AIAA 2010-2177

Adaption of the Col-CC Integrated Management System to the new MPLS network

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The Integrated Management System (IMS) in the Columbus Control Center (Col-CC) is software capable of monitoring and commanding almost all of the subsystems of the complex Columbus Ground Segment. One of the subsystems monitored is the IGS network (Interconnection Ground Subnetwork). This network provides the basis for communication between Col-CC and its international partners (NASA, ESA, ATV-CC, etc.) and all user support and operations centers (USOCs) across Europe. The IGS network was originally designed to use ATM technology, but due to cost reductions many centers were connected via ISDN. Since last year the ATM and ISDN technology was replaced by a MPLS (Multiprotocol Label Switching) network. The migration from ATM/ISDN to MPLS implies a lot of configuration and testing work within the Integrated Management System (IMS) in parallel to real-time operations. In the ATM/ISDN network the IMS was configured to monitor the ATM/ISDN connections and to start/stop the ISDN lines towards the remote user centers (USOCs) in order to maintain the costs under control. In the MPLS network the main focus is on monitoring the IGS network since start/stop of connections is not necessary anymore. The paper deals with the changes in the monitoring and commanding approach and the comparison of the different monitoring issues. Focus is on the subsystems of Col-CC, which were affected by the MPLS migration: The IGS network itself (including the WAN monitoring), the Voice System (VoCS) and the Video System (MVDS).

Nomenclature

ATM	=	Asynchronous Transfer Mode
ATV-CC	=	Automated Transfer Vehicle Control Center
BRI	=	Basic Rate Interface
B-USOC	=	Belgian User and Support Operations Center
Col-CC	=	Columbus Control Center
DaSS	=	Data Service Subsystem
FCT	=	Flight Control Team
GCT	=	Ground Control Team
GSOC	=	German Space Operations Center
GUI	=	Graphical User Interface
HOSC	=	Huntsville Operation Support Center
IGS	=	Interconnection Ground Subnetwork
IMS	=	Integrated Management System
ISDN	=	Integrated Services Digital Network
MARS	=	Microgravity and Advanced Research Center
MCC-H	=	Mission Control Center Houston
MCC-M	=	Mission Control Center Moscow
MPLS	=	Multiprotocol Label Switching
MUSC	=	Microgravity User Support Center
MVDS	=	MPEG2 Video Distribution Subsystem

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SNMP = Simple Network Management Protocol
SSE = Subsystem Engineer
USOC = User Support and Operations Center
VoCS = Voice Communication System
WAN = Wide Area Network
VoCS = Voice Communication Subsystem
VoIP = Voice over IP

I. Introduction

THE German Space Operations Center (GSOC) is part of the German Aerospace Center (DLR) and is located in Oberpfaffenhofen, near Munich, Germany. The tasks of the GSOC comprise satellite missions for earth observation, communication, reconnaissance and exploration of the solar system as well as human spaceflight missions.

Since February 2008 the European Columbus research module is attached to the International Space Station (ISS). The Columbus laboratory is used for various experiments which require zero gravity and is operated by the Columbus Control Center (Col-CC). The Col-CC is integrated in the GSOC and responsible for the operation of the Columbus space and ground segment.

Space segment operations include controlling of power, thermal and environmental subsystems as well as running various science instruments installed in different payload racks of the Columbus module.

The Columbus Ground Segment consists in the infrastructure needed locally in the Col-CC and it provides the infrastructure needed for the research network which connects researchers remotely (in User Support and Operations Centers, USOC) with the Col-CC. Furthermore, the Ground Segment enables the connection of the Col-CC with its

