AMS: Aeronautical mobile service

AMT: Aeronautical mobile telemetry

ATM: Air traffic management

GNSS: Global navigation satellite service

ICAO: International Civil Aviation Organization

MSS: Mobile satellite service

RNSS: Radionavigation satellite service

RR: Radio Regulations

TT&C: Telemetry, tracking & telecommand

# 3 Relevant ITU-R Recommendations and Reports

Recommendations

ITU-R [M.1038-0](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

ITU-R [M.1741](https://www.itu.int/rec/R-REC-M.1741/en)-0 Methodology for deriving performance objectives and its optimization for IP packet applications in the mobile-satellite service

ITU-R [M.1787-4](https://www.itu.int/rec/R-REC-M.1787/en) Description of systems and networks in the radionavigation-satellite service (space-to-Earth and space-to-space) and technical characteristics of transmitting space stations operating in the bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz

ITU-R [M.1901-3](https://www.itu.int/rec/R-REC-M.1901/en) Guidance on ITU-R Recommendations related to systems and networks in the radionavigation-satellite service operating in the frequency bands 1 164-1 215 MHz, 1 215-1 300 MHz, 1 559-1 610 MHz, 5 000-5 010 MHz and 5 010‑5 030 MHz

ITU-R [M.1903-1](https://www.itu.int/rec/R-REC-M.1903/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/en) Characteristics and protection criteria for receiving earth stations in the radionavigation-satellite service (space-to-Earth) operating in the band 1 164-1 215 MHz

[ITU-R M.1638](https://www.itu.int/rec/R-REC-M.1638/en)-1 Characteristics of and protection criteria for sharing studies for radiolocation (except ground based meteorological radars) and aeronautical radionavigation radars operating in the frequency bands between 5 250 and 5 850 MHz

ITU-R [RS.1260-2](https://www.itu.int/rec/R-REC-RS.1260/en) Feasibility of sharing between active space-borne sensors and other services in the range 420-470 MHz

ITU-R [SA.363-5](https://www.itu.int/rec/R-REC-SA.363/en) Space operation systems

Reports

ITU-R [M.2413-0](https://www.itu.int/pub/R-REP-M.2413-2017) 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

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

# 4 Suborbital vehicles

4A) Description of suborbital vehicles

Following further considerations and taking into account the diversity of applications, it may be necessary to provide more flexibility to the description of suborbital vehicles:

 “A suborbital flight is defined for Radio Communication purposes, as an intentional flight of a vehicle to reach the upper atmosphere and return to Earth with a portion of its flight path that may occur in space without completing a full orbit (see No. **1.184**) around the Earth or without becoming a satellite (see No. **1.179**).

 A suborbital vehicle is a vehicle executing a suborbital flight, and which may be reusable.”

4B) 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

 Examples of suborbital flights



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.

Another example of a more conventional space launch provider uses a first-stage reusable booster in these missions, which falls under the definition of suborbital vehicles in its concept of operation

The global demand for space launches is increasing and new methods of accessing space will help meet that demand. At least, one administration predicts an increase in global commercial launch activity to meet the increasing demand for access to space. More details are provided in Report ITU-R M.2477.

 4C) Regulatory considerations

Radio stations operating onboard sub-orbital vehicles are expected to operate in frequency bands currently allocated for certain terrestrial and space radiocommunications services, while not changing the interference environment with existing applications of the same service and on other radiocommunication services in-band and in adjacent frequency bands.

There is no intention to define a new category of station in the RR, and hence the station onboard a sub-orbital vehicle would have to conform to the definitions of *terrestrial stations* in RR No. **1.62**, *earth stations* in RR No. **1.63**, and *space stations* in RR No. **1.64.**

As the sub-orbital vehicle may be physically located within the major portion of Earth’s atmosphere and/or for a brief period of time in space, the definitions could lead to an inconsistency in the application of the regulations for the stations on the sub-orbital vehicle which intend to operate as terrestrial and/or earth stations, due to the brief period of time in space, since the terrestrial and earth stations would have to remain in the major part of the Earth’s atmosphere to comply with these definitions.

