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# Global Hawk

## Payload Network Communications Guide November 2008

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## 1 INTRODUCTION

Payload communication on the NASA Global Hawk (GH) aircraft is implemented using an ethernet network. An ethernet switch in each payload area provides a port for each instrument, plus spare ports. Various services are available on the network, including housekeeping data broadcast, global narrow-band and limited wide-band satcom, payload monitoring, message logging, a data storage and database Geographic Information System (GIS) server, and time synchronization. Wide band satcom routing and database services are provided by the Link Module system, and most other services are provided by the NASA Airborne Science Data Acquisition and Telemetry (NASDAT) system. Facility payload power control and operations monitoring is an independent function of the Master Payload Control System (MPCS).

Instruments are required to include an ethernet interface and, at a minimum, to participate in the payload monitoring system by providing a simple Comma Separated Value (CSV) status packet, which can optionally include parameters for the facility data streams and displays. Instruments are also required to implement Universal Time Coordinated (UTC) time synchronization via Network Time Protocol (NTP), IRIG-B, or GPS signal. Science mission project offices may also have other mission-specific science data communication requirements.

## 2 AIRCRAFT NETWORK

The aircraft network is a standard ethernet TCP/IP LAN using airworthy switches with 10/100T ports. Connections to the switches are made with standard RJ45 connectors which are held captive using MIL-DTL-38999 Series III connector shells.

It's recommended, but not required, that experiments use similar ruggedized RJ45 connector jacks on their instruments (the connectors are available from Amphenol Socapex, or similar "Industrial Ethernet" products from various vendors).

The cable is airworthy shielded Cat5 cable, with the shield terminated at the switch end. In some cases this cable will be provided to instrument owners by the Global Hawk Project Office. Contact the project office (Section 11, Contact Information) if you have any questions.

### 2.1 Aircraft Network Configuration

Aircraft network addresses are in the 10.x.x.x private domain. Instruments will be assigned static IP addresses and port numbers as needed, but please note that these assignments, and all other networking parameters, may well change and should therefore be configurable.

Routing of any direct connections to the ground via the wide band satcom link, when available, is done using Network Address Translation (NAT) by the Link Module which acts as the default router. Direct connections via the narrow band Iridium

satcom are not normally enabled; instead the NASDAT serves as a rate limiting, packet forwarding proxy server for all always-on low rate traffic.

## 2.2 Aircraft Network Configuration Parameters

The following are the aircraft network configuration parameters:

- Network: 10.3.1.0
- Net Mask: 255.255.255.0
- Broadcast: 10.3.1.255
- DNS: none (remove resolv.conf file or equivalent)
- Router: 10.3.1.1
- NASDAT: 10.3.1.10
- NTP: 10.3.1.10
- IP Address: 10.3.1.x (static address assigned for each instrument)
- Housekeeping Data: UDP from: broadcast/5000 (Section 3)
- Status Packets: UDP to: broadcast/5100 (Section 4)
- Iridium SatCom: UDP from/to: NASDAT/[assigned] (Section 6)
- Wide Band SatCom: TCP/IP via: Router (Section 7)
- Message Logging: UDP to: NASDAT/5200 (Section 5)

## 3 HOUSEKEEPING DATA DISTRIBUTION

Real-time housekeeping data is broadcast on the aircraft network by the NASDAT, as 1 Hz Universal Datagram Protocol (UDP) packets. The packet format is a simple ASCII CSV format named IWG1; please see Appendix A for the description. This format is supported on all the NASA and NCAR aircraft and replaces the legacy aircraft-dependent data formats which were generally available via a serial bus. Housekeeping data is acquired from various sources, including the aircraft's LN-100G IMU and the GH flight computer.

The IWG1 specification allows for additional parameters to be added at the end. Experimenters can request that data from their instrument status packets be appended to the IWG1 packets. This is typically only necessary if other instruments need it in real time, as instrument status packet data is telemetered to the Global Hawk Operations Center (GHOC) payload network for display purposes regardless.

Other data formats and different rates are readily available, including binary formats. For instance, imagers and scanners often require faster rates for real-time motion compensation. Additional aircraft parameters or calculated parameters (besides what's available in the IWG1 packet) may be available. The NASDAT makes creating custom formats straightforward, and automatically generates a metadata description

for those custom formats. Note that the legacy 1 Hz ASCII data formats can also be accommodated but their use is discouraged especially for new installations.

