Interagency Working Group for Airborne Data and Telecommunications

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Abstract – The Interagency Coordinating Committee for Airborne Geosciences Research and Applications (ICCAGRA) was established to improve cooperation and communication among agencies sponsoring airborne platforms and instruments for research and applications, and to serve as a resource for senior level management on airborne geosciences issues. The Interagency Working Group for Airborne Data and Telecommunications Systems (IWGADTS) is a subgroup to ICCAGRA for the purpose of developing recommendations leading to increased interoperability among airborne platforms and instrument payloads, producing increased synergy among research programs with similar goals, and enabling the suborbital layer of the Global Earth Observing System of Systems. This paper introduces the reader to the objectives of the IWGADTS along with the strategy for achieving these objectives, and provides a summary and outlook for activities.

Keywords: *airborne research, instrumentation, data systems, data formats*

1. INTRODUCTION

Airborne research in the United States is conducted by a variety of agencies that maintain numerous manned and unmanned aircraft platforms, and hundreds of sensor systems designed for atmospheric in-situ and earth-observing remote sensing measurements. Each of these aircraft has data systems and services that evolved independently over the years, and are largely incompatible. This creates a detrimental effect on the productivity of researchers and instrument developers who need to adapt to different incompatible platforms.

Today's environment offers impetus and opportunity to improve the effectiveness and value of airborne science activities. Impetus emerges from the vision for building a ***global-scale*** system of Earth observation capabilities. In 2002 the Commission on the Future of the United States Aerospace Industry concluded that increased investment is needed in test and measurement infrastructure, as well as development and demonstration of the capabilities to continuously monitor and survey the Earth, its atmosphere, and space for a variety of military, civil, and commercial applications (Aerospace).

Furthermore, the World Summit on Sustainable Development highlighted the urgent need for coordinated observations relating to the state of the Earth. In response the United States formed the Interagency Working Group on Earth Observations (IWGEO) (Johannesburg), which produced a strategic plan for the development and implementation of the U.S. Integrated Earth Observation System. Today, the IWGEO has been replaced by the United States Group on Earth Observations (US GEO), which since 2005 has been a standing subcommittee of the National Science and Technology Council Committee on Environment and Natural Resources (CENR).

The Integrated Earth Observation System (IEOS) is a contribution to this integration for the U.S. airborne science community. In 2004, discussion among airborne science platform operators began to focus on the lack of interoperability or commonality between the data systems on these platforms. Each platform has its own legacy data system that tends to have its own hardware interfaces and software data formats. Advances in information technology made most of these interface-related issues unnecessary. New manned platforms such as the Gulfstream V (GV) High-Performance Instrumented Airborne Platform for Environmental Research (HIAPER) of the National Center for Atmospheric Research (NCAR) (Boulder, Colorado, USA) and numerous unmanned vehicles were already driving the development of the next generation of data systems. Maintaining proprietary interfaces and data formats was deemed improper because individual instruments need to be able to operate on a variety of airborne platforms, and instruments collectively benefit from leveraging common services across platforms.

In 2005, under the banner of the Multi-Agency Data Distribution Systems Working Group it was decided to organize the Interagency Working Group for Airborne Data and Telecommunications Systems (IWGADTS), as a working group under the auspices of The Interagency Coordinating Committee for Airborne Geosciences Research and Applications (ICCAGRA). ICCAGRA has worked for nearly a decade to improve cooperation, foster awareness, and facilitate communication among federal agencies sponsoring airborne platforms and instruments for research.

The U.S. contribution to the envisioned Global Earth Observing System of Systems (GEOSS) is the Integrated Earth Observation System (IEOS). GEOSS and IEOS will facilitate the sharing and applied usage of global, regional, and local data from satellites, ocean buoys, weather stations, and other surface and airborne Earth observing instruments. The end result will be a simplified and better-organized access to an unprecedented amount of environmental information integrated into new data products, which will benefit societies and economies worldwide.

