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MODERNIZING WORKSTATION TECHNOLOGY FOR THE INTERNATIONAL SATELLITE COMMUNICATION SYSTEM (ISCS)

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1. INTRODUCTION

During 2004, the International Satellite Communication System (ISCS) underwent a fundamental change in communication protocol from X.25 to Transmission Communication Protocol/Internet Protocol (TCP/IP). This paper will describe the transition from X.25 to TCP/IP, from the perspective of modernizing workstation technologies that were needed for the transition. This paper will also discuss some of the forthcoming data changes in the World Area Forecast System (WAFS), particularly as they relate to the impending termination of T4 chart products.

2. WAFS HISTORY

The International Civil Aviation Organization (ICAO) and World Meteorological Organization (WMO) mandate the WAFS program to broadcast and disseminate aviation meteorological data and products. Presently, two World Area Forecast Centers (WAFCs) are responsible for this dissemination.

The United Kingdom Meteorological Office (UKMO) in Exeter, the United Kingdom, distributes data and products through the Satellite Distribution System (SADIS), whose footprint covers Europe, Africa, the Middle East, and much of Asia.

The National Oceanic and Atmospheric Administration (NOAA) in Washington, DC, distributes data and products through the International Satellite Communication System (ISCS), whose footprint covers the Atlantic, the Americas, and the Pacific (including the Pacific Rim countries in Asia). There are two satellites for the ISCS: one satellite is for the Atlantic Ocean Region (AOR) and the second is for the Pacific Ocean Region (POR).

SADIS and the ISCS comprise the total worldwide WAFS communication infrastructure.

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The WAFS transmission includes the following data types to support aviation meteorology:

- OPMET data (METARS, TAFS, bulletins, etc.)
- Wind-Temperature (W-T) data
- Significant Weather (SigWx) data

The W-T and SigWx products are furnished in the form of T4-format "fax" charts and raw GRIB data.

During the 1990s, several meteorological institutes had responsibilities to create and provide T4 products. The chart production responsibility eventually consolidated to the two present-day WAFCs. Each WAFC serves as a backup to the other, in case there is a data transmission outage at one of the facilities.

3. TIMELINE OF X.25 TO TCP/IP

The first generation of WAFS in the early 1990s was developed on the backbone of X.25, which was a popular communication protocol for packet-switched data networks. Later, ICAO and WMO decided to move away from X.25 -- favoring a migration to the TCP/IP protocol, which is a universal Internet standard.

TCP/IP is also better suited as a transport medium to maintain reasonable queue times as increasing amounts of meteorological data are fed through the uplink transmission.

In order to receive the X.25 broadcast, the workstations needed proprietary boards built into the hardware or third-party "plug in" cards that convert the X.25 packets to the native TCP/IP of the PC platform. With TCP/IP data protocol from ISCS (or SADIS), proprietary solutions are avoided because TCP/IP is the standard protocol for Local Area Network (LAN) interfaces on a PC.

During 2002, NOAA began the ISCS format migration to TCP/IP. First, a contract was awarded to MCI for the conversion of the uplink from X.25 to TCP/IP protocol, and the continued transmission of data for the ISCS. MCI conducted data beta tests during 2003 and 2004, then began regular broadcast of ISCS data with TCP/IP protocol. The X.25 transmission continued concurrently during a transition period.

4. DEVELOPING THE NEW ISCS WORKSTATION TECHNOLOGY

The migration from X.25 to TCP/IP rendered obsolete the previous-generation Satellite Telecommunication and Analysis for Region IV ("Star4") workstations, manufactured by Alden Electronics, which serviced all the ISCS one-way and two-way sites. Alden developed the Star4 workstations during the early 1990s. In 2000, GST obtained the service contract with NOAA for the maintenance of Star4, and during the subsequent year, teamed with 3SI to proffer a new generation of ISCS workstation that could replace Star4 systems.

For these replacement ISCS workstations, requirements documentation was developed by WMO RA-IV member states. The requirements included the interface to TCP/IP, some additional visualization modules (see Section 7), and a mandate to create W-T charts from GRIB data and SigWx charts from BUFR data.

GST and 3SI began joint product development in 2001 of a "WAFS-MetLab" workstation, which would address the new ISCS requirements to replace the Star4. The first system was purchased by NOAA and sponsored at a beta test site in Curacao at the Meteorological Department of the Netherlands Antilles & Aruba (MDNA&A). At the time the system was installed in Curacao in 2002, the transmission protocol was still X.25, but the Curacao site served the purpose of testing new workstation functionality, such as rendering of W-T charts from GRIB. These early experiences in Curacao were very productive and fruitful. User comments were extremely helpful in refining some of the visualization techniques, particularly with respect to presentation of W-T information, retrieval of specific alphanumeric bulletins by $T_1T_2A_1A_2ii$ header, and the visualization of the RECCO bulletin, which provides hurricane reconnaissance information.

