DC-8 Experimenter Communications Guide, v1.4 Draft

David Van Gilst
NSRC Lead Systems Engineer

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Contents

1 Basic Networking

1.1 Wired Ethernet Connections

The DC-8 Housekeeping System provides an onboard ethernet network consisting of 8 port industrial switches located every 15-20 feet throughout the cabin. Each of these switches provides 7 100 MB/s (FastEthernet) ports for accessing aircraft resources over a 1 GB/s network backbone. A single 1GB/s port is available at each switch for instruments with higher data volume requirements.

Figure 1: Network Switch Box

Figure 2: 4 Port Switch

Rack mountable 4 Port Ethernet switches are available for instruments which require large numbers of ethernet connections between components.

Attachment to the DC-8 network is via a standard RJ-45 plug and Cat-5 or above cabling. Due to recent changes in NASA Armstrong policy, ethernet connections are required to use a cable with a low-smoke zero halogen (LZSH) jacket. These cables are available upon request from the DC-8 Avionics and Housekeeping teams. If you wish to procure your own, we recommend purchasing a Cat-6 Sheilded LZSH cable assembly from L-Com. They can he found here: http://www.l-com.com/ethernet-shielded-cat-6-cable-assemblies

If connections faster than 100MB/s are needed between components of an instrument, we recommend using a separate, faster switch within the instrument rack and attaching to the aircraft network at a single point. If your instrument rack does incorporate an ethernet switch, please coordinate with NSRC staff to ensure that this is appropriately incorporated into the overall network.

Figure 3: Rack Mountable Switch and RS-232 Converter

Figure 4: DC-8 LZSH Patch Cable

1.2 Wireless Network Connections

In addition to the Wired Network, the DC-8 provides access to all network services by way of of an 802.11ac Wifi network. This network is available on both the 2.4 Ghz and 5 Ghz Wi-Fi bands. The system is back compatible with all 802.11 standards from b through ac, and should work with all standard wifi devices including phones, tablets and laptops.

Due to IT Security concerns, a WPA2 password is required for access to this network. The password for each project will be provided to experimenters at the time of their arrival for the project.

Although the Wi-Fi network provides considerable convenience for the operation of tablets and laptops without being tethered to a network cable, it is recommended that instruments and other equipment for which continuous connectivity is critical be attached via wired network.

1.3 IP Addressing

The DC-8 Experimenter network uses a single, private class C (/24) IPv4 address range. No IPv6 network services are currently enabled onboard the DC-8.

Instruments and other equipment for which connectivity is critical should be assigned static IP Addresses within this range. Please contact the data system staff to receive static IP address assignments for a given campaign.

When configuring for a static IP address, please use the following settings:

- IP Address: As assigned.
- Subnet Mask: 255.255.255.0
- Default Gateway: 10.1.1.1
- DNS / Nameserver: 10.1.1.1

PLEASE NOTE: Although we will do our our best to accomodate requests to retain the same IP address assignments between campaigns, this is not guaranteed, particularly for fuller missions.

2 Timing Services

The DC-8 is equipped with redundant time sources. Both timeservers use GPS as a time source, with an internal TXCO oscillator maintaining the time if the gps signal is interrupted during flight. Recent upgrades have reduced our signal acquisition time and good time is generally available within 1-2 minutes of housekeeping system startup. From these two servers, we provide both the NTP Time service over Ethernet and an IRIG-B Timecode.

Please note that although GPS is the timing source for all timestamps used within the DC-8 data system, the times reported are in UTC or "Zulu" time. As of the writing of this document there is an 18 second difference between UTC and GPS second-of-week, and this will increase every time that a leap second is declared. This can result in a discrepency when comparing time derived from some GPS receivers to the housekeeping system.

2.1 Using NTP

The NTP protocol version 4 is defined by the Internet Engineering Task Force RFC 5905 and is widely supported by most computing devices as a method of synchronizing system clocks over ethernet . The specifics of how you configure your device will vary by operating system.