2. GOALS AND IMPLEMENTATION

The primary purpose of IWGADTS is to increase the effective utilization of the Federal airborne fleet in support of airborne geoscience research programs conducted by the individual agencies. Specifically, the IWGADTS will:

1. Identify interagency needs for data and networked systems
2. Improve interoperability of instrumentation between airborne platforms operated by different agencies

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3. Enhance opportunities for interagency sharing of aircraft resources, airborne instrumentation, and data to minimize duplication; and to expand access for researchers to interagency assets
4. Provide references of technical standards for senior level decision makers
5. Evaluate the current state of interoperability and recommend, as appropriate, interagency standards to facilitate the development of common data and networking systems leading to a fully interoperable global observing system which includes suborbital and space-based components.

From the IWGADTS charter (Appendix A) the following strategy elements can be inferred:

1. Invite interested parties to participate, even if for only certain aspects of integrated development.
2. Work toward a suborbital platform fleet that is an effective and sustainable component of the to-be-implemented Integrated Earth Observation System.
3. Focus on interoperability at the point of data ingestion or network transmission, not through common hardware systems that generate that information.
4. Promote telecommunication technologies that enable real time interactive connectivity between the airborne and other research networks. Over time, instrument networks on suborbital platforms migrate toward being observation nodes on a suborbital "sensor web."

The term ***sensor web*** is used here to define the Integrated Earth Observation System encapsulating airborne sensors as one or more suborbital sensor webs.

The approach of the IWGADTS is to provide interoperability by focusing on making it easier for sensor operators to integrate instruments on multiple platforms, and on making every flight hour more productive. For mature sensors that cannot afford to adapt to newly introduced services, a "no instrument left behind" philosophy that eliminates the risk of current sensors becoming obsolete solely because of legacy data system interfaces is adopted. Instead, new data systems must emulate legacy interfaces for specific instruments/platform pairs. Thus, the data system developers will be able to manage the migration to the Integrated Earth Observation System without disrupting ongoing operations.

3. ACCOMPLISHMENTS AND WORKS IN PROGRESS

3.1 Collaborations

Contributing newly adopted technologies to the research community is an important part of the philosophy of the IWGADTS. For example, just as the Internet Relay Chat (IRC) has been recognized as a vital tool for researchers during field campaigns, the National Science Foundation (NSF), and the National Center for Atmospheric Research (NCAR) Earth Observing Laboratory (EOL) have made available their chat server to other agencies saving time and resources to work on other issues. The installation of Iridium (Bethesda, Maryland, USA) and other satellite communications systems on aircraft has allowed for effective group communications between ground and aircraft participants using IRC software and is now being used on non-NSF platforms.

3.2 User Survey

The IWGADTS conducted a survey of recent platform users, in which about 50 responses were received. The five primary items offered in response to the question of, "What would make your life easier as a (PI) integrating your instrument between multiple aircraft?" included: common instrument racks, common power and data system interconnects, common real-time data feed, common documentation requirements, and common data formats. Some of the newer features requested were Ethernet capability, even wireless and satellite communications on all aircraft for data downlink and instrument control from the ground. Eighty-four percent indicated "common data file format across platforms for time-series data" as highly desirable.

3.3 Practical Recommendations

The following recommendations have been developed by the IWGADTS:

3.3.1 Timing for data recording

Time will be Coordinated Universal Time (UTC), not Global Positioning System (GPS) time or local time zone.

It is recommended that all platforms provide at least Inter Range Instruments Group Code B (IRIG-B) so that all measurements have accurate time tags. IRIG-B provides deterministic timing to single digit microseconds. This should meet most instrument needs. IRIG-B does tend to be more expensive as it requires specialized receiver cards at the instrument end and dedicated cabling on the platform.

Optionally, platforms may provide other time sources such as Network Time Protocol (NTP). NTP typically provides accuracy in the single digit milliseconds. NTP has the advantage of being accessible to anyone with a network connection, making it a low cost solution.

There are several time servers available on the market that use a GPS antenna input and provide IRIG, NTP, Pulse Per Second (1PPS) and a 10MHz oscillator output. Emerging technology in some of these servers includes extensions of NTP with Precision Timing Protocol (PTP), enabling sub-microsecond timing precision where necessary.

3.3.2 Real-time data feeds

IWGADTS has converged on the use of user datagram protocol (UDP) across Ethernet as a baseline preferred protocol for minimum-latency data transfer. Additional protocols and services add value as needed.

