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**ITU-R**  
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**Report ITU-R M.2286-0**  
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# **Operational characteristics of aeronautical mobile telemetry systems**

**M Series**  
**Mobile, radiodetermination, amateur  
and related satellite services**



International  
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Union

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<b>BS</b>	Broadcasting service (sound)
<b>BT</b>	Broadcasting service (television)
<b>F</b>	Fixed service
<b>M</b>	<b>Mobile, radiodetermination, amateur and related satellite services</b>
<b>P</b>	Radiowave propagation
<b>RA</b>	Radio astronomy
<b>RS</b>	Remote sensing systems
<b>S</b>	Fixed-satellite service
<b>SA</b>	Space applications and meteorology
<b>SF</b>	Frequency sharing and coordination between fixed-satellite and fixed service systems
<b>SM</b>	Spectrum management

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## REPORT ITU-R M.2286-0

**Operational characteristics of aeronautical mobile telemetry systems**

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**1 Introduction**

Aeronautical mobile telemetry (AMT) describes a particular use of the mobile service (MS) for the transmission from an aircraft station of results of measurements made onboard, including those relating to the functioning of the aircraft. Examples of AMT data include engine temperature, fluid pressure, and control surface strain gauges, among many other functions. This Report describes the operational details of AMT systems that, when combined with traditional link budget analyses, will provide a full-description of how AMT systems might affect, or be affected by, the operations of other systems in either co-channel or adjacent channel scenarios.

Related texts are Recommendations ITU-R M.1459 and M.1828; Reports ITU-R M.2118, ITU-R M.2119, and ITU-R M.2238; CPM Report to WRC-03 (§ 2.8.1, pages 89-98); and Radio Regulations Article **21**, Table **21-4**.

AMT data is essential for the safety of pilots and persons on the ground during flight test activities as it is *the* critical source of real-time measurement and status information transmitted from airborne vehicles during live tests of manned and unmanned aircraft.

AMT equipment is supplemental in nature, installed expressly to give ground personnel access to information normally not available during flight. AMT routinely conveys detailed information related to vehicle state (position, velocity, acceleration, altitude, orientation, etc.), vehicle structure conditions, propulsion system conditions, navigation system performance, and personnel condition. More and more, AMT data streams are also used to monitor voluminous on-board digital messaging activity within and between major subsystems like control system computers, navigation systems, sensing systems, etc.

## 2 Typical aeronautical mobile telemetry facilities

FIGURE 1  
Typical open-air test range

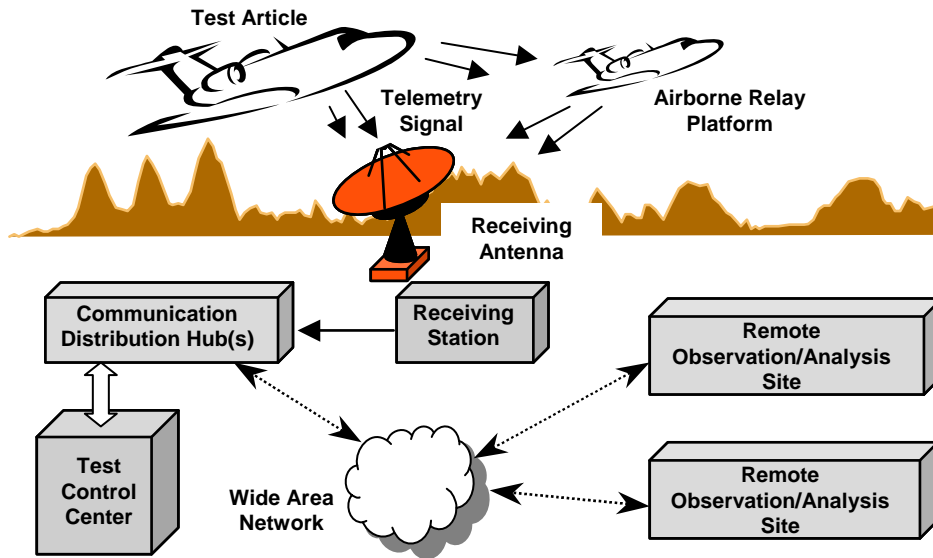


Figure 1 is a simplified pictorial of typical players and facilities found at open-air test ranges. Operations are conducted at locations around which airspace is restricted. This may also coincide with controlled land or sea areas consistent with safe conduct of high-risk test flights. The test article (TA) depicted could be a manned aircraft, an unmanned aircraft, or any other type of airborne vehicle.

Before takeoff, on-board instrumentation and AMT transmitters are typically activated to facilitate TA status checks, equipment calibrations, and the like. Telemetry signals are received by a high performance receiving station. Sensitive directional receiving antennas are required due to limitations on transmitted power and transmit antenna performance. State-of-the-art feed assemblies and low noise amplifiers are used to achieve the greatest possible performance. They acquire initial signal track prior to takeoff and track the vehicle throughout each flight. Relay platforms, shown as a second aircraft in this figure, may be used to extend coverage over water and, when overland, to other ranges. It is not unusual for manned aircraft to traverse thousands of kilometres in test flights lasting 10 to 12 hours. Relay stations can also be shipborne when long-range tests are conducted over water.