Consequently, as a result of the beta work in Curacao, a number of improvements were made to the WAFS-MetLab workstation that addressed specific user needs in WMO RA-IV.

Each two-way site is capable of transmitting bulletins configured to its own $T_1T_2A_1A_2ii$ CCCC, as well as sending out a "heartbeat" message to inform the National Weather Service Telecommunications Gateway (NWSTG) that the site is up and functioning. The workstation hooks up via crossover cable to the Hughes Receiver. The visualization software for the workstation displays alphanumeric bulletins, GRIB model data, SigWx BUFR data, and T4 charts – all staples of the ISCS data feed. Moreover, visualization modules are available for station models, drawing, text edit, and graphing (thermodynamic profiles, vertical cross-sections, time-height cross-sections, and time series). Some of the new visualization techniques will be described in Section 7. After the data is received by the primary WAFS-MetLab computer, it may be displayed on additional visualization display stations if these are connected on a LAN.

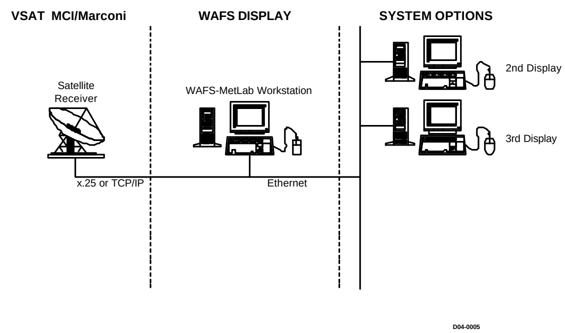

Fig. 1 System Architecture

5. THE TCP/IP ISCS VSAT COMMUNICATION LINK

The NWSTG collects worldwide meteorological data, processes, groups and validates the data, then transmits the data back to the world user community via the ISCS VSAT -- a communication link developed and managed by MCI. UKMO conducts the role of data collection and dissemination reciprocally for the SADIS transmission.

NWSTG is responsible for providing WAFS data via the ISCS to the AOR and the POR. WAFS data is initially transmitted from the NWSTG to a MCI ISCS Hub located in Andover, Maine. WAFS data is categorized into three groups: Alphanumeric text files, T4 (DIFAX) charts and GRIB model output. The data is further re-categorized according to the regional necessity or desirability by the end user. Socket stream inter-process communication is utilized to transmit the WAFS data from NWSTG to the MCI Andover Hub. GST assisted in the development of the socket reception software at the Andover Hub server to process the data incoming from the NWSTG.

Nine sockets are used – three groups (AOR, POR, General) of 3 primary data types (Alphanumeric, T4, GRIB). In early 2005, SigWx BUFR data is scheduled for operational transmission, and will be carried via an existing socket.

As each file is received and processed at the Hub Server via one of the sockets, it is forwarded to a "holding" folder, maintaining its data type and destination region status. Based on the number of files and/or elapsed time, the grouped data is collected into TAR files (Tape ARchive, a UNIX style file collective), which are transmitted to the sites via TCP/IP protocol. The AOR WAFS data are transmitted from Andover, Maine to the AOR ISCS satellite for reception by the AOR sites.

Fig. 2 Atlantic Region

The POR WAFS data are transmitted from the Andover Hub to a secondary Hub located in Yucult, Washington for transmission to the POR sites.

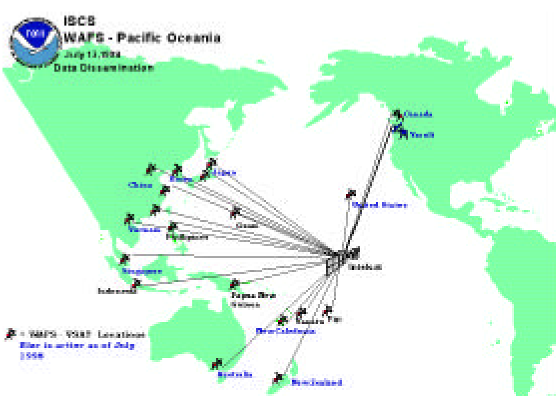

Fig. 3 Pacific Region

The original design of the new TCP/IP ISCS VSAT communication link called for socket stream transmission/reception through its entirety, from the NWSTG to each site. However, subsequent design reviews revealed that each new site would burden the communication link and soon fill the available bandwidth. Therefore, NOAA decided to utilize a broadcast method for disseminating the data from each Hub to the sites. A third-party software package consisting of a multi-cast transmission program at the Hubs and a counterpart multi-cast reception program at each site was added to the design.

