AMS-02 Computing and Ground Data Handling

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Abstract

AMS (Alpha Magnetic Spectrometer) is a space-born experiment to search for dark matter and antimatter. The AMS detector had a precursor flight in 1998 (STS91, June 2-12, 1998). The final detector (AMS-02) will be installed on the International Space Station (ISS) in the beginning of 2008 for at least three consecutive years [1]. This paper gives an overview of the AMS Ground Data Handling System emphasizing the distributed data processing based on a client/server approach. We also present several data transfer tests that have been made between CERN (Geneva, Switzerland) and AMS remote centers in Europe, USA and Asia.

AMS DETECTOR

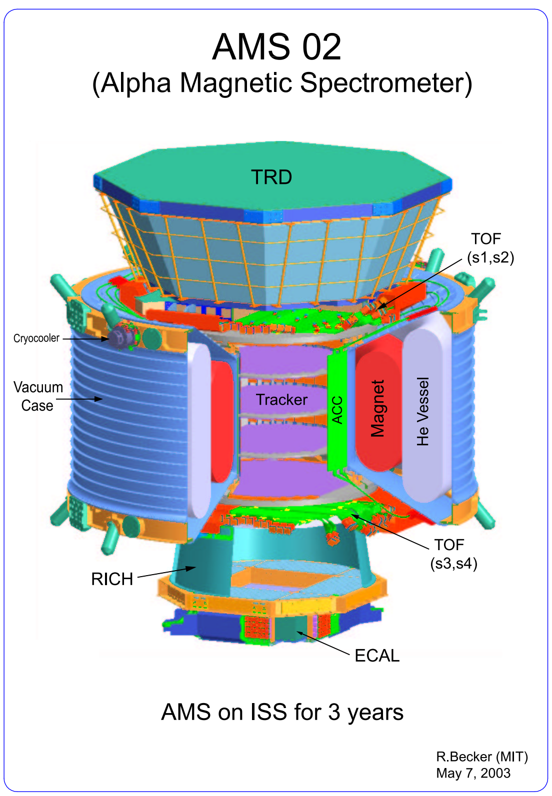

Figure 1: AMS Detector

Fig 1 identifies the most important detector components. The cylindrical superconducting magnet, measuring about 2m in height and 1m in diameter, will create a field of 1 Tesla. In the magnetic field, a positively charged particle (matter) will bend one way and a negatively charged particle (antimatter) will bend in the opposite direction. Within the hollow magnet an array of precision particle detectors is situated, to measure momentum, velocity, charge and position of particles that penetrate the spectrometer. A *Transition Radiation Detector* (TRD) allows to reject protons to better than 10^{-2} and provide lepton identification up to 300 GeV. The *Time of Flight* (TOF) scintillator panels and photomultipliers at the spectrometer top and bottom provide a time of flight measurement to an accuracy of 100ps and a measurement of the particle energy loss. The silicon *Tracker* is supported by five honeycomb support plates which are located inside the magnet. The tracker provides a three-dimensional measurement of the particle trajectory with a coordinate resolution of about 10μm and also measures the specific energy loss. The *Veto Counter* rejects particles that leave or enter through the shell of the magnet. The *Ring Image Cerenkov Counter* (RICH) measures the velocity (and charge) of particles or nuclei. This information together with the measurement of momentum in the tracker will enable AMS to directly measure the mass of particles or nuclei. The 3-D sampling *Electromagnetic Calorimeter* (ECAL) measures the energy of gamma-rays, electrons and positrons and distinguishes electrons and positrons from hadrons. The *Trigger* and data acquisition electronics will provide an instantaneous selection of data.

The aggregate data volume is estimated to 60 TByte per year and about 200 TByte for the whole ISS mission. Data will be buffered in the AMS Crew Operation Post computer (*ACOP*) installed on board of ISS and then transmitted via satellite to NASA Marshall Space Flight Center (*MSFC AL*) and then to CERN (Geneva, Switzerland) for processing and analysis. The processed data will be available for the collaboration and data samples will be transmitted to Regional Centers in Europe, USA and Asia.

CLASSES OF AMS DATA

AMS data can be divided into three groups.

