

Introduction

The standard network services consist of the aircraft housekeeping data, NTP time service, instrument UDP packet handling, and various ground web services. Other network services can include ssh/sftp access to instruments via Inmarsat, and custom or higher rate data feeds to instruments. Use of any and all network services on the ER-2 is encouraged but entirely optional.

Aircraft Housekeeping Data Distribution (also known as Nav Data)

Data in IWG1 format is broadcast on the aircraft network by the NASDAT as 1Hz UDP packets. The packet format is a simple ASCII CSV format which is now standard on most NASA and NCAR aircraft; please see http://www.eol.ucar.edu/raf/Software/iwgadts/IWG1_Def.html. Other data formats, parameters and update rates are available on request. Legacy RS232 housekeeping data outputs are still available but discouraged for new designs.

Time Synchronization

The aircraft master time source is a Spectrum Instruments GPS time reference clock with ovenized crystal providing UTC; all NASDAT outputs including NTP and IRIG-B reference this clock. Inaccurate timestamps are often a source of trouble, so setting instrument time using NTP or IRIG-B (or an internal GPS) is encouraged. IRIG-B is most precise, but NTP on the aircraft LAN is accurate to <1 msec once synchronized. The IWG1 stream can also be used but is much less accurate due to the latencies involved. Setting clocks once before flight is much less accurate than continuously tracking, and may result in large errors (because NTP and IWG time can take some time to become valid). Timestamps should be in UTC (note GPS time has a number of seconds offset).

Instrument UDP Packet Handling

The standard instrument UDP packet data communication service supports two packet types, known as "status" (a defined CSV format), and "user" (short for "user-defined"). Instruments send both packet types to the NASDAT, and receives user packets from the NASDAT, which forwards them to/from servers on the ground. Over Iridium, these packets are rate-limited to one every ten seconds (or five seconds on lightly loaded missions), and also size-limited (normally 550 bytes). These limits are also true over Inmarsat by default, but can be higher on request. The rate-limiting is accomplished by the NASDAT (and ground Iridium server) sending the most recent packet at the scheduled transmit time, and dropping the rest. Therefore instruments can send these packets at any rate; 1 Hz is a good nominal rate to limit added latency, but higher rates are fine as well. Iridium packets are often lost due to checksum or other transmission errors, which needs to be kept in mind during experiment design. Inmarsat normally has much better quality of service than Iridium, but can possibly have outages or failures, so it's best to plan on sending these packets over both the Iridium and Inmarsat links for redundancy. This is accomplished by sending identical packets to the NASDAT on two different ports; one gets forwarded by Iridium and the other by Inmarsat. Please see below for detailed information on instrument status and user packets.

Ground Web Services

Ground services consist primarily of the web server for the IWG1 data and instrument status and user packets (asp-interface-2.arc.nasa.gov), a simple flight tracker (airbornescience.nasa.gov/tracker), and the Mission Tools Suite web server (mts.nasa.gov) for flight tracking, status packet data display, IRC chat and collaboration tools. Integration with the MTS requires advance coordination with the MTS support staff. Often experimenters will generate their own displays from live data and make them available, either independently or via the MTS. For status and user packets experimenters retrieve the packet contents on the ground from a per-stream URL via HTTP GET, and send to the aircraft via HTTP POST (user packets only). The GET URL can be munged with Start and End parameters (using either ISO 8601 timestamps, or seconds past Jan 1, 1970) to request more than just the most recent packet. HTTPS is available, and password access can be enabled on request.

Additional Services

Please contact the data system support staff to discuss any special requests. Higher rate housekeeping data is available on request, as are custom data formats and various parameters not included in the IWG1. Instrument status data can be merged with other data, calculations can be added, and new data streams created on-board or on the ground. UDP packet data can be forwarded from the web server instead of using using the HTTP interface (but this often runs into firewall issues). Non-network services include IRIG-B and PPS signals, and also RS232, RS422 and ARINC-429 input/output (but these are used typically to support legacy systems and not encouraged for new designs).

Inmarsat - Additional Services

Higher bandwidth data and instrument login access can be available using Inmarsat, except at high latitudes. There is a cost for Inmarsat, currently \$5.88/Mb, however current policy is to not charge this back for small usage (less than ~6 Mbyte/hour/aircraft). In addition to the standard status and user packets via the NASDAT, experimenters can also send UDP packets directly home (bypassing the web server interface, and the NASDAT rate-limiting features), however random internet firewalls and filters may cause issues. Experimenters can also ssh/sftp into their instruments if first given an account on the on-board router (a Linux system) using a "two hop" connection, and setting up a ssh tunnel should be possible that way as well (to enable direct bidirectional TCP/UDP communications); however this should be be considered in addition to the base UDP packet forwarding services since Inmarsat is normally not turned on until just before aircraft takeoff, and can possibly have outages or failures. X11-forwarding and remote desktop over Inmarsat is not normally allowed because of the inefficient bandwidth use.