The multi-cast reception program receives the TAR files originally assembled at the Andover Hub. Once a TAR file is handed off to the end-user workstation, the ISCS communication transmission is complete. The workstation is then required to extract the individual files from the TAR collective, categorize the files according to type, and process the files into a database for display and analysis.

Two-way sites also have the capability to transmit bulletins back through the ISCS to the NWSTG via an ftp process (point-to-point transfer utilizing ip addresses within the ISCS).

In a 24-hour period, NWSTG transmits an average of 58,000 files through the ISCS VSAT communication system. GST/3SI assisted NOAA throughout the transition from X.25 to TCP/IP to assess the quantity, quality and latency of the WAFS data received at workstations throughout the world.

6. OPERATIONAL ROLLOUT AND ISSUES

Shortly after the Curacao beta site was installed (January 2002), NOAA contracted GST/3SI to install WAFS-MetLab systems at five NOAA facilities. The systems were installed at NWSTG - Silver Spring, National Hurricane Center (NHC) - Miami, NWS - San Juan, Aviation Weather Center (AWC) – Kansas City, and NWS - Honolulu. These sites are the backbone of the ISCS for NOAA because they all receive the ISCS data feed and provide monitoring of data and products for other end-user stations throughout the ISCS footprint.

These five systems at NOAA facilities originally received data via X.25 protocol, until the workstations were upgraded during 2003-2004 with new WAFS-MetLab software for TCP/IP reception. The physical network migration with MCI involved a switching of the Hughes Receiver from one satellite transmission network to another.

GST/3SI also installed WAFS-MetLab systems in 2004 under a separate NOAA contract at aviation weather facilities in the following countries: Bahamas, St. Maarten, Belize, Honduras, Guatemala, Nicaragua, El Salvador, Costa Rica, Panama, and Colombia. The installed WAFS-MetLab systems at these sites were TCP/IP-enabled, and directly replaced the Star4 machines.

There were some rollout issues. When MCI first started the TCP/IP broadcast on a regular basis in 2004, occasional data outages occurred at the Andover Hub.

These outages became less frequent and shorter in duration as the year progressed. Also, there were periods of significant data latency during the early days of the TCP/IP transmission. Eventually, the latency decreased and the data reception at the end-user sites was timely.

The workstation performance was generally good; however, some sites experienced occasional system “freezes” that were attributed to power management conflicts on the Dell machines with the Red Hat Operating System (OS). The OS power management was disabled, and the system lockup problem improved.

7. NEW VISUALIZATION AND OPERATIONAL TECHNIQUES

The WAFS-MetLab workstation brought many new visualization and analytical capabilities, when compared to the previous-generation Star4 system. Some of the major functionalities that changed include:

a) **Alerts:** Capability to alert the user when a certain parameter threshold has been observed (e.g., wind speed > 39 knots)
b) **Time Profile:** Visualize Time-Height cross-sections of GRIB model data at a given aerodrome
c) **SigWx BUFR:** Visualize SigWx data, given in BUFR format, over ICAO or user-defined projections
d) **Tropical Analysis:** Wind representation as streamlines, Divergence displays with max/min labeled, RECCO bulletin added to Station Model, and Geostrophic Wind calculator
e) **Folders**: Macro-generated folders that show unique parameter combinations
f) **Additional GRIB model parameters**: Create “derived” parameters from raw parameters found in the WAFS data flow
g) **Profile Analysis:** Interpolate values in a thermodynamic graph, such as determining the level of wet-bulb zero or the rate of change of wet-bulb temperature with height

Examples of new visualization products are shown in Figs. 4 and 5. Fig. 4 is a Time-Height Cross-Section (i.e., Time Profile) of wind and relative humidity for the model time steps at a given aerodrome, based on the nearest model grid point. Areas of relative humidity greater than 70% are shaded, indicating areas of potential or expected cloud coverage, depending on height and relative humidity value. The wind depiction in the Time Profile is particular helpful for showing the passage of fronts.

Fig.5 is a SigWx chart that is produced from BUFR format data of SigWx elements (jet streams, CAT, etc.).

The WAFS-MetLab workstation also includes system administration tools that help diagnose when a data flow problem occurs, as well as utilities to rapidly clean and repopulate directories or databases, if need be. An archival copy of raw data is kept on the computer hard drive in case the database needs to be rapidly repopulated for any reason.