Many instruments require real-time navigation data and basic atmospheric state parameters for their operation in flight. Most investigators have indicated that one update per second is sufficient, but some need high-rate platform attitude and airspeed. Our solution is to develop a packet that would meet the needs of 80%-90% of users while remaining common across all platforms.

The "IWG1" packet was defined to specify the contents of a data packet or record without specifying how it is transmitted. The record is ASCII, with a leading keyword, a timestamp, followed by 31 or more comma separated values. The first 31 values (Table A) are predetermined and may not change. A specific parameter may be omitted by placing two commas together if it is not available on that platform. Anything after the 31st parameter is extendible by the platform operator on a flight-by-flight, or campaign-by-campaign basis.

Sample format:

IWG1,yyyymmddThhmmss,value,value,value,…., value\r\n

Sample string:

IWG1,20010920T151702,14.6211,96.4268,4231.57,,4258.42,4236.6,136.854,135.162,209.318,0.162768,0.140627,185.121,189.053,4.13252,2.91712,1.05973,0.448692,2.91955,5.53124,7.22863,14.1497,614.574,72.9203,858.012,8.32743,81.4657,0.248214,0.820221,0.750576,,

Table A. Fixed Portion of the IWG1 Parameter List

Description	Units	Range
ISO-8601 formatted date and time	UTC	
Platform Latitude	degree_N (dec)	-90 to 90
Platform Longitude	degree_E (dec)	-180 to 180
GPS Altitude, Mean Sea Level (MSL)	m	Zero or greater
WGS 84 Geoid Altitude	m	Zero or greater
Pressure Altitude	feet	Zero or greater
Radar Altimeter Altitude	feet	Zero or greater
Ground Speed	m/s	
True Airspeed	m/s	
Indicated Airspeed	knots	
Aircraft Mach Number		
Aircraft Vertical Velocity	m/s	
True Heading	degrees_true	0 to 360
Track Angle	degrees_true	0 to 360
Drift Angle	degrees	
Pitch	degrees	-90 to 90
Roll	degrees	-90 to 90
Side Slip Angle	degrees	
Angle of Attack	degrees	-90 to 90
Ambient Temperature	degrees_C	
Dew Point	degrees_C	
Total Temperature	degrees_C	
Static Pressure	mbar	
Dynamic Pressure	mbar	
Cabin Pressure / Altitude	mbar	
Wind Speed	m/s	Zero or greater
Wind Direction	degrees_true	0 to 360
Vertical Wind Speed	m/s	
Solar Zenith Angle	degrees	
Sun Elevation from Aircraft	degrees	
Sun Azimuth from Ground	degrees_true	0 to 360
Sun Azimuth from Aircraft	degrees_true	0 to 360

There are no restraints on transmission method or protocol (e.g. RS-232 vs. Ethernet UDP). For Ethernet transmission, the UDP protocol has been chosen, and the group is currently requesting to use a specific port number from the Internet Assigned Numbers Authority (IANA).

3.3.3 CSV Format for Data Exchange

The IWG1 packet definition is an example of using Comma Separated Value (CSV) formats that the IWGADTS is adopting for most of its data exchange tasks. CSV packets are convenient to implement, easy to read, and work well on low bandwidth connections. For example, a 50-byte packet transmitted 10 times per second will consume 10Kbps of bandwidth.

Promoted for use by instruments, the CSV template consists of a unique identifier as the first value, followed by an ISO-8601 time stamp, followed by user-defined values. Note that the IWG1 packet in 4.1.2 is a CSV packet with "IWG1" as the identifier string. The CSV template enables any instrument to send nearly any set of scalar variables at arbitrary time intervals.

Example formats:

IDENTIFIER,yyyy-mm-ddThh:mm:ss,value,value,value,,value
IDENTIFIER,yyyymmddThhmmss,value,value,value,,value
IDENTIFIER,,value,value,value,value

Note the third example does not include time. Instruments that do not have time may leave the time field blank.

Sample string:

NOAA_SP2, 20090120T145531, 15.7738, -96.2707, 137.462

3.4 Works in Progress and Future Directions

Works in progress include recommendations for sensor alert services and for command/query of remote instruments during real-time operations. For post flight data files; formats, metadata and data discovery recommendations are in very early stages.