Each receiving station must receive the TA signals and convert them back to baseband digital data streams with acceptably low rates of bit detection error. Once reconstituted, the digital stream is passed to the next system segment. Relay stations retransmit the streams via RF link to the nearest fixed station or the next relay link. Fixed stations in receiving infrastructures forward the baseband digital data streams to communications hub and data distribution facilities via terrestrial point-to-point microwave relays or dedicated land lines.

The distribution facility provides at least three services. For local distribution, data is decoded, framing is detected and data sample sequences are restored on a measurement-by-measurement basis. Sorted data is then routed to real-time displays for test conductors and area specialists located in test control centres. Storage facilities are available to record data, voice communications and other information that may be available from ground-based support services like radar or from differential global positioning system equipment. Many distribution facilities regroup measurement data for selective distribution to remote sites via dedicated or commercial wide area networks. Large sums of money are saved today by direct distribution of data to manufacturer facilities, often obviating the need for design specialist presence at test ranges.

Economic viability and workload dictates that test ranges be capable of supporting several tests simultaneously. Major test ranges are capable of supporting at least 2 to 6 simultaneous tests including tests involving multiple autonomous vehicles such as unmanned aerial vehicles.

### **3 The role of telemetry**

Uses for AMT can be listed in three broad categories: safety, diagnostics, and productivity.

#### **3.1 Safety**

Safety is the pre-eminent driver of AMT system characteristics in terms of data transport latency and link reliability. Even though design technology is advanced in terms of performance prediction, test flights separate the worlds of simulation and implementation. AMT provides extra eyes on the ground. Specialists in structural integrity, flying qualities, and propulsion systems, to name just a few systems, continuously monitor vehicle or subsystem status in their respective specialties and advise test conductors whenever anomalous or unexpected behaviour is detected. In turn, test conductors prioritize these inputs and are able to warn the pilots as necessary in order to avoid catastrophic failures. These and other safety-related tests (such as “flutter” tests designed to stress wings and control surfaces) leave no margins for error.

#### **3.2 Diagnostics**

Successful initial flights lead to “flight envelope expansion” programs. Envelope expansion is a carefully planned matrix of test sequences leading to increased speed, increased altitude, more extreme manoeuvres, or use of more of the TA’s other capabilities. Extra eyes on the ground are no less important during envelope expansion than during early flights. Each test point leads to higher stress levels in some vehicle components or more complex interactions of subsystems. Each new step can yield surprising results. If a major failure occurs (fortunately an infrequent event), ground recordings of telemetry data are often the only source of diagnostic information to support accident investigation. This is particularly true for test vehicles that are not recoverable. AMT data recorded by receiving stations prior to TA loss is the only means of knowing how and why particular outcomes occurred.