As the round trip time on the aircraft net work is significantly sub-millisecond, NTP times can be safely assumed to be accurate to within a millisecond.

The DC-8 has two ntp servers available:

- 10.1.1.5 - This is the primary time server. If only one server may be specified in your system, this is the one that should be used.
- 10.1.1.4 - This is the secondary time server. If multiple servers can be provided, both of these should be provided.

2.1.1 Windows

Although Windows does have native support for setting your clock from "Internet Time", this service has historically been a bit limited in it's configuration options. Consequently, we recommend using the Meinberg NTP server software, which can be downloaded https://www.meinbergglobal.com/english/sw/ntp.htm:

When configuring ntpd, the -G and -g options should be used to start the Daemon; This will cause the time to be set immediately when the ntp daemon starts, rather than "slewing" the clock.

2.1.2 Linux

Most Linux Distributions will include some version of the venerable ntpd.

When configuring ntpd, the -G and -g options should be used to start the Daemon; This will cause the time to be set immediately when the ntp daemon starts, rather than ”slewing” the clock.

2.1.3 Other

Other systems may have their own methods of supporting NTP. Please consult your manufacturers documentation.

2.2 Using IRIG-B

In addition to the NTP Time service, an IRIG-B Timecode signal is provided through BNC Connectors at each DC-8 network interface box. The variant provided is specifically IRIG-B 123. This corresponds to:

- Sine Wave Modulation
- 1 KHz Carrier Frequency
- BCD and SBS data encoding.

Additional information on IRIG-B can be located at:
https://en.wikipedia.org/IRIG_timecode

2.3 Other Timecodes

Other timing options including NMEA and Pulse-Per-Second (PPS) are available upon request. Please consult with data system staff prior to integration if you require an alternate timing signal, as some additional wiring may be required.

3 Housekeeping Data

The DC-8 data sstem can provide a wide variety of housekeeping parameters, including local meterological conditions, Aircraft performance parameters, and cabin conditions. These parameters can be made available in a wide variety of rates and formats both in real-time and post flight.

3.1 UDP Data Distribution

In the standard configuration, the DC-8 provides all housekeeping data via UDP Broadcast on the onboard network. Non-standard products may be unicast to a specific instrument.

3.2 Serial Data Distribution

For instruments that require a RS-232 or RS-422 data feed, a small converter box will be attached to the rack. This box can provide standard serial feeds at speeds from 300 baud up to 115200. No power is required aside from the incoming ethernet feed.

3.3 Other Data Distribution

If you require another format (ARINC-429, Mil-Std-1553 or other custom digital or analog format) please contact the data systems staff well before integration, as these options require extensive configuration.

3.4 IWG1

The IWG1 data format is an inter-agency standard used aboard research aircraft for the distribution of 33 commonly used real-time parameters, primarily related to local meterological conditions, position and aircraft attitude. The IWG1 Packet Columns can be found in Appendix A.

For FireEx, it will be available at 1 and 10Hz. The IWG1 feed can be received either as broadcast UDP Packets on port 7071(1Hz) and 7072(10Hz), or via the Status Packet API described in Appendix B.

3.5 ChemWAD

Starting with the ATOM Campaigns, the DC-8 has provided a supplemental feed known as the ChemWAD. This 1Hz data stream consists of the 33 columns from the IWG1 data stream, followed by 1 or more mission specific parameters contributed by the experimenter instruments.

3.5.1 Change Control

The precise format of this data stream is likely to change throughout the campaign, subject to the following rules:

- All changes will consist of appending additional parameters to the end of the stream.
- No changes will be made day of flight.

3.5.2 Column Headers

A comma separated file containing the headers for each column will be provided:

- Onboard the Aircraft: http://10.1.1.1/usefulfiles/Chemwad-Header.csv
- On the ground: https://asp-interface.arc.nasa.gov/usefulfiles/N817NA-Chemwad-Header.csv

The ChemWAD is distributed via UDP Broadcast on port 5104, or via the Status Packet API described in Appendix B.