3.4.1 Sensor Alerts

Sensor alerts are needed to mark events or to signal that instrument conditions are outside the defined operating limits. We are looking into methods for a common sensor alert format. These could also be designed around the CSV packet.

Sample format:

ALERT,source,timestamp,action,destination,message

Sample strings:

ALERT,ACD_TDL,,SMS,303-497-1044,Laser inoperative.
ALERT,CVI,13:45:00,EMAIL,cjw@ucar.edu,System rebooted.

For example; these sensor alerts could be sent via UDP on the aircraft, picked up by an IRC script which would copy them into a chat room for alerts; then another script on the ground could parse the message, map it to additional messaging/notification protocols, or otherwise initiate appropriate action.

3.4.2 Data File Formats

Discussions on post flight data file formats, metadata, and data discovery are ongoing. There are two main types of data files, ASCII and binary. Binary formats include netCDF (Unidata) and HDF (HDF).

The predominant ASCII formats are the National Aeronautics and Space Administration (NASA) Data Exchange Format (Gaines) and a derivative called ICARTT (Williams).. These formats are useful for exchanging small datasets (less than fifty columns). They are easily read into programs such as spreadsheets and MATLAB® (The MathWorks, Natick, Massachusettes, USA).

The main disadvantages are that there is no random access to data for intelligent software programs, and these formats don't scale well to large datasets (e.g. the NCAR C130 typically has 300 variables). Many of the current ASCII file formats also are not extendible, requiring customized, non-standard modifications to add new metadata in the header. For example, the NASA DEF format and derivatives do not clearly specify how measurement units shall be placed in the header, making it difficult for software packages to locate the units if they even exist in the file.

The main disadvantage of binary files is the difficulty and learning curve of accessing them. You either need to know the exact file format a priori, or need to have an Application Programming Interface (API) to use (e.g. netCDF and HDF).

Ideally a single ASCII format for lightweight use and a single binary format for heavyweight use would be established, along with translators to go between the two.

4. CONCLUDING COMMENTS

An Interagency Working Group for Airborne Data and Telecommunication Systems has been established to help the fleet of airborne science platforms increase their value by becoming more interoperable with each other. Implementation of common data protocols, instrument interfaces and final data storage formats will enable researchers to utilize the national airborne fleet more efficiently by collaborating on the development of new tools, techniques, and services.

Currently, the National Aeronautics and Space Administration , the National Science Foundation, the Department of Energy, and the Office of Naval Research are participating agencies in this activity and additional participants are welcomed. The products and recommendations of this group are being used by the constituent organizations and have already made a positive impact in terms of generating greater productivity for multiple customer groups. The Interagency Working Group for Airborne Data and Telecommunications Systems is working to keep airborne science fleets at the forefront of the emerging Earth observation system of systems.

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APPENDIX A

IWGADTS Charter

The working group addresses interagency cooperation issues as they pertain to the use of airborne platforms and instrument payloads for individual investigators as well as national and international field campaigns.

Purpose and Functions

The primary purpose of IWGADTS is to increase the effective utilization of the Federal airborne fleet in support of airborne geoscience research programs conducted by the individual agencies. Specifically, the IWGADTS will:

1. Identify interagency needs for data and networked systems.
2. Improve interoperability of airborne platforms between agencies.
3. Enhance opportunities for interagency sharing of aircraft resources, airborne instrumentation and data to minimize duplication, and to expand science investigators' access to interagency assets.
4. Provide technical standards recommendations to senior level decision makers.
5. Evaluate the current state of interoperability and recommend, as appropriate, interagency standards to facilitate the development of common data and networking systems leading to a fully interoperable global observing system which includes suborbital and space-based components.

Structure

The IWGADTS will consist of representatives from the principal geosciences research aircraft sponsoring agencies, e.g., NASA, NSF, NOAA, DOE, DOI, and ONR. A Chairman and an Executive Secretary will be elected annually from the principal agencies.

Meetings

Committee meetings will be called by the Chairman who will also approve the agenda. The Committee will meet at least quarterly for the first year and thereafter on a suitable schedule as decided by committee members, but no less than two times per year.