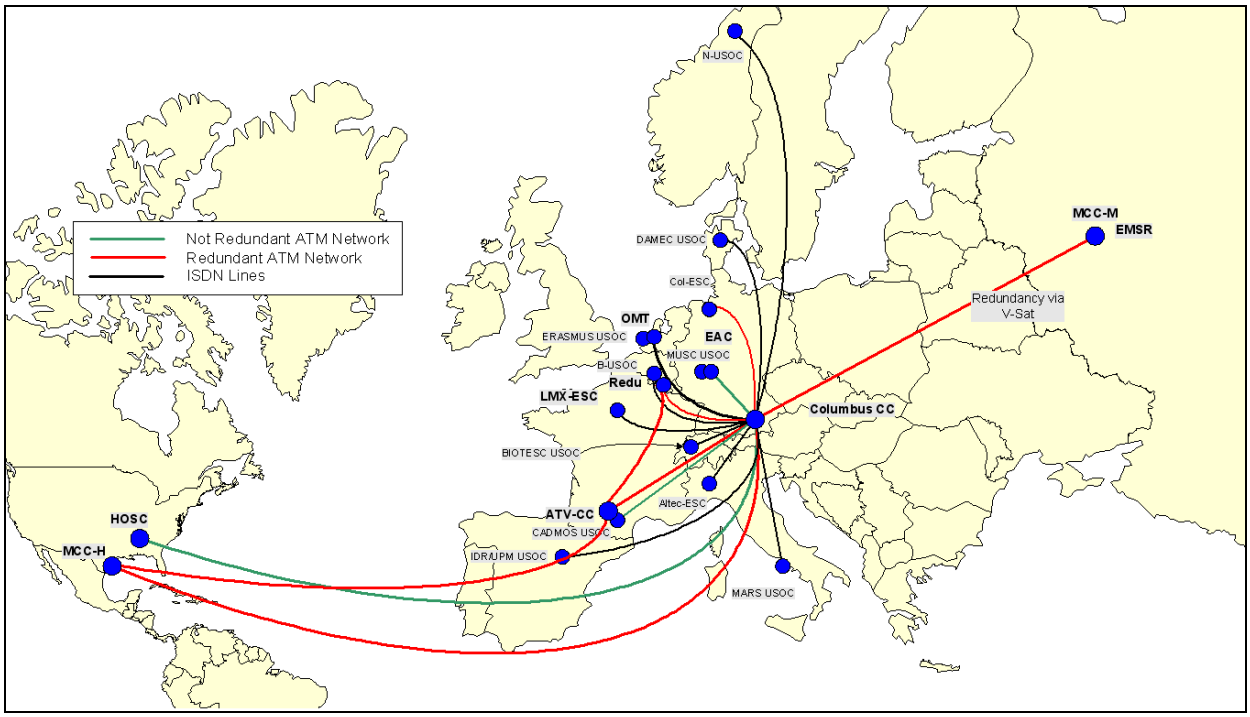

Figure 1. The Columbus Ground Segment. *The Columbus Ground Segment connects the Columbus Control Center (Col-CC) to its international partners andto the User Support and Operations Centers (USOC).*

international partners and European control centers. The Ground Segment has a star-like topology with a central node at Col-CC. Figure 1 gives an overview of the Columbus Ground Segment.

While the Flight Control Team (FCT) is in charge of controlling the space segment of the Columbus module the Ground Control Team (GCT) is responsible for the ground infrastructure. As the FCT also the GCT is operating on a 24/7 basis. All subsystems of the Col-CC are controlled by the GCT from the Ground Operations Control Room. The subsystem engineers (SSE) at Col-CC are available on an 8/5 basis only. Hence, due to a lack of engineering presence a management system was needed to help the GCT in order to support the continuous operations.

In the design phase of the Col-CC it was decided not to control and monitor every subsystem separately from its own console but to integrate the management of the various subsystems under a single umbrella management subsystem: The Integrated Management System (IMS). This is a customized software designed to support the daily work of Ground Controllers (GCs) and System Controllers (SysCons) at Col-CC. In Ref. 1 a general overview of the IMS is provided and the monitoring and commanding of all subsystems at Col-CC is taken into account.

The IMS gathers subsystem status information, allows commanding of subsystems and enables a notification service from the subsystems towards the IMS. The communication between the subsystems and the IMS is performed via so-called element managers. The element managers are part of the subsystems and act as the central point for the IMS to connect to. Via SNMP or similar technologies the element managers poll data from or send commands to devices of a subsystem. The element managers provide an interface for data and commands towards the IMS.