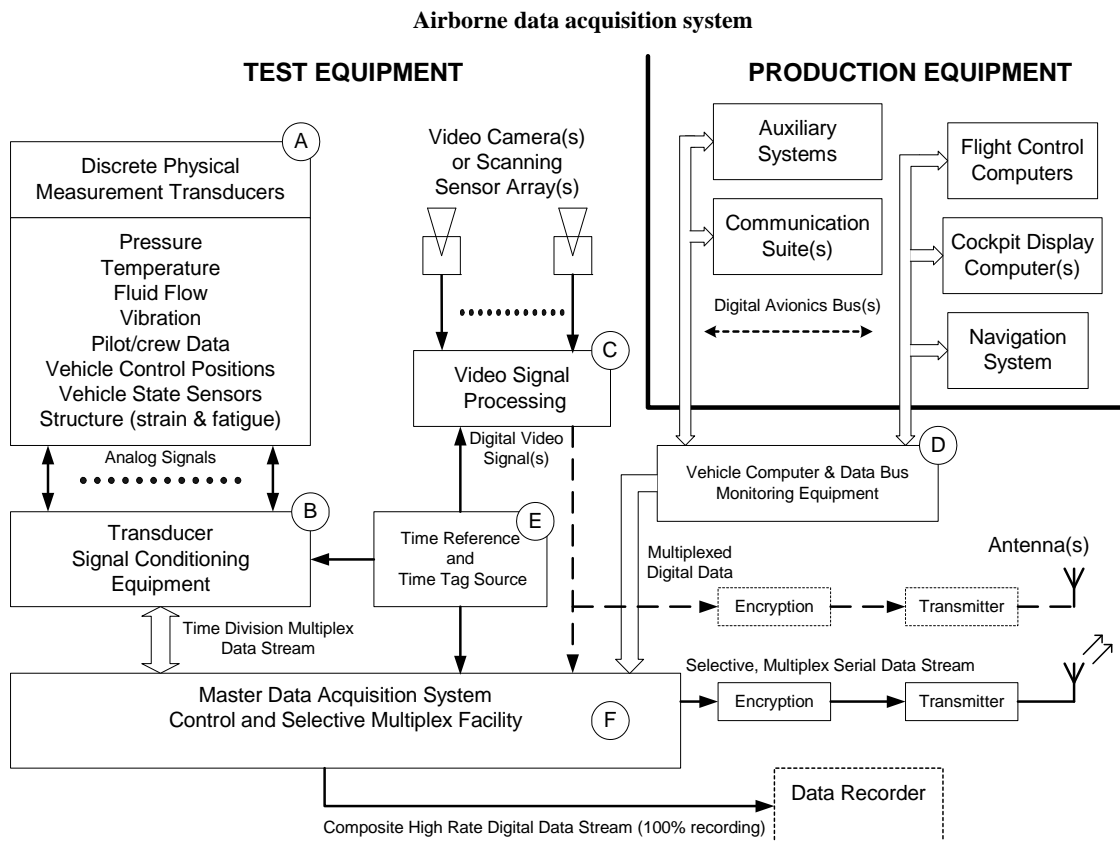
#### **3.3 Productivity**

Productivity plays an increasingly important role in AMT. Major test programs for new commercial aircraft, for example, are placing more and more emphasis on real-time availability and evaluation of data. Consistent with safety, the purpose is to accelerate test schedules, thereby reducing or at least controlling the huge, escalating costs of testing, and accelerating time-to-market. Additional specialists assess system behaviour in the context of matching measured behaviour to predicted and past behaviours. If no critical safety limits are reached, these specialists are responsible for determining if conditions are consistent with immediate progression to the next scheduled test during the same flight.

To accomplish the above objectives requires a sophisticated suite of instrumentation and sensors. Figure 2 is a highly simplified diagram of flight test instrumentation equipment commonly used during experimental and development phases of a TA. Note that there are two categories of equipment, i.e. equipment installed specifically for testing, and production equipment that is a significant source of test data in its own right. Block “A” is a representative list of sensor types installed for test purposes. These devices, known as transducers, convert some physical property like temperature or pressure to electrical signals (voltage or current). The number of transducers installed can range from a few dozen to several thousand, with the exact number depending upon the type of test being conducted, the aircraft’s purpose, its stage of development, and associated test risk, among other factors.

Most data acquisition systems create and capture digital data samples to provide good measurement precision and to capitalize on data transport efficiencies offered by digital time division multiplex techniques. Block “B” represents equipment required to energize the transducers, amplify and filter their signals, and convert each signal into digital word form. The output of block “B” is typically a time division multiplex collection of the digitized transducer signals at bit rates ranging from 0.5 to over 50 Mbit/s.

FIGURE 2



Imagery (block “C”) is a part of many test programs. Video is used for applications ranging from cockpit activity monitors to exterior scene viewing. Imagery also extends to sensor array data (non-visible light) associated with scientific work. Today, most video signals are converted to digital form for compatibility with digital recorders, encryption, and multiplexing. Full motion, standard/enhanced definition, colour video signals produce digital data at rates on the order of 4-12 Mbit/s. Compression is often used to reduce this load; however, this comes at the expense of image quality or image update rates. High-resolution, high-speed scientific experiments can

produce data at rates of 20-100 Mbit/s or more, and the information from these sources is generally not amenable to compression.

Capture and analysis of on-board computer network traffic has become a major challenge for test teams. Aircraft have evolved into flying computer systems connected to sensory input and inter-subsystem communication networks. Large volumes of digital message traffic flow between computers, backup computers, computer-based avionics equipment, specialized sensor suites, and external communication devices. State-of-the-art vehicles 20 years ago carried one or two digital data busses with aggregate message traffic in the 0.2-0.7 Mbit/s range. The number of busses has grown dramatically over time. New vehicles (and upgrade projects) are being fitted with high-speed network media like Ethernet and fibre channel to shuttle message traffic at speeds up to 1 Gbit/s. Intra-vehicle network traffic is intercepted with custom equipment shown generically in block "D". Most implementations provide for selective and, when necessary, complete capture of bus message traffic. Just one high-speed bus tap can increase data capture and transfer demand by 10 s to 100 s of Mbit/s.

Block "E" references explicit measurement time correlation. Some applications require the data acquisition system to correlate inter-channel or inter-system events with microsecond precision. In these cases, individual samples and avionics message segments are time-stamped at the instant of sampling. Time tags can become a significant source of test data in their own right.

The data sources converge in block "F". Transducer samples, image data blocks, and data bus message segments are sorted and stuffed into pre-allocated transmission time slots within "transport frames". Data is shuttled out in a continuous serial stream at an aggregate bit rate, which is the sum of transport frame overhead and the sum of bit rates from all data sources selected for transmission. The serial transmission stream is often encrypted prior to application to transmitters which can add to bandwidth requirements.

#### **4 Conclusion**

The information provided herein enhances the ability to carry traditional link budget analyses beyond the traditional physical layer in which, for example, the budget is complete when a particular value of bit error rate or overall link availability is achieved. By providing details of the sub-systems that underlie the air-to-ground telemetry link, it becomes possible to extend link budget analyses to an assessment of the impact of link budget performance on overall AMT system performance.

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