3.5.3 Data

The ChemWAD Data is available via two methods:

- Onboard the aircraft, it is broadcast on UDP port 5104.
- Onboard the aircraft *and* on the ground, the ChemWAD data is available via the API at the following links:

  Aircraft: http://10.1.1.1/API/parameter_data/N817NA/ChemWAD
  Ground: https://asp-interface.arc.nasa.gov/parameter_data/N817NA/ChemWAD

  These links behave according to the API described in Appendix B.

3.6 DC8 Legacy Format

The legacy DC-8 Housekeeping format is broadcast on port 5101. We continue to broadcast this format in support of legacy software, however, no new software development should be dependent on this message format.

4 Instrument Data

Real-time instrument data is provided to the housekeeping data system for onboard display and telemetry to the ground via a number of methods. For timeseries data, consult Appendix B, the Status Packet protocol. Other options include providing quicklook images, and non-standard data formats. Please contact the data system staff for your mission if you plan to contribute quick look data for a mission.

5 Instrument Command and Control

The NSRC Data system provides a number of opportunities for remote command and control, both from within the aircraft and from the ground. The most common method of remote command and control is a modified version of the Global Hawk "User Packet" mechanism, described in Appendix C.

If you wish to take advantages of services for remote monitoring or command and control of your instrument, or the protocol in Appendix C does not meet your requirements, please contact the NSRC Data systems team as soon as possible.

6 Webdisplay Services

The NSRC data system provides a variety of situational awareness tools onboard the DC-8 at http://10.1.1.1, including:

- A moving map based on the OpenLayers javascript library and the Open Streetmaps data set. Flight track and flight plan information will always be made available via this map; Additional data such as satellite overlays can be included on upon request.
- A table of parameters will be provided listing curent values for aircraft parameters and timeseries data provided by experimenters.
- Quicklook products from onboard instruments, such as LIDAR curtain plots.
- Video feeds for forward and nadir facing cameras.

These tools are best accessed via a reasonably modern version of the Chrome or Firefox web browsers. Not all services will work in older browsers or browsers derived from internet explorer.