The IMS is designed to rebuild both the subsystems and the ground segment infrastructure using various graphical displays (GUIs – graphical user interfaces). The status data gathered from the element managers are shown on the graphical displays. As shown in Fig. 2 the IMS gives an overview on the Columbus Ground Segment. The

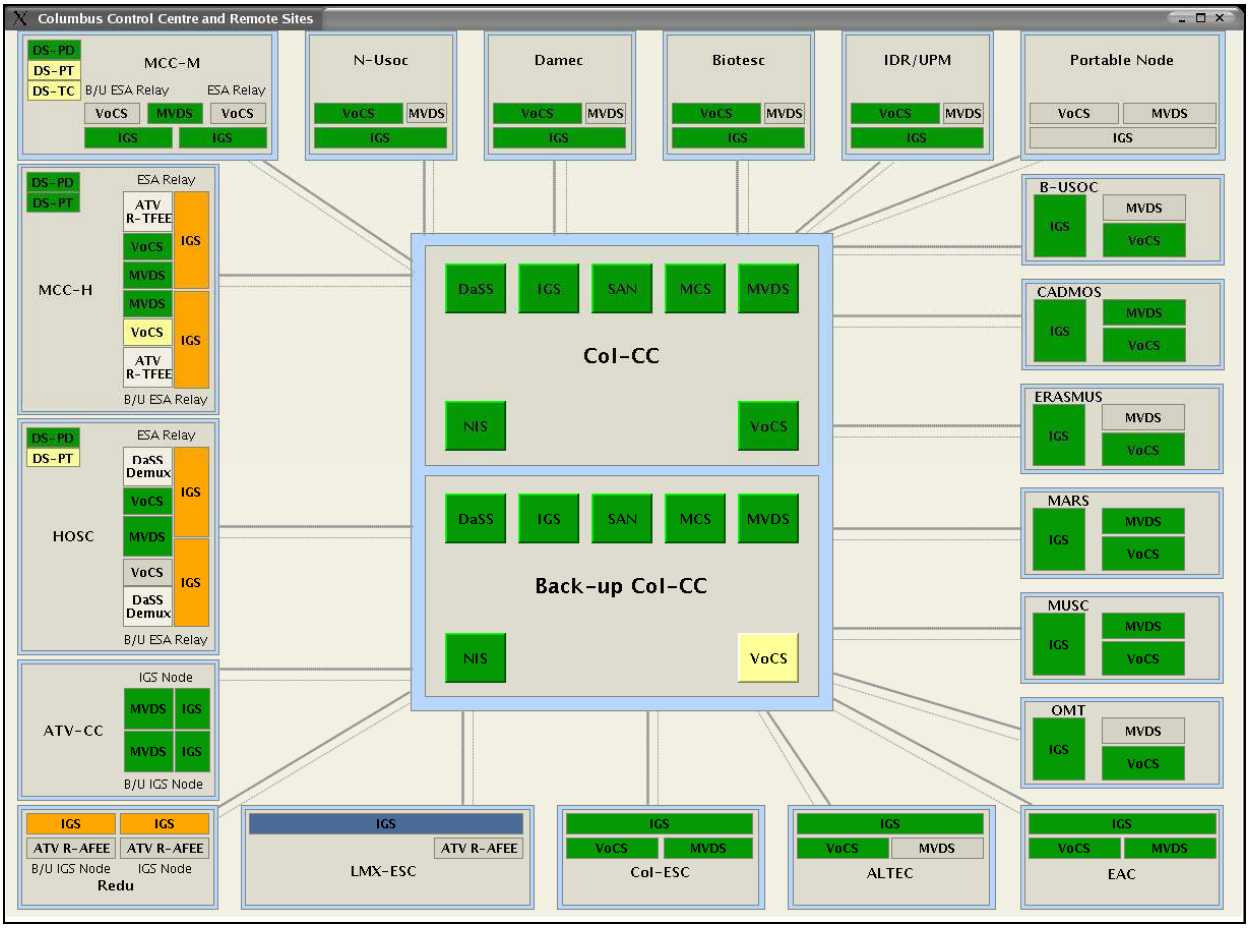

Figure 2. The IMS overview of the Columbus Ground Segment. *The IMS overview of the Columbus Ground Segment shows the different sites connected to the Columbus Control Center (Col-CC). Legend: green – nominal; yellow – standby; orange – warning; red – alarm; blue – not connected.*