If a data stream besides the default IWG1 is desired, please contact the GH Project Office well before the instrument upload. If for some reason a legacy physical interface (not ethernet, but rather RS-232, ARINC-429 etc.) is required, please contact the GH Project Office as soon as possible to discuss the issue and possible alternatives.

Although the IWG1 format has accurate timestamps, use of a data feed to synchronize instrument clocks for data time stamping purposes is not considered good practice because of various latency issues. Instead instruments should use NTP, IRIG-B, or an internal GPS receiver. In all cases the time should be set to UTC time (not GPS time which is offset by many seconds). The goal is to have all instrument clocks on the aircraft synchronized to within 1 msec throughout the flight, which is generally easy to achieve with NTP on a switched LAN. It is understood that instruments with long sampling periods may not have a scientific need for such time accuracy.

#### **4 INSTRUMENT STATUS PACKETS (REQUIRED)**

Instruments on the NASA Global Hawk are required to provide a simple CSV instrument status packet. The purpose of this requirement is so that some amount of automated payload status monitoring can be performed, so that the Mission Scientist and Payload Operator can have situational awareness. This is particularly important on the GH where flights can have up to a 30 hour duration.

However, these status packets serve another useful purpose, which is to integrate instrument data into the facility data systems. UDP CSV packets have emerged as the preferred way to do this, and are becoming a standard method on all the platforms. By providing additional parameters beyond the minimum requirement of a timestamp and a status value, instrument data can be incorporated into the facility displays and data streams. Experimenters are encouraged to provide science data such as atmospheric tracers, and also to add engineering parameters for instrument health monitoring.

##### **4.1 Packet Format**

The packet format is almost identical to the IWG1 format described in Appendix A. Like the IWG1 format, it is a simple CSV ASCII format with a leading identifier, with comma separated values, and with the first value being a timestamp. The other status packet parameters are user defined except:

1. The second parameter shall be an instrument status code (defined below).
2. There shall be not more than 16 parameters total.

The other requirements are:

3. Rate is 1 Hz nominal, but any rate from 10 Hz to 30 seconds is acceptable.

4. Use “nan” or “” (adjacent commas) for bad or missing values (not 9999 or -9999).
5. Provide the GH Project Office with a description of the status packet including the leading identifier and parameter names; also the upper/lower limits and units if applicable.

#### 4.2 Status Code Value

The status code value is created by adding the following values, as appropriate:

- 1 = Ready
- 2 = Operating
- 4 = Calibrating
- 8 = Warning
- 16 = Invalid
- 32 = Failed
- 64 = reserved
- 128 = reserved
- 256 (and up) = User defined

Note that regardless of the status flags, all instrument status data is regarded as “preliminary uncalibrated data for real-time indication purposes only, and not for any postflight use without the Principal Investigator's prior permission”.

#### 4.3 Example Packet

An example packet would be:

```
“MLPPP,20081019T145530.133,3,-96.2707,nan,127,132.551\r\n”.
```

Note the leading identifier, the ISO-8601 timestamp with milliseconds resolution, the status code of “3”, and the use of “nan”. The trailing <cr><lf> is optional.

#### 4.4 Packet Processing

Some background information on how these status packets are processed:

- The NASDAT merges them, and transmits as binary 5 sec packets via Iridium, and records on board at 1 Hz.
- The Link Module also records these status packets.
- The MPCS checks packet heartbeat, timestamp accuracy and status code, and reports problems.
- The MPCS also checks and telemeters Experiment Interface Panel (EIP) status, volts, amps, and payload bay temperatures.

- The GHOC servers can display and/or restream this data to experimenter workstations.
- The NASDAT provides an XML metadata server for all the instrument status packets, although notionally the instruments themselves should provide this in the long term future.

## 5 TEXT MESSAGE LOGGING SERVICE

Text messages can be recorded as part of the data system flight logs, and also telemetered to the ground where they will be seen in an IRC chat window. Instruments that generate event or error messages can use this service. Messages should be of reasonable size and infrequent to preserve Iridium bandwidth.

There are two ways to use this service. The first is to simply use the Unix syslog service on the NASDAT with facility of LOG\_LOCAL3 and severity LOG\_INFO or LOG\_ERR. The second way is to send a UDP packet, with the ASCII text message payload, to the NASDAT message logging port.