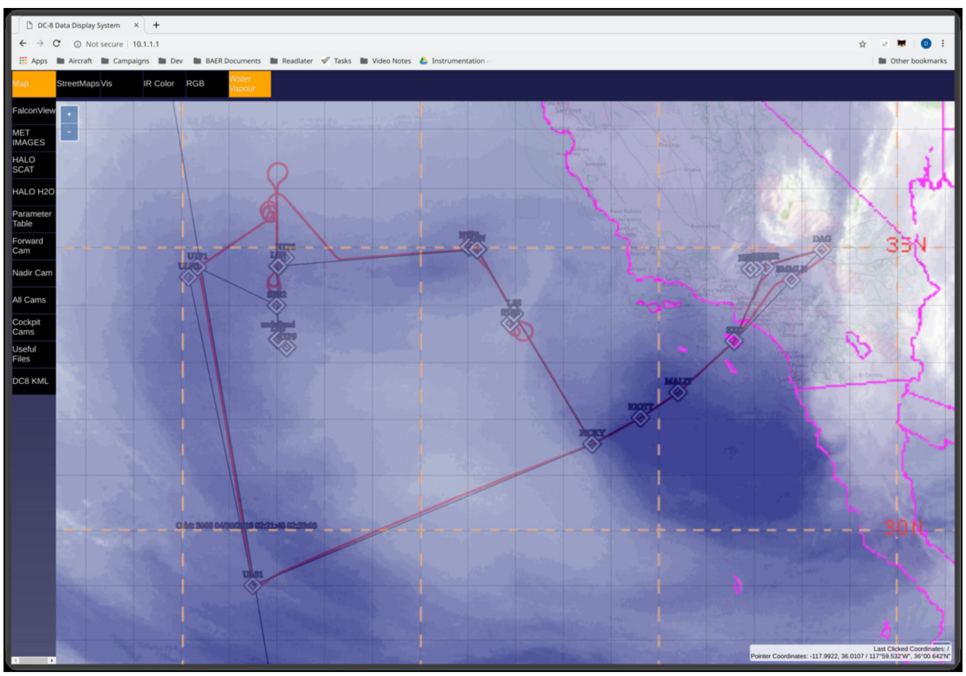


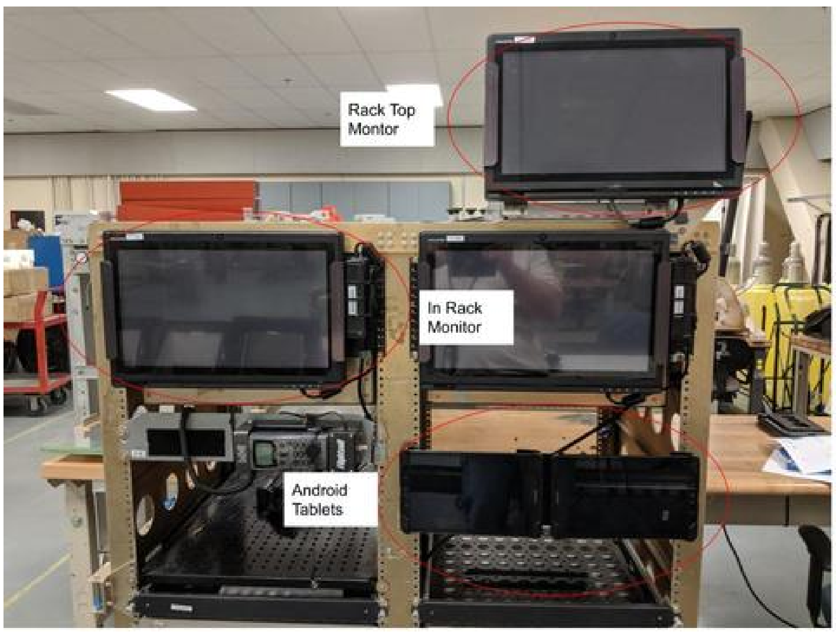
Figure 5: DC8 Map with Water Vapour map overlay.

6.1 Touchscreen Displays

The DC-8 project has available a number of rackmountable touchscreen displays that can be used to provide additional situational awareness. These comes in two varities.

The first, a 15 inch industrial PC can be mounted either on top of or on the front of any of our experimenter racks.

The second option is an Android Tablet with a provided mount. These can be mounted singly or side by side on a 3U plate, or can be mounted to other mounting solutions has required.



Touchscreen Option	Weight	Rack Height
Rack Top Monitor	16.5 lbs	NA
In-Rack Monitor	11.5 lbs	7" / 4U (Mounting Plate)
Side-By-Side Tablets	4 lbs	5.25 / 3U (Mounting Plate)
Single Tablet	1.5 lbs	Mounting Dependent

7 IRC / X-Chat

Text communications to the ground are provided via our IRC based "X-Chat" system.

Further details including configuration instructions for most common platforms can be found here:

8 Appendix A: IWG1 Columns

Example:

IWG1,2018-10-18T19:02:05.003, -81.720771790, -22.953014374, 1901.0, 1901.0, 7681.0, 1836.5, 140.4, 138.5, 253.7, 0.438, -512.0, 348.29, 345.8, -2.7, 1.08, -0.77, , , -24.2, -74.4, -14.8, 761.8, , 958.2, 8.7, 100.2, , 79.7, 10.7, -87.5, -75.8

Additional historical IWG1 data for the DC-8 and other platforms can be found at asp-archive.arc.nasa.gov.