Col-CC and its backup facility are located in the middle of the display. Status information of the Col-CC subsystems (DaSS, IGS, SAN, etc.) is provided via status buttons. Remote sites connected to the Col-CC are also included in the display. Via status buttons the current status of the remote site is shown. The status of a remote site consists in different areas, i.e. the IGS part, the VoCS (Voice) part or the MVDS (Video) part. By clicking on any status button another display will open and more detailed information is provided. For example, by clicking on the orange IGS status button at MCC-H (Fig. 2) the detailed display of the IGS part at MCC-H may show a problem with a network device at MCC-H.

II. Requirements for IGS network monitoring in IMS

For communication, transfer of data and commanding a ground network is needed to connect the Columbus Control Center to its international partners and to the scientific users (i.e. User Support and Operations Center – USOC). For this purpose a WAN network was set up between all sites which is called the Interconnection Ground Subnetwork (IGS).

The IGS network consists in data lines which are provided by national telecommunication companies and in so-called IGS relays or IGS nodes which are located in the premises of the international partners (IGS relay, redundant configuration) or USOCs (IGS node, single or redundant configuration). From the technical point of view the IGS relays and nodes are identical apart from its single or redundant design. Hereafter they are referred to as IGS node. The IGS node is an assembly of routers, switches, network cables, etc. which provides connectivity of a remote site to the IGS network. The IGS node divides the data from the IGS network into different data flows used for operations: operational data, operation-support data, video data and voice data. At Col-CC a so-called IGS Central Node is installed where all data lines terminate from remote sites. Concerning the data lines two different technologies were applied for the IGS network: ISDN and ATM. Originally the IGS network was designed to use only ATM technology to connect all remote IGS nodes to the Central Node at Col-CC and the ISDN lines were foreseen as backup solution. But due to cost reduction it was necessary to switch to ISDN connections for smaller sites (mainly USOCs).

On the consoles in the Ground Operations Control Room at Col-CC the operator monitors the IGS network in order to check the correct status and to react in case of failures. For this task the Integrated Monitoring System provides various displays which show the status of the Central Node at Col-CC as well as the status of the IGS nodes at remote sites. Figure 3 shows the monitoring display of the Central Node at Col-CC with all monitored network equipment. The Central Node is implemented with prime and backup devices.