## 6 LOW RATE PACKET FORWARDING

The NASA Global Hawk may be outside of wide-band satcom range for long periods. A limited amount of worldwide bandwidth is made available via four bonded Iridium modems operated by the NASDAT system, giving a nominal 9600 bps bandwidth. Instrument traffic on this link shares bandwidth with the housekeeping and the status packet telemetry data. While this link does provide a path for instrument communication, it needs to be carefully managed, and is easily overwhelmed by excess traffic. For this reason the NASDAT does not normally serve as a simple router, but instead functions as a rate-limiting packet forwarding proxy server.

### 6.1 Packet Forwarding Mechanics

To use this service, instruments send UDP packets to a specified NASDAT port, which are then sent by Iridium to the GHOC modem server, which sends them to the experimenter's workstation located in the GHOC. For the reverse path experimenters send UDP packets to a port on the GHOC modem server. Different ports are used for each instrument. Users can expect to be rate-limited to one UDP packet every 10 seconds in both directions, with extra packets quietly dropped. Some packets will also be dropped occasionally due to Iridium issues. Packet contents should normally be no larger than 550 bytes. Please note that binary or compressed packet contents will help maximize mission bandwidth.

### 6.2 Packet Forwarding Configuration

From the experimenters perspective the packet forwarding scheme looks like this:

```
exp1:  udp://instrument1/10001    <=>    udp://NASDAT/10001    and
      udp://modemserver/10001    <=>    udp://workstation1/10001
```

exp2: udp://instrument2/10002 <=> udp://NASDAT/10002 and  
udp://modemserver/10002 <=> udp://workstation2/10002

The instrument sees the NASDAT as the workstation, and the workstation sees the GHOC modem server as the instrument. Note that the NASDAT firewalls and rate-limits the downlink, and the modem server firewalls and rate-limits the uplink.

### 6.3 Notes on Packet Forwarding Services

This service is separate from the instrument status packets, and is considered ad-hoc since the GH facility does not know or care what the packet contents are. This can be useful when instrument communication needs to be bidirectional (for instance, command and control), or the data is not suited for the status packet due to quantity or format (for instance, profiles, imagery, or proprietary binary formats). Please provide the GH Project Office with an estimate of packet size and rate when planning to use this service.

One particularly encouraged use of this low rate packet service is to drive experimenter's custom displays. Data down-linked via this method can be displayed on experimenter's workstations, and that display can be shared around the GHOC or on the web if wanted. This gives a method to have world-wide always-on real-time displays from the aircraft, for instrument data that does not fit in the scheme of the GHOC project-provided displays based on the housekeeping and instrument status packets.

When the aircraft is inside the wide-band satcom footprint, normal TCP/IP communications are possible, and so this rate-limited UDP scheme is not then strictly necessary. However please note that the same UDP packets can be routed at higher rate through the Link Module directly to the experimenter's workstation; or the low rate UDP data can be left running while taking advantage of the standard networking and GIS database services of the Link Module.

## 7 WIDE BAND SATCOM NETWORKING (LIMITED RANGE)

Higher bandwidth communications are available when the aircraft is within the wide band satellite footprint. The geographical extent of coverage may vary from mission to mission, depending on which system is installed on the aircraft, and on the service provider. The available bandwidth is anywhere from 56Kbps for basic Inmarsat service, up to 50 Mbps, depending on the implementation of a Ku system.

The Link Module system acts as the router between the aircraft and GHOC networks. All standard ports are open, so all standard network protocols can be used, similar to when the aircraft is in the hangar and connected by wire. Packet rates are not limited at the present time, but experimenters should exercise caution to avoid their instrument causing any inadvertent denial of service attack.

The Link Module also provides data recording and GIS-enabled SQL server capabilities. In most cases, it will be more productive if an experiment constantly stores data on the Link Module while airborne, so that GIS queries can be made for

specific ROI or other interesting data, rather than to simply begin sending the current data when the aircraft comes back into range.

## **8 DATA CAPTURE, STORAGE, AND DATA BASE SERVICES**

The Link Module system acts as the on-board file server and database as well as the wide-band router. Instruments can use it for backup storage of data, but also for caching of flight data for requests from the ground. With this approach, bandwidth is optimized since large data products or high-resolution data slices can be downlinked on request for regions or time periods of interest.

Files can be written using ftp, nfs or samba; streaming data can also be stored using packet capture. A GIS enabled PostgreSQL server will accept SQL writes and queries. On-board algorithms can perform real time georectification and registration of data products for inclusion in GIS style displays. Access to the Link Module from the ground is via ftp, http, and SQL queries.