Table 1: IWG1 Parameters

Position	**Name**	**Units**	**Notes**
1	IWG1		IWG 1 Text
2	Timestamp	Seconds	ISO Timestamp (2019-01-02T03:04:05.006)
3	Latitude	Degrees North	Provided from LN-251 EGI
4	Longitude	Degrees East	Provided from LN-251 EGI
5	GPS Altitude	Meters From Sea Level	Provided from LN-251 EGI
6	GPS Altitude	Meters Above WGS84 Geoid	Provided from LN-251 EGI
7	Pressure Altitude	Feet Above Sea Level	Derived from ADC-85
8	Radar Altitude	Feet above Ground Level	Derived from APN-232
9	Ground Speed	m/s	Provided from LN-251 EGI
10	True Airspeed	m/s	Provided from ADC-85
11	Indicated Airspeed	knots	Provided from ADC-85
12	Mach Number		Provided from ADC-85
13	Vertical Velocity	m/s	Provided from LN-251
14	True Heading	Degrees (0 to 360)	Provided from LN-251
15	Track Angle	Degrees (0 to 360)	Provided from LN-251
16	Drift Angle	Degrees (0 to 360)	Provided from LN-251
17	Pitch Angle	Degrees (-90 to 90)	Provided from LN-251
18	Roll Angle	Degrees (-90 to 90)	Provided from LN-251
19	Side Slip Angle	Degrees	Not Present
20	Angle of Attack	Degrees	Not Present
21	Ambient Temp	Degrees C	Provided from ADS-85
22	Dew Point	Degrees C	Provided by Buck 3-Stage
23	Total Temp	Degrees C	Provided by ADS-85
24	Static Pressure	Millibars	Provided by ADS-85
25	Dynamic Pressure	Millibars	Not Present
26	Cabin Pressure	Millibars	
27	Wind Speed	m/s	Derived from LN-251 and ADS-85 Data
28	Wind Direction	Degrees (0 to 360)	Derived from LN-251 and ADS-85 Data
29	Vert Wind Speed	m/s	Not Present
30	Solar Zenith	Degrees	
31	Sun Elevation AC	Degrees	
32	Sun Azimuth Gnd	Degrees	
33	Sun Azimuth AC	Degrees	

9 Appendix B: The Status Packet Protocol

9.1 Status Packets

The primary method of providing time-series data to the DC-8 data system is through the transmission of Status Packets.

9.1.1 Format

Status packets are a simple CSV string formatted nearly identically to the IWG1 packet described in Appendix A. The columns are defined as follows:

- The first item should be an instrument identifier, such as NOAA_SO2
- The second item should be an ISO Timestamp. Most programming languages support some form of the strftime function; This timestamp can be produced from strftime with a format of "%Y-%m-%dT%H:%M:%S.%f", although not all implementations of strftime will support the %f for fractional seconds. In this case, it is best to omit the fractional seconds so long as the data rate is 1 Hz or less.
- The third item is an optional "Status Code" Value. This value, if defined should be a bit field, defined as follows:
  - Bit 0 - Ready
  - Bit 1 - Operating
  - Bit 2 - Calibrating
  - Bit 3 - Warning
  - Bit 4 - Invalid
  - Bit 5 - Failed
  - Bit 6 - Reserved
  - Bit 7 - Reserved
  - Bit 8+ - User defined
- Remaining values

  This Status byte was defined with unmanned operations in mind, and several of the bits are less relevant in a manned environment; However the ability to flag calibration or other invalid data is very helpful in the context of data display if it can be provided.
- Remaining values should be float or integer values as defined by the user. As the DC-8 is less restricted than the Global Hawk, more than 16 values may be used. If a value is invalid, it is strongly preferred that the value be set to 'nan' before transmission. If a value is missing,

Examples:

- ISAF,2017-09-11T17:53:40.500888,2,125.30,0.53,0.25,1.03,3.61
- NOAA_SP2,20170911T180408,3,0.000,0.250,2.363
- UCATS,20170911T175701,01,-000.6,nan,nan,nan,nan

9.1.2 Transmission

Status packets conforming to the above standard should be broadcast as UDP Packets to 10.1.1.255 on port 5100.