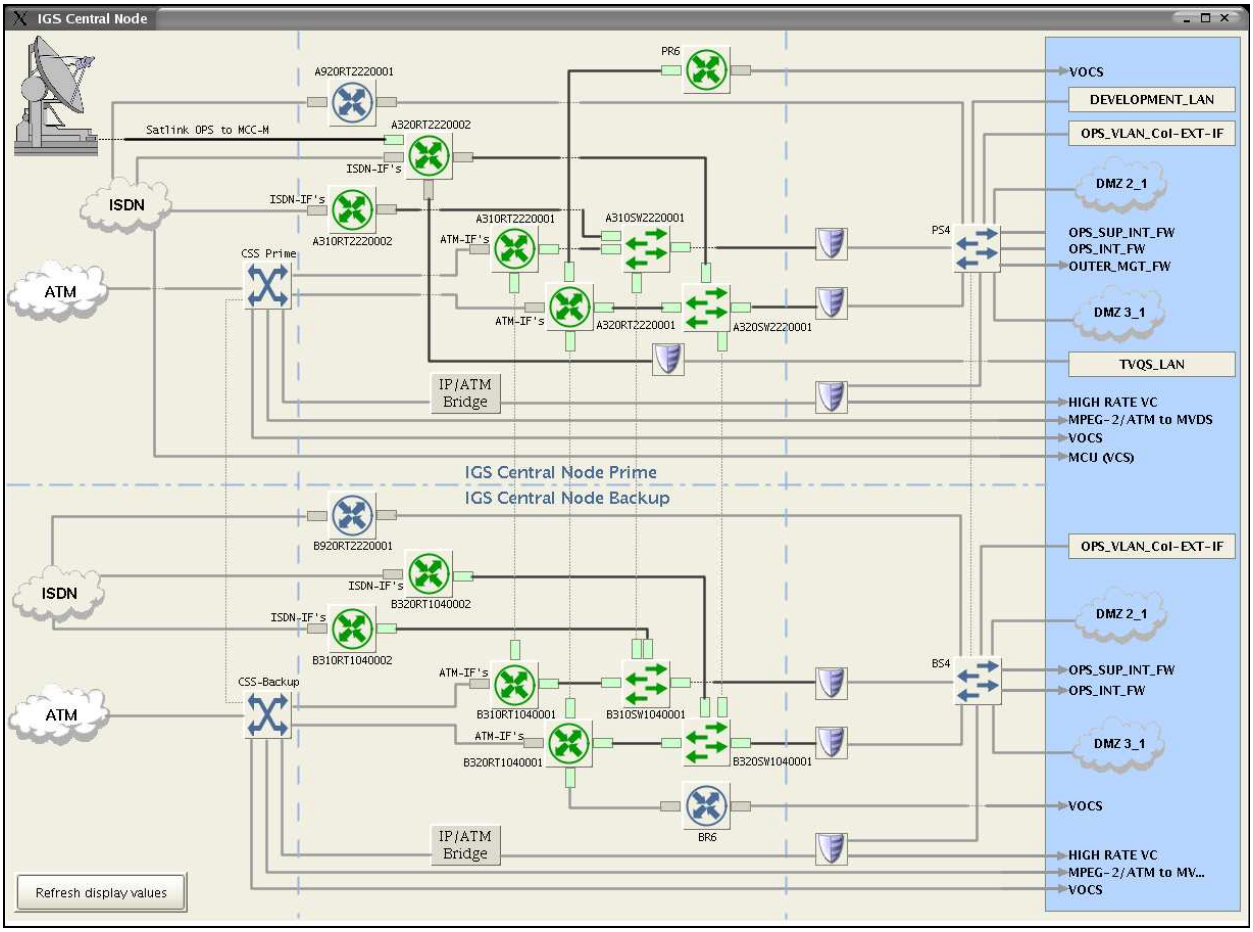

Figure 3. Monitoring display of the Central Node at Col-CC. *Various network devices are monitored and status information is provided to the operator on console. Legend: green – nominal; blue – not monitored; black lines – connected; grey lines – not monitored.*

The IGS nodes at remote sites are shown in separate displays in the IMS. In Fig. 4 two examples of IGS node monitoring are given: The monitoring of the Belgian USOC (B-USOC) which is connected only via ISDN and monitoring of the Italian remote site MARS which is connected via ATM and ISDN (for backup).