Status Packets – Details

Status packets have a defined CSV ASCII format similar to IWG1. There is a leading identifier (instrument name) followed by up to 16 parameters, consisting of an ISO-8601 time-stamp, an unsigned integer status code, and 0-14 more numbers representable as IEEE-754 single-precision floating point, in any format readable by the C library function `strtod()`. Missing or bad values are given by "nan" or "" (adjacent commas), not -9999 etc. The status code value is created by adding the following values as appropriate:

Status Packets – Details (cont)

1 = Ready
2 = Operating
4 = Calibrating
8 = Warning
16 = Invalid
32 = Failed
64 = Reserved
128 = Reserved
256 up = User defined (bits 8-23 are available)

An example would be: “MLPPP,20081019T145530.133,3,-96.2707,nan,127,132.551\r\n”. Note the leading identifier, the ISO-8601 timestamp with optional milliseconds, the status code of “3”, and the use of “nan”. The trailing <cr><lf> is optional.

Status packets have become something of an Airborne Science standard. Besides being telemetered to the ground, they are parsed by the NASDAT and can be used on-board the aircraft for calculations or sharing between instruments if wanted (either via NASDAT outputs or directly). They can also be displayed in the Airborne Science Mission Tools Suite for web display, and are a good way of sharing of live parameter data via the web interface server. Experimenters are encouraged to include science data such as atmospheric tracers, and engineering data for instrument health monitoring. Note that regardless of status code, all status data is regarded as “preliminary uncalibrated data for real-time indication purposes only, and not for any post flight use without the Principal Investigator's prior permission”. Note that providing status packets allows real-time awareness of any problems, including time-stamping problems, and also easier sharing of the job of instrument monitoring during long flights.

User Packets - Details

This service provides a mechanism to send small UDP packets between airborne instruments and experimenter ground computers. Common uses are for data that does not fit in the status packet scheme due to size or format (binary, text, scan vectors, etc.), for instrument command and control, and for experimenter-provided displays. In contrast to the CSV Status Packets, these packets are unicast, bidirectional, format is arbitrary, and packets are not parsed by the NASDAT or displayed in MTS by default (however with enough lead time it's possible for MTS to display, for instance, swaths and profiles by request). To use this service an instrument sends from its primary address to its assigned ports on NASDAT, and receives from the NASDAT on the same port number, while the ground computer read or sends to the assigned URL on the web Server. In effect, the instrument thinks the NASDAT is the ground computer, and the ground computer thinks the ASP server is the instrument, except the ground computer has to strip or add the HTTP wrapper on the packet payload.

Keep in mind Iridium packet drops and blackouts and possible Inmarsat problems, so that serializing operations or depending on start/stop commands may allow misadventures. Also note that over Iridium, smaller packets give better results during poor conditions.

Instrument Control Notes

This section mostly applies to instrument control via UDP packets. Telemetered packets are usually dropped if corrupted due to the network frame checksums; corrupted packets have not been seen yet but should still be considered for critical applications. Because packets are often dropped and link outages are a frequent occurrence (a few minutes is fairly common, while longer outages happen occasionally) careful thought has to go into any control protocol design. Link activity timers and fail-safe modes should be considered. One method that has been proven to work well is to consider the instrument as a state machine, and include the entire desired state in each command packet to the aircraft, and the actual state in each packet to the ground, with a time-stamp or sequence number in both. Both sides send these packets at intervals regardless of any change, while discarding any packets received on either end that are too late or out of order. This avoids most potential problems and also ensures that any changes to the instrument state (including unexpected changes) or failed commands get reported to the ground, which can easily be seen by comparing the expected to the actual state. It's also a good idea to include a ground station identifier in uplink packets (or if communicating directly over Inmarsat instead of using the UDP user packet forwarding web service, inspect the source IP address) and implement an active controller time-out, so that only one ground station can be in control at a time. The idea here is that the instrument "latches" on the first controller, but after a timeout waiting for packets, is open to receiving commands from a new controller. This allows control by team members in different locations while preventing any confusion.

Network Hardware

A switch in each EIP provides quadraX connector ethernet ports, which is an aircraft ethernet standard and is very reliable. The quadraX cable is Tensolite NF24Q100, but on the ER-2 Cat6 ethernet cable is normally used, with a quadraX/Cat6 adapter stub at the EIP, and terminated at instruments with a standard RJ45. Instrument ethernet ports should be set for 100T, although GigE (for subsystem interconnect between payload bays) using two quadraX cables is possible if required.

Network Configuration

Aircraft network addresses are in the 10.x.x.x private domain. Experiments are assigned five contiguous static IP addresses (first is reserved for the instrument), and also five contiguous port numbers (first two for user packets, via Iridium and Inmarsat). Please note these assignments will change between missions/aircraft and should be configurable in the field.

Network: 10.9.1.0/24 (N809NA) or 10.6.1.0/24 (N806NA)
Instrument: 10.9.1.x or 10.6.1.x, assigned per instrument (x one of [100, 105, 110, ... 200])
Broadcast: 10.9.1.255 or 10.6.1.255
DNS Server: none (remove resolv.conf file or equivalent)
Router: 10.9.1.1 or 10.6.1.1 (or none, to avoid spurious costs; ssh and UDP still available)
NASDAT: 10.9.1.10 or 10.6.1.10
NTP server: 10.9.1.10 or 10.6.1.10, or listen for NTP broadcast on port 123
IWG1 Nav Data: broadcast UDP from NASDAT to port 7071
Status Packets: broadcast UDP from instruments to port 5100
User Packets over Iridium: unicast UDP to NASDAT on port 19000+x or 16000+x
User Packets over Inmarsat: unicast UDP to NASDAT on port 19001+x or 16001+x