- Critical Health and Status (H&S) data, provide summary status of the detector (for example: magnet state (charging, quenched, stable), input power, temperature, DAQ state). This data is needed in real time (RT) at AMS ground control centers. The data will be also available to ISS crew and NASA. The data rate is low (approx. 1Hz).

- Monitoring Data (aka Housekeeping data). All data from all sensors. The data rate is about 10 Kbit/sec. We need some of this data in RT, the complete copy will be needed later for science analysis. Data will be visible to ISS crew via *ACOP*.

- Science data. These data we need to do physics. Data are buffered in *ACOP* and downlinked to the ground when Ku-band resources become available. Samples of data are needed for the detector monitoring (7/24) in near real time mode, the complete copy of data is needed for physics analysis.

The AMS data flow from ISS to ground centers is shown on Fig 2. *ACOP* will record data on removable hard disks. Once data is recorded it can be played back when transmitting resources become available. The downlink rate is limited to 2 MBit/s (orbit average), more statistics can be recorded with the help of *ACOP* and later carried to ground. *ACOP* also can be used to command the detector in off-nominal situation, the usual source of AMS commands is the Payload Operations and Control Center.

AMS GROUND CENTERS

The ground computing system [2] can conceptually be divided into the following functional units:

- Ground Support Computers (GSC): receive monitoring and science data from POIC[1]; buffer science, housekeeping and NASA ancillary data for transmission to Payload Operations and Control Center and Science Operations Center.

- Payload Operations and Control Center (POCC): center where AMS operations take place, including commanding, storage and analysis of housekeeping data and partial science data analysis for rapid quality control and feedback.

- Science Operations Center (SOC): receives and stores all AMS science and housekeeping data, as well as ancillary data from NASA, ensures full science data reconstruction, calibration and alignment; keeps data available for physics analysis; archives all data.

- Regional Centers (RC) will contain analysis facilities to support physicists from geographically close AMS universities and laboratories, RC will also provide access to SOC data for visualization, detector verification studies and status of data processing.

DATA TRANSFER AND NETWORKING

Facing the long running period (more than 3 years) and the way how the data will be transmitted from the detector to the ground centers, the development of secure and reliable ways of data transferring is one of the vital issues in ground data handling. It was also important to understand if public Internet is sufficient to serve AMS-02 needs for data transfer.

We adopted and enhanced programs developed by the BaBar experiment (`bbftp` and `bbcp` [3]). The programs are using multiple TCP streams between client and server to take advantage of RFC 13423 and speed up data transfer. Sending data is not the only important thing. Making it available such that regional centers can access it was also one of the main goals, thus automatic book-keeping and data retransmission are implemented. The first version of file catalogs is implemented as relational database tables.

Fig 3 shows transfer rates achieved with `bbftp` between MIT (Cambridge MA, USA) and CERN (Geneva, Switzerland) versus number of streams and file size. In this particular tests 15 streams and 80MB file size was optimal with a resulting transfer rate of 3.1MByte/sec. This is a very good performance and within a few percent of that achieved using `iperf` with TCP and similar streams and window size. Tests results are summarized in Table 1. Poor `bbftp` performance between CERN and Milan is due to the 16MBit/s limit of the CERN/INFN Milan network. The transmission rate varies between 1.2 and 3.1 MByte/sec, the performance is lower by factor three to four for small files. From the long distance tests between Europe and USA we can conclude that the Internet provides a sufficient bandwidth to transmit AMS-02 data from MSFC to CERN. It was observed that the input and output rate was not the same for all centers. Although in theory the data transfer should be at the same rate in both ways, a discrepancy was found. This could be due to writing to slower disks or WAN rerouting in star points.