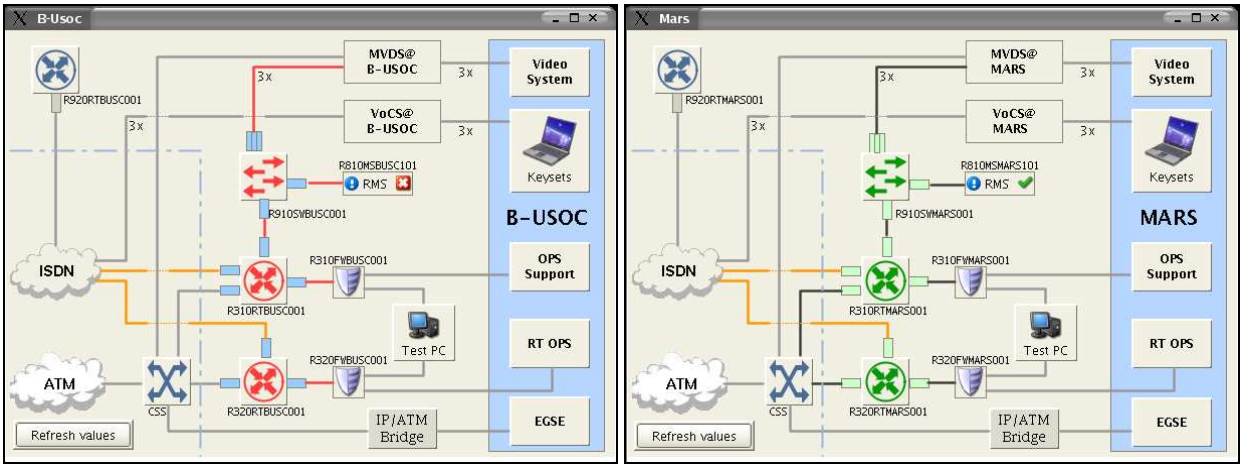

Figure 4. Monitoring display of remote sites B-USOC and MARS. *The left display shows the IGS node monitoring of the Belgian USOC (all ISDN lines are not activated at the moment) and on the right display the IGS node monitoring of the Italian remote site MARS is shown (currently connected via ATM; ISDN lines are not activated). Legend: green – nominal; red – alarm; blue – not monitored; black lines – connected; orange lines – not active; grey lines – not monitored.*

The data displayed in IMS are provided by so-called L1 servers, which act as element managers in the IGS network. The L1 servers mainly use SNMP in order to poll status data or to send commands to the devices in the IGS node. For each IGS node a rack monitoring system (RMS) is installed in order to monitor important parameters of the rack in which the IGS node equipment is located. For example the temperature of the IGS rack is checked regularly. If a certain threshold of the temperature is exceeded an alarm is shown to the operator on console at Col-CC.

The remote sites of international partners (MCC-H, MCC-M, HOSC, ATV-CC) and some more remote sites are permanently connected to the Col-CC via ATM data lines. Towards USOCs only ISDN lines are available. The ISDN lines are brought up only if a connection to the USOC is needed (i.e. for data transfer or voice communication). If the ISDN lines are not needed they are disabled in order to keep connection costs under control. The management of the ISDN lines is a task of the operator on console at Col-CC. The operator uses the IMS in order to check, bring up or disable the ISDN lines. In the IMS a script server is available on which scripts can be activated by the operator which then directly command the interfaces of the ISDN router.

In Fig. 5 the ISDN overview display is shown where all connections to remote sites are monitored. Two different ISDN connections to a remote site are possible: the operational data line (OPS) and the operation-support data line (OPS-SUP).

In the middle of Fig. 5 the Col.-CC ISDN router assembly in the IGS Central Node is visible which is diveded into two OPS and two OPS-SUP routers (prime and backup). Marked with “IF” the ISDN interfaces are drawn which can be down (orange), up (green) or not monitored (blue). In this example a ISDN line is active which provides OPS data. The connection is established from the Col-CC backup ISDN router to the remote site ERASMUS. The remote sites which have a green interface status (MCC-H, HOSC, etc.) are permanently connected via ATM (ISDN is foreseen only for backup). Due to the available monitoring path via ATM connections it is possible to get status data of the remote ISDN interfaces. Consequently, it is not possible to get status information from the remote sites which have only ISDN lines (MUSC, MARS, CADMOS, etc.). These sites have blue ISDN interfaces in Fig. 5.

For each remote site a couple of buttons in available to the operator in order to check, bring up or bring down the ISDN lines which are evident from Fig. 5. The upper row of buttons is used for the OPS lines and the lower one for the OPS-SUP lines.