Details of the Link Module interfaces continue to be refined. Please contact the GH Project Office if you would like to use this feature.

## **9 GROUND NETWORK CONFIGURATION**

The GHOC network is a standard ethernet switched LAN, in the 10.x.x.x private domain, on a separate subnet from the aircraft LAN. All standard network services such as DHCP, DNS, and NTP are provided. Access to the internet is provided using NAT through the DFRC IT firewall, with no special restrictions. RJ45 jacks are provided for experimenter network connections, and space is provided for both tower PCs and notebook computers. Project display/application computers are also provided at each experimenter workstation in the GHOC, along with access to a VOIP phone.

Network configuration information will be provided on arrival at the GHOC. In some cases, experimenters may want to request a static IP address for operational purposes.

The GHOC network is also extended to the GH hanger, and to the staging ramp for GH preflight. While on the ground, either in the hangar or at the staging ramp, the aircraft network is connected to the GHOC network via copper wire and a router (not the default internet router). While in the air the wide band connection is made via a GHOC router, and the Iridium connection is made by a modem bank located at DFRC. In any case, no access to the aircraft LAN is allowed from outside the GHOC LAN.

## **10 GROUND DATA SERVICES**

Services on the GHOC network include:

- Project provided web displays: parameters, track plot, strip charts, video images.
- Project provided blade server workstations for displays and general use.
- Project provided displays on wall monitors in the GHOC and hangar.

- Experimenter provided display sharing via video servers and/or a video switch.
- UDP data streams (housekeeping IWG by default, and others on request).
- Connectivity to the aircraft as described in the above sections.
- RBNB server for “munged URL” access to live data.
- Google Earth flight data server (CDE/RTMM/RBNB).
- IRC server for text chat and aircraft messages.
- file server for ftp/http file sharing and post-flight data distribution.
- Data server external to DFRC firewall for external flight data access and viewing.
- Advanced tools from NASA Ames Research Center (ARC): a collaborative environment is planned to include:
  - Harmonized variant of RTMM and CDE with data from either ARC or MSFC mirrors.
  - GIS data delivery system capable of on-the-fly reformatting and geographic reprojection.
  - GIS enabled online PostgreSQL database.
  - Visualization facilities including Google Earth, Browser, and GIS tools.
  - XMPP (Jabber) server with unlimited access.
  - Real Time MPEG4 (h.264) video feed, and links to open source viewers.
  - All these leverage current infrastructure developed for the Ikhana/WSFM campaigns.

## 11 NASA GLOBAL HAWK PROJECT OFFICE – CONTACT INFORMATION

If you have any questions on the NASA Global Hawk Payload System, please contact the NASA DFRC Global Hawk Project Office:

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## 12 LIST OF ABBREVIATIONS AND ACRONYMS

ARC	NASA Ames Research Center
ASCII	American Standard Code for Information Interchange
CDE	Collaborative Decision Environment
CSV	Comma Separated Value
DFRC	NASA Dryden Flight Research Center
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name Service
EIP	Experiment Interface Panel
GH	Global Hawk
GHOC	Global Hawk Operations Center
GIS	Geographic Information System
GPS	Global Positioning System
IP	Internet Protocol
IMU	Inertial Measurement Unit
IRC	Internet Relay Chat
IRIG-B	Inter-Range Instrumentation Group time code format B
IWG1	Interagency Working Group standard format number 1
LAN	Local Area Network
MPCS	Master Payload Control System
MPEG4	Motion Picture Experts Group standard format 4
MSFC	NASA Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NASDAT	NASA Airborne Science Data Acquisition and Telemetry system
NAT	Network Address Translation
NCAR	National Center for Atmospheric Research
NTP	Network Time Protocol
RBNB	Ring Buffered Network Bus
ROI	Region of Interest
RTMM	Real Time Mixed Media
SQL	Structured Query Language
TCP	Transport Control Protocol
UDP	User Datagram Protocol
UTC	Universal Time Coordinated
VOIP	Voice Over IP
VPN	Virtual Private Network
XML	eXtensible Markup Language
XMPP	eXtensible Messaging and Presence Protocol

## **APPENDIX A. The IWG1 Format**

The Interagency Working Group standard format number 1 (IWG1) format is a simple ASCII CSV format which is transmitted as the content of an UDP packet at 1 Hz. It is designed to provide a common aircraft housekeeping data format which will replace all the various legacy formats on the different aircraft. It is already in wide use on the NASA and NCAR platforms. Typically the legacy formats are still available, but use of the IWG1 format is highly encouraged, especially for new installations.