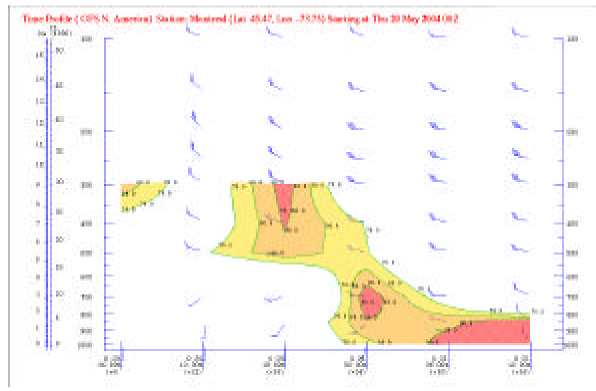

Fig. 4 Time Profile created from GRIB model data

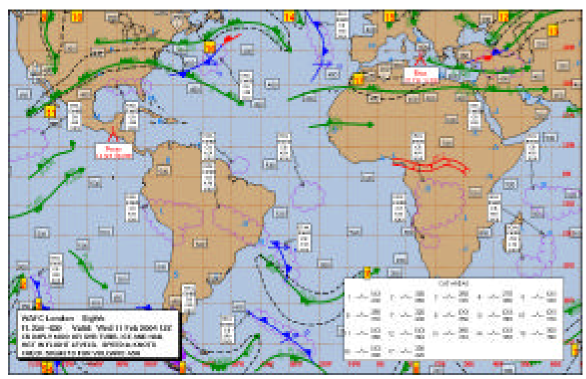

Fig. 5 SigWx chart created from BUFR data

8. UPCOMING DATA CHANGES ON THE ISCS

The ISCS data suite is changing in 2005 to include SigWx data in BUFR format. As of 2004, only UKMO produces high-level SigWx (SWH) data operationally for SADIS. The Aviation Weather Center (KKCI) is producing SWH BUFR files, which will be operational on the ISCS in 2005.

Both WAFCs share a joint responsibility for the encoding and decoding of SigWx BUFR data messages. Beginning November 2004, both WAFCs specified a change to include jet stream height (+DD/-DD) information. This will show the vertical extent of the jet, as opposed to a single flight level.

In 2005, it is expected that both WAFCs will begin transmitting medium-level SigWx (SWM) BUFR data. The SWM covers FL100-FL450, whereas the SWH covers FL250-630.

WAFS-MetLab was updated with a new SigWx BUFR module in 2004 for the workstation production of SWH charts. During the development of the module, a very robust period of interaction occurred with UKMO. GST/3SI uncovered technical items that needed improvement in the WAFCs' BUFR encoding software and documentation.

The transmission of the SigWx BUFR files on WAFS is a necessary step for the termination of T4 (DIFAX) charts, which is scheduled to occur in mid-2005. Once the T4 charts are terminated, the users will solely rely upon their workstations to create W-T charts from GRIB and SigWx charts from BUFR.

The BUFR format may also be used to code other data types, such as radar information. WMO RA-IV members are presently discussing the need and preference to disseminate regional radar information.

9. CONCLUSION

The conversion from X.25 to TCP/IP protocol on the ISCS provided an opportunity for end-users to receive increased amounts of meteorological data, as well as new workstations that would advance their meteorological analysis and data visualizations. The new workstation technology must create W-T charts from GRIB and SigWx charts from BUFR.

The configuration changes of the workstation were developed in a beta stage at one test site, and then propagated at the time of deployment for operational use.

The MCI hubs in Andover and Yucult transmitted both X.25 and TCP/IP protocol during most of 2004. The X.25 transmission is scheduled for removal in late 2004 or early 2005.

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LIST OF ACRONYMS

AOR – Atlantic Ocean Region
BUFR – Binary Universal Format
CAT – Clear Air Turbulence
DIFAX – Digital Facsimile
FL – Flight Level
GRIB – Gridded Binary
ICAO – International Civil Aviation Organization
ISCS – International Satellite Communication System
LAN – Local Area Network
METAR – Surface airways synoptic code
NOAA – National Oceanic and Atmospheric Administration
NWSTG – National Weather Service Telecommunication Gateway
OPMET – Operational Meteorological Data
POR – Pacific Ocean Region
RECCO – Reconnaissance aircraft bulletin
SADIS – Satellite Distribution System
SIGWX – Significant Weather
STAR4 – Satellite Telecommunication and Analysis for Region IV
T4 – Facsimile transmission format
TAF – Terminal Area Forecast
TCP/IP – Transmission Communication Protocol/Internet Protocol
UKMO – United Kingdom Meteorological Office
VSAT – Very Small Aperture Transmission
W-T – Wind-Temperature
WAFC – World Area Forecast Center
WAFS – World Area Forecast System
WMO -- World Meteorological Organization