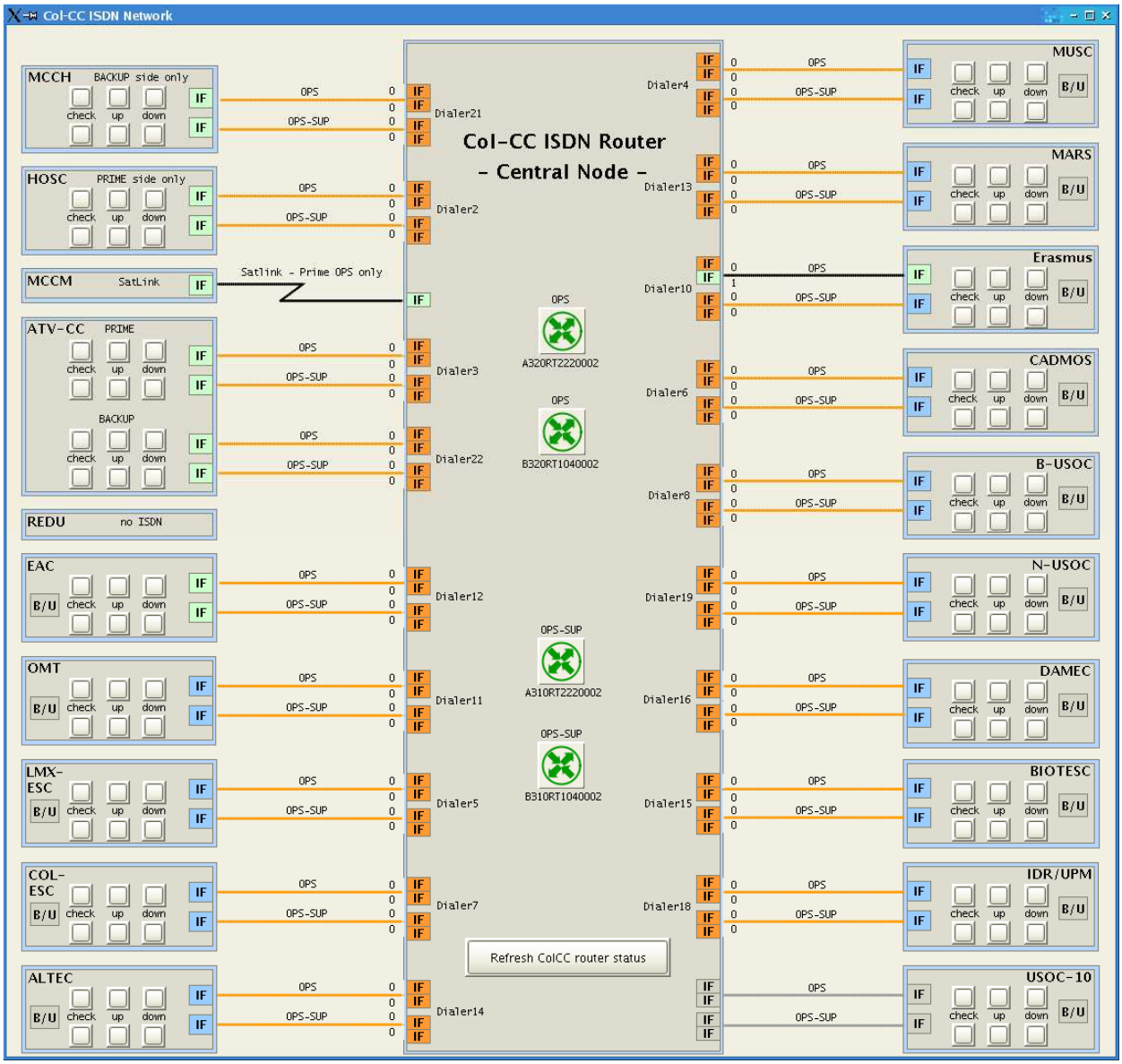

Figure 5. The ISDN overview in IMS. *The ISDN overview shows the connection status of ISDN lines towards remote sites and allows to manage them. Legend: orange – down; green - up; blue – not monitored; orange line – connection not established; black line – connection established.*

In order to allow the operators at the remote site to obtain a status of their IGS node a display is available via the so-called Web Export of the IMS. Through a dedicated http connection to the Col-CC a remote site gets a graphical display which can be accessed with a standard web browser. The display contains the same content which is available for the operator at Col-CC in IMS.