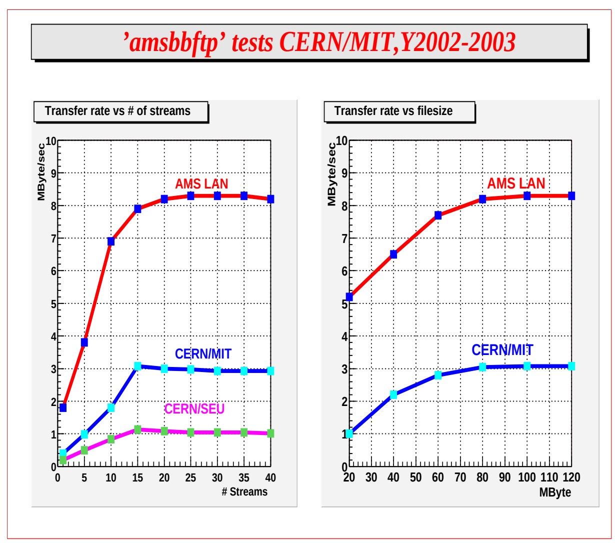

Figure 3: Transfer rate vs number of streams and file size

[1] Payload Operations and Integration Center at MSFC, Huntsville, Alabama

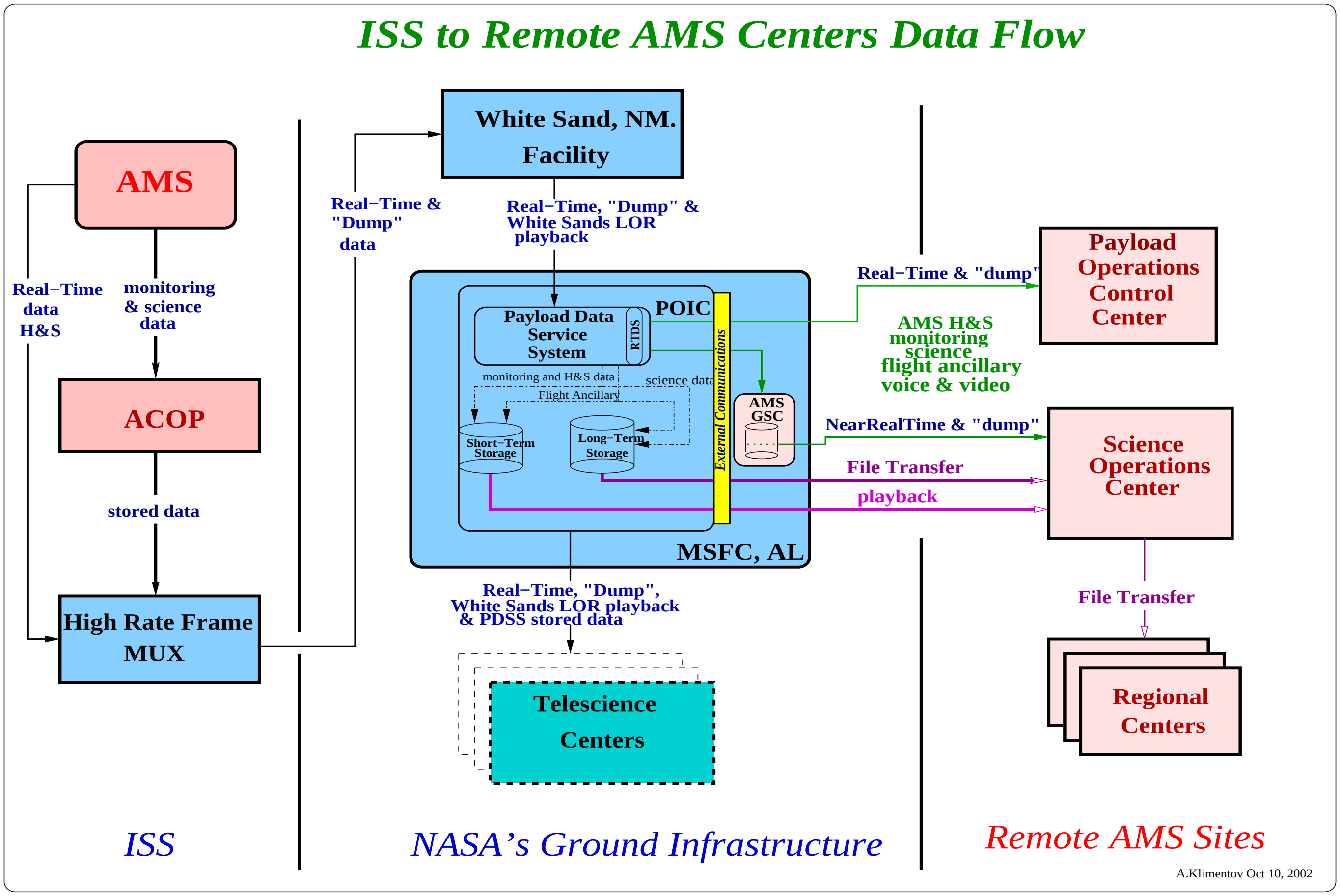

Figure 2: AMS Data Flow

AMS DISTRIBUTED DATA PRODUCTION SYSTEM

Computer simulation of the detector response is a good possibility to study not only detector performance, but also to test hardware and software solutions that will be used for AMS-02 data processing. Due to a large required statistics an enormous CPU time is needed. It is practically impossible to do MC simulation using computing facilities of a single center, even if it is as large as CERN. Data are thus generated in different geographical locations, transmitted to the central repository and then available for the analysis.

The AMS distributed production system uses CORBA client/server technology for interprocess communication. The system was designed to minimize human intervention during data processing and to use remote computing facilities for data production.

The system is built around a central relational database which stores all the relevant information, the description of regional centers and their computing facilities, authorized users, jobs parameters, files catalogs, version of programs and executable files. Currently we are using *Oracle*, but we also successfully tested MC production with *mySQL*, the database driver is defined at startup time. The access to database and repository is provided via Web interface, production control and monitoring is also implemented via Web. There are two types of processes, *servers* and *producers (clients)*. Data processing is done by *producers*, *servers* provide access to the database, control *clients*, and do book-keeping. To achieve greater flexibility different modes of operation are implemented:

- Local automated mode. This mode, which is implemented at CERN, allows all the production (and processing) to be done without human intervention as soon as simulated data requirements are defined, put into database and the first server is started. The computer to start client(s) is chosen automatically, based on host resource information (CPU-clock, memory size, number of active processes). The *producer* requests from the *server* calibration constants, slow control corrections and service information (e.g. the