One view from the study is to consider that the RR No. **1.64** is the baseline for the classification of a station onboard sub-orbital vehicle. The view considers that in accordance with the definition of the RR. No. **1.64**, the classification of the stations on-board a sub-orbital vehicle has to be “*space stations”* when the operation “is beyond, is intended to go beyond, or has been beyond, the major portion of Earth’s atmosphere”. These stations need to use the appropriate space service allocation. However, the relevant space service allocation or directions of the space services to be used for sub-orbital vehicles do not always exist in the current Table of Frequency Allocations. In this case, completing the Table of Frequency Allocations with relevant space services or with relevant direction of the appropriate space services would be a solution. However, the *resolves* 2 of Resolution **772 (WRC-19)** states “excluding any new allocations or changes to the existing allocations in Article **5**”. Consequently, an earth station or of a terrestrial station onboard sub orbital vehicle operating in space could then only be notified under RR No. **4.4**. The radiocommunications requiring to apply RR No. **4.10** for aeronautical application would then have to remain beyond the major portion of the atmosphere. The Method also addresses the safety radiocommunications when located outside airspace under international or national aviation regulation while remaining in major portion of the atmosphere. If the application of RR No. **4.4** is not sufficient for earth stations or terrestrial stations intending to reach space, then following additional studies would be required to be undertaken under possible new agenda item for WRC-27 by completing of the operational scenarios for the different types of sub-orbital vehicles intending to reach space and to define functional requirements in terms of radiocommunications, list if any, listing of the current aeronautical safety of life radiocommunication systems and associated frequency bands which require RR No. **4.10** when located in space, listing the need of non-safety of life radiocommunication systems and associated frequency bands which would require coexistence provisions when operated in space, conducting for the frequency bands listed previously; appropriate regulatory, technical and operation studies complying with RR No. **1.64** on the definition of space stations when sub-orbital vehicles are operated in space while not adversely affect the services sharing the band and in the adjacent band.

Another view is to consider that the sub-orbital vehicle terrestrial and earth stations retain the status of the terrestrial station or earth station during the whole flight. A *terrestrial station* is defined as, “a station effecting *terrestrial radiocommunication,*” and *terrestrial radiocommunication* (RR No. **1.7**) is defined as, “any radiocommunication other than *space radiocommunication* or *radio astronomy*”. As per RR No. **1.61**, each station shall be classified by the service in which it operates permanently or temporarily. While the sub-orbital vehicle is physically located beyond the Earth’s atmosphere for a brief period of time, the physical location of the sub-orbital vehicle on which the stations are located does not change the need for, or purpose of the use of, specific radiocommunication applications. A further view was expressed that, upon review of the RR provisions, it could be considered that there are no difficulties with the existing RR Article **5** allocations when a *space station* on-board sub-orbital vehicle goes beyond or is intended to go beyonda major portion of the Earth’s atmosphere, based on the space radiocommunication service in which the station operates.

Report ITU-R M.2477 states that some sub-orbital vehicle operations may require temporarily making unavailable large areas of international and national airspace for conventional aircraft during their transition to and from space. This results in airspace disruptions, extra travel time, re‑routing flight paths, additional aircraft fuel consumption, etc. The studies also show the technical capability of some current aircraft avionics systems to be operated onboard sub-orbital vehicles, to facilitate the safe integration of sub-orbital vehicles into the same airspace as conventional aircraft during their transition to and from space to minimize the airspace disruption.

The Report also identifies several existing radiocommunications services that are envisaged for use by stations onboard sub-orbital vehicles including, but not limited to:

a) Aeronautical radionavigation service for surveillance and navigation;

b) Aeronautical mobile service, including the aeronautical mobile (Route service), for VHF voice and data communications and automatic dependent surveillance -broadcast (ADS-B);

c) Aeronautical mobile satellite service, including the aeronautical mobile satellite (Route) service (AMS(R)S), for voice and data communications and surveillance ADS‑B and automatic dependent surveillance - contract;

d) Mobile satellite service, including AMS(R)S, for communications and telemetry, tracking and command (TT&C) applications;

e) Aeronautical radiodetermination service (not a specifically defined service in the RR) for surveillance;

f) Radionavigation satellite service (RNSS) for navigation with global navigation satellite systems operating in the frequency bands 1 164-1 215 MHz and 1 559-1 610 MHz, and;

g) Space operation service for TT&C.