If you have a packet that cannot be made to conform to the format above, please consult the DC-8 data system staff for delivery details. In most instances, we will ask that you send the packet on a different port and we will develop an alternative ingest.

9.1.3 HTTP API

When onboard the aircraft, you can receive status packets being broadcast by your instrument and others on port 5100. This method has two major limitations:

- Broadcast packets can only be received within the same local area network (Onboard the aircraft).
- There is no capability to retreive historical information, packets can only be received at the time that they are sent.

In order to work around these limitations, the NSRC data system provides a Web-based API for the retreival of Status Packet data on the aircraft and on the ground. This API is relatively simple, and should be easily accessible in most programming environments.

URL Structure All of the status packet operations provided by the API utilize the same URL structure:

https://*server*/API/parameter_data/N817NA/*instrument_id*

server should be substituted for the server you're accessing

- 10.1.1.1 onboard the DC-8
- asp-interface.arc.nasa.gov for ground access.

instrument_id should be the label of the packet you're looking to retreive. Usually this will be the first item in the packet. For example. IWG1 data is retreived using the IWG1 label, while SP2 data is accessed as NOAA_SP2.

Retreiving Most Recent Packet In order to retreive the most recent packet, simply GET the URL. As an example, copy the following URL to your web browser to see the latest IWG1 packet from the DC-8.

https://asp-interface.arc.nasa.gov/API/parameter_data/N817NA/IWG1

Note that this may return a blank page at some times if the aircraft is not currently flying.

Retreiving a Range of Packets

In addition to retreiving the most recent packet, the API can be used to retreive the a range of packets by specifying a start and end time. This start and end time will be determined using the timestamp embedded in the packet, so it is important that instruments report their time correctly for this functionality. This is done by providing a pair of optional parmeters, Start and End. The Start and End each take a timestamp as a value, either an ISO Timestamp (in the format of the IWG1 Packet) or an integer number of seconds from Midnight, Jan 1 1970.

These can be provided either as part of the URL as an HTTP GET or as HTTP Post variables. Either method works equivalently, but the examples below will use GET for clarity.

All Packets from Start of Flight To get all packets from the start of the flight, use a START value of Jan 1, 1970. As all packets are cleared between flights, this will retreive all available packets for this flight.

https://asp-interface.arc.nasa.gov/API/parameter_data/IWG1?Start=0

Retreiving Packets After a Specific Time To get all packets after a specific time, use your desired start time. For instance, to incrementally load a given data stream, this is as simple as using the timestamp from the last packet. If the last IWG1 packet that was 2018-10-18T19:02:05.003, the following URL would return all packets from this time to the present:

https://asp-interface.arc.nasa.gov/API/parameter_data/IWG1?Start=2018-10-18T19:02:05.003

Retreiving Packets In a Specific Time Range To get all packets in a specific time range, use your desired start time and end time. The following URL would retreive all packets between 1 and 2 AM, UTC.

https://asp-interface.arc.nasa.gov/API/parameter_data/IWG1?Start=2018-10-18T01:00:00.000&End=2018-10-18T02:00:00

10 Appendix C: The User Packet Protocol

ChemWad

10.1 User Packets

The User Packet mechanism is somewhat altered on board the DC-8 from it's original Global Hawk form, due to differences in network architecture. For purposes of this document, "User Packets" refer to free-form UDP packets sent to an assigned IP and Port onboard the DC-8 aircraft for telemetry to the ground. We do not have a strict size limit, but in general these should be restricted to no more than 10k. There is no assigned format for these packets, and they are transmitted through the telemetry system without parsing or modification.

10.2 Transmission

Each user packet configuration will have the following information:

- A URL for Ground Side Access. This URL can be used to both retreive and transmit packets from the DC-8 using the protocol outlined below.
- A port number on the aircraft for the instrument to transmit user packets to. User packets are unicast to this port number on IP Address 10.1.1.1 for transmission to the ground.
- Optionally, a port number on the aircraft at which the instrument will receive packets. User packets from the ground will be unicast to this Port on the instrument IP.