**Appendix B** describes the Inter-Agency Working Group Airborne Data and Telemetry Systems (IWGADTS) definition of the IWG1 format. It is provided on the following pages for convenience. For the most recent official copy, please refer to the

[http://www.eol.ucar.edu/raf/Software/iwgadts/IWG1\\_Def.html](http://www.eol.ucar.edu/raf/Software/iwgadts/IWG1_Def.html)

## APPENDIX B. IWG1 ASCII Packet Definition

The following information is from:

[http://www.eol.ucar.edu/raf/Software/iwgadts/IWG1\\_Def.html](http://www.eol.ucar.edu/raf/Software/iwgadts/IWG1_Def.html)

(Last update: Tue Oct 9 07:05:56 MDT 2007)

- String will be prefaced with IWG1 as the magic-cookie to identify this stream.
- The date-time (UTC) field will use **iso-8601**, any of the following **iso-8601** forms is acceptable:
  - yyyy-mm-ddThh:mm:ss
  - yyyy-mm-dd hh:mm:ss
  - yyyymmddThhmmss
- Omitted time-zone shall be interpreted as UTC. This deviates from the 8601 specification requiring "Z" or "UTC" descriptors. Other forms of times specified in ISO-8601 [may be acceptable|are not considered conforming to this definition].
- Values will be comma separated. This will allow for little loss of bandwidth for missing values.
- Data values other than date will be in any format acceptable to the ANSI C string-to-double function **strtod(3)**.
  - Recommend to implementors to use appropriate significant figures.
  - inf and nan are acceptable.
  - Fields not supplied or available will be left empty (e.g. '...,4.523,,48.234,...').
- String will be terminated by `\r\n` (carriage return, newline).

---

### Example Format

IWG1,yyyy-mm-ddThh:mm:ss,value,value,value,,value\r\n

IWG1,yyyymmddThhmmss,value,value,value,,value\r\n

### Example String

IWG1,20010920T145530,15.7738,-  
96.2707,137.462,,132.551,19971.1,12.725,13.1574,24.6281,0.00140888,0.0235585,2  
58.411,258.348,0.138373,0.838461,0.492826,0,0,29.7952,20.2783,29.8763,998.294,0  
.984893,996.779,0,0,0,0.910509,0.660288,,\r\n

---

### Parameter List

The list of variables will be fixed in the following order, these are all platform 'best' values. Custom parameters may be added **at the end** of this list on a per platform then per deployment basis.

Short Name	Units	Description
Date/Time	UTC	ISO-8601 formatted date and time
Lat	degree_N (dec)	Platform Latitude
Lon	degree_E (dec)	Platform Longitude
GPS_MSL_Alt	m	GPS Altitude, Mean Sea Level (MSL)
WGS_84_Alt	m	WGS 84 Geoid Altitude
Press_Alt	feet	Pressure Altitude
Radar_Alt	feet	Radar Altimeter Altitude
Grnd_Spd	m/s	Ground Speed
True_Airspeed	m/s	True Airspeed
Indicated_Airspeed	knots	Indicated Airspeed
Mach_Number		Aircraft Mach Number
Vert_Velocity	m/s	Vertical Velocity
True_Hdg	degrees_true	True Heading
Track	degrees_true	Track Angle
Drift	degrees	Drift Angle
Pitch	degrees	Pitch
Roll	degrees	Roll
Side_slip	degrees	Side Slip
Angle_of_Attack	degrees	Angle of Attack
Ambient_Temp	degrees_C	Ambient Temperature
Dew_Point	degrees_C	Dew Point
Total_Temp	degrees_C	Total Temperature
Static_Press	mbar	Static Pressure
Dynamic_Press	mbar	Dynamic Pressure (total minus static)
Cabin_Pressure	mbar	Cabin Pressure / Altitude
Wind_Speed	m/s	Wind Speed
Wind_Dir	degrees_true	Wind Direction
Vert_Wind_Spd	m/s	Vertical Wind Speed
Solar_Zenith	degrees	Solar Zenith Angle
Sun_Elev_AC	degrees	Sun Elevation from Aircraft
Sun_Az_Grd	degrees_true	Sun Azimuth from Ground
Sun_Az_AC	degrees_true	Sun Azimuth from Aircraft