path to disk where data files will be stored) and then starts event by event processing. The *server* keeps the table of running *clients* and hosts, number of processed events and runs, updates hosts and job status tables, starts/stops *clients*. The *database server* process handles all interactions with the database. This allows to reduce the number of processes accessing database and to keep production system independent from the

Table 1: *bbftp* performance

Source	Destination	Nominal BandWidth MBit/sec	Test duration (hours)	Max Rate MBit/sec
CERN	CERN	100	24	66.3
CERN	Milan	100/16/100	13	8.0
CERN	MIT	100/255/100	12x3	24.8
MIT	CERN	100/255/100	12x3	24.8
CERN	MSFC Al	10/255/10	24x2	9.5
MSFC Al	CERN	10/255/10	24x2	9.5
CERN	SEU Nanjing	100/255/10	12x3	11.2
SEU Nanjing	CERN	100/255/10	12x3	9.2

type of relational database.

- Remote automated mode. In this mode, implemented in all regional centers which have reasonably fast connections to the Internet, the job description files are generated by request of a remote user via the web interface. The user submits the job description files to a regional batch queuing system. The client-server interaction as well as data transfers are essentially the same as with the "Local automated mode".

- Standalone mode. Used in some regional centers with poor network connectivity or behind dedicated firewalls. The job description files are generated by request of a remote user the via web interface. The user receives them together with a stripped database version and submits jobs on his own computing facilities. *Producers* do not communicate with central servers during job execution and the user is responsible for data (and log file) transmission to CERN. A dedicated program parses log files, validates data and updates the database.

CONCLUSIONS

The AMS-02 distributed data processing concept has been successfully tested. The data production software has proven to be stable and to deliver 95% performance for periods of months. A Monte-Carlo distributed production is in progress with remote sites in Europe, USA and Asia (more than 10 TB of data has been generated in 19 centers and transmitted to CERN).

Data transfer via `amsbbftp` is efficient and reliable between USA and Europe via public Internet, currently it is used to transmit Monte-Carlo data.

REFERENCES

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