10.3 HTTP API

10.3.1 Packet Retreival (Instrument to Ground)

The User Packet mechanism as originally employed in the NASA Global Hawk communications model relied on instrument command and control occuring from a single local area network on which UDP packets could be freely transmitted. This model breaks down somewhat for aircraft that do not have a designated control facility. In order to work around this limitation, the NSRC data system provides a Web-based API for the retreival of User Packet data on the aircraft and on the ground. This API is relatively simple, and should be easily accessible in most programming environments.

URL Structure All of the status packet operations provided by the API utilize the same URL structure:

https://*server*/API/binary_packet_data/N817NA/*instrument_id*

server should be substituted for the server you're accessing

- 10.1.1.1 onboard the DC-8
- asp-interface.arc.nasa.gov for ground access.

instrument_id should be the label of the packet you're looking to retreive. This will be provided by the NSRC data system staff.

Retreiving Most Recent Packet
In order to retreive the most recent packet, simply GET the URL. As an example, copy the following URL to your web browser to see the latest INSTRUMENT packet from the DC-8.

https://asp-interface.arc.nasa.gov/API/binary_packet_data/N817NA/INSTRUMENT

Note that this may return a blank page at some times if the aircraft is not currently flying.

Retreiving a Range of Packets
In addition to retreiving the most recent packet, the API can be used to retreive the a range of packets by specifying a start and end time. These times will be based on the time of packet receiption. This is done by providing a pair of optional parmeters, Start and End. The Start and End each take a timestamp as a value, either an ISO Timestamp (in the format of the IWG1 Packet) or an integer number of seconds from Midnight, Jan 1 1970.

These can be provided either as part of the URL as an HTTP GET or as HTTP Post variables. Either method works equivalently, but the examples below will use GET for clarity.

All Packets from Start of Flight To get all packets from the start of the flight, use a START value of Jan 1, 1970. As all packets are cleared between flights, this will retreive all available packets for this flight.

https://asp-interface.arc.nasa.gov/API/binary_packet_data/SP2_FULL?Start=0

Retreiving Packets After a Specific Time To get all packets after a specific time, use your desired start time. If the last SP2_FULL packet that was received was 2018-10-18T19:02:05.003, the following URL would return all packets from this time to the present:

https://asp-interface.arc.nasa.gov/API/binary_packet_data/SP2_FULL?Start=2018-10-18T19:02:05.003

Retreiving Packets In a Specific Time Range To get all packets in a specific time range, use your desired start time and end time. The following URL would retreive all packets between 1 and 2 AM, UTC.

https://asp-interface.arc.nasa.gov/API/binary_packet_data/SP2_FULL?Start=2018-10-18T01:00:00.000&End=2018-10-18T02:00:00

10.3.2 Packet Transmission (Ground to Instrument)

Transmitting Instrument data to the aircraft is the inverse process of receiving user packets; Packets are submitted to the ground server (asp-interface.arc.nasa.gov) via HTTPS, and delivered to the instrument on the aircraft at an assigned IP address and port.

To submit packets to the aircraft, the same instrument identifier from the user packet retreival is used, however the URL is altered:
https://*server*/API/packet_submission/N817NA/*instrument_id*

This URL takes three parameters:

- user - This should contain the username assigned by the NSRC Datasystem staff.
- password - This should contain the username assigned by the NSRC Datasystem staff.
- packet - This should contain the content you wish to transmit to the aircraft. If this value is base64 encoded, it will be decoded before transmission, otherwise it will be transmitted unaltered.

These parameters should be provide via HTTP POST. Each packet POSTed in this manner will be transmitted to the aircraft, and an attempt will be made to deliver it to the instrument. Note that UDP is not a reliable delivery mechanism, and although the best effort will be made to deliver each message, it is possible for messages to be lost in transmission.

Please also note the use of HTTPS for all packet submission operations. HTTP cannot be used, as it would expose credential information in an unencrypted form.