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

## 5.1 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).

### 5.1.1 Telemetry, tracking and command

Telemetry, radio telemetry and space telemetry are defined in Radio Regulations (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 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.

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 the vehicle experiences significant attenuation due to plasma effects caused by extreme heating and ionization of air around the vehicle.

### 5.1.2 Communications

It is expected that sub-orbital vehicles will establish and maintain communications with ground-based mission control centres during the full duration of flight through either direct communication between the suborbital station and ground, or through relay satellites or space stations. These communication links are like the communications commonly established by aircraft. To integrate into airspace used by conventional aircraft, suborbital vehicles are expected to use the same internationally standardized aviation safety systems available to conventional aircraft . Passenger communications which may, for example, be for entertainment purposes would not be considered safety of life.

### 5.1.3 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.

### 5.1.4 Navigation

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

Since different technical requirements may be expected between the RNSS receivers, which are operated under RNSS (space-to-Earth) allocations, and RNSS receivers, which are operated under RNSS (space-to-space) allocations, whether the same RNSS receivers can have the same performance 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.

### 5.1.5 Radiolocation

Radiodetermination is defined as the determination of the position, velocity and/or other characteristics of an object, or the obtaining of information relating to these parameters, by means of the propagation properties of radio waves (see No. 1.9), whereas radiolocation is radiodetermination used for purposes other than those of radionavigation (see No. 1.11).

Sub-orbital vehicles can use the radiolocation service (see No. 1.48) as currently provided by the RRs, for example, to support a flight termination decision or to predict impact or landing site of re-entering SOVs.

## 5.2 Spectrum needs for sub-orbital vehicles

The expectation is that suborbital vehicles will use the space and terrestrial radiocommuniccations similar to systems used by conventional aircraft for the purposes of air traffic management.

Considering that suborbital vehicles are expected to consist of only a small fraction of overall aviation traffic, the spectrum requirements for the operation of suborbital vehicles are not expected to significantly impact on overall aviation spectrum requirements.

 Some examples of frequency bands identified for stations on-board sub-orbital vehicles can be found in the Annex.

# 6 Summary of studies

[To be added]

Annex

Co-existence and regulatory considerations to facilitate operating stations
on board sub-orbital vehicles

Under this agenda item, it is recognized that the frequency accommodation for suborbital vehicles should not negatively impact the current use of frequencies by any other radiocommunication services.

## 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, in accordance with ICAO SARPs.

– AMS(R)S receive only: ADS-B, in accordance with 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 and non-safety applications.

– MS: 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. According to ITU-R RS.1260-2, Telecommand applications in particular for flight safety purposes can use frequency band 420‑450 MHz.

– Radiolocation Service: The radiolocation service in the frequency band 5 450-5 850 MHz can be used for SOV tracking in safety and non-safety applications.

## A3.2 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 application of MSS systems to support suborbital vehicles would require communications between the MSS satellite and the MES at all stages of the flight, including when the mobile earth station (MES) is on the ground, in the atmosphere and when in space. The existing RR Article **9** procedures are/would be adequate to capture any new coordination requirements in the operation of MESs 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 MESs on sub‑orbital vehicles in space would result in less interference to terrestrial services, relative to the comparable case of an MES 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 MES to the Earth when operating in regions of space.

Similarly, no changes would be necessary for MSS satellite transmissions to support the operation of MESs 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 MES and associated MSS satellite, together with a reduction in the atmospheric impairment and multipath degradation.

The 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 MESs 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.

Since the definition of an MES requires it to be either on the Earth’s surface or within the major portion of the Earth’s atmosphere (see RR Nos. **1.25** and **1.63**), it would be necessary to clarify the regulations to ensure that MESs may also be used on suborbital vehicles when beyond the Earth’s atmosphere.