Since the operator uses the IMS not only for IGS monitoring and commanding, but also for monitoring of other subsystems (voice, video, data, etc.) not all IGS displays can be shown at the same time. In order to overcome this problem a general status bar is permanently shown on the IMS screens. The status bar contains overall status buttons for each subsystem at Col-CC as well as overall status buttons of every remote site with its IGS node. In this way the operator is able to monitor several subsystems and remote sites at once. The overall status of a subsystem or a remote site is determined by calculation of a derived parameter status from several important realtime parameters. In

the design phase of the IMS it was specified which realtime parameters of a subsystem or a remote site are essential to be part of a derived sum parameter.

Figure 6 shows the IMS status bar with the current status information: several subsystems are in warning (orange) or alarm (red) state and some remote sites are nominal (green) and some are not connected (blue).

Figure 6. The IMS status bar. *The IMS status bar allows to obtain an overall status information on subsystems or remote sites at once. Legend: green – nominal; orange – warning; red – alarm; blue – not connected; yellow – standby.*

III. Transition of the IGS network to MPLS technology

During the course of the Columbus project it was decided to migrate the IGS network from ISDN/ATM to a new transmission technology for several reasons: provision of higher bandwidth to the remote sites (especially to the USOCs), reduction of connection costs (especially ISDN connections) and update of the ageing ATM technology which may not be provided much longer. Several concepts were studied in detail and in the end it was found that the MPLS technology (Multiprotocol Label Switching) fits best to the specifications for a new transmission technology.

The principle of the MPLS technology is not part of this paper but can be found in literature. Concerning the implementation of MPLS at Col-CC an overview and a detailed technical description are given in Ref. 2.

In the Integrated Management System IMS the monitoring concept of the IGS network remains unchanged for transition to MPLS. The L1 servers still act as element managers and collect data from the IGS nodes. Since ISDN lines are not longer available in the IGS network the commanding functionality is disabled for these lines via the script server in IMS. The MPLS connections to the remote sites are permanently up and so it is not necessary for the operator to manage the data lines.

However, the IMS displays had to be adapted to the new configuration of the MPLS network. For every IGS node various devices for ATM or ISDN had to be removed, i.e. the ATM CSS (Customer Service Switch), the IP/ATM bridge and the ISDN router at Col-CC. The MPLS lines from the local telecommunication company terminate at the IGS node in so-called CE-routers (Customer Edge routers) now. In this CE-router the data flow is divided into three sub streams, i.e. operational data, operation-support data and high-rate data. The high-rate data is used for high-rate data transmission mainly for the Data Service Subsystem (DaSS) at Col-CC. The CE-router offers an SNMP interface which is used for status data polling via the L1 servers.

Figure 7 shows the updated IMS display for the IGS Central Node at Col-CC. The devices necessary for ISDN and ATM connections are still present in the IMS display since ATM is needed for the connection to MCC-H and the ISDN BRI (basic rate interface) is still used for out-of-band management. The CE-routers for MPLS are added to the IMS display and their status is monitored. In the ATM network it was not possible to monitor the Customer Service Switch (CSS) and the associated data lines, but for the MPLS network it is possible to get status information both on the CE-router and on the data lines. Furthermore a separate data line for high-rate data (HR) is now present and monitored additionally to the existing operational (OPS) and operation-support (OPS-SUP) data lines. For the voice subsystem two VoIP boxes (Voice over IP) were added which will be described later in the course of this chapter.

Concerning the migration of remote sites to MPLS in Fig. 8 the IMS displays are shown in which both examples from Fig. 4 are adapted to the new MPLS configuration. The ISDN/ATM equipment was removed, apart from the ISDN router which is still used for out-of-band management. The CE-router was added and monitoring information for the MPLS equipment was made available. For the MARS remote site the high rate (HR) data line was made available and it is monitored in the IMS display. Moreover, the video devices were updated (decoder, encoder) and associated data lines adapted. For all remote sites a VoIP box was added to allow monitoring of VoIP devices for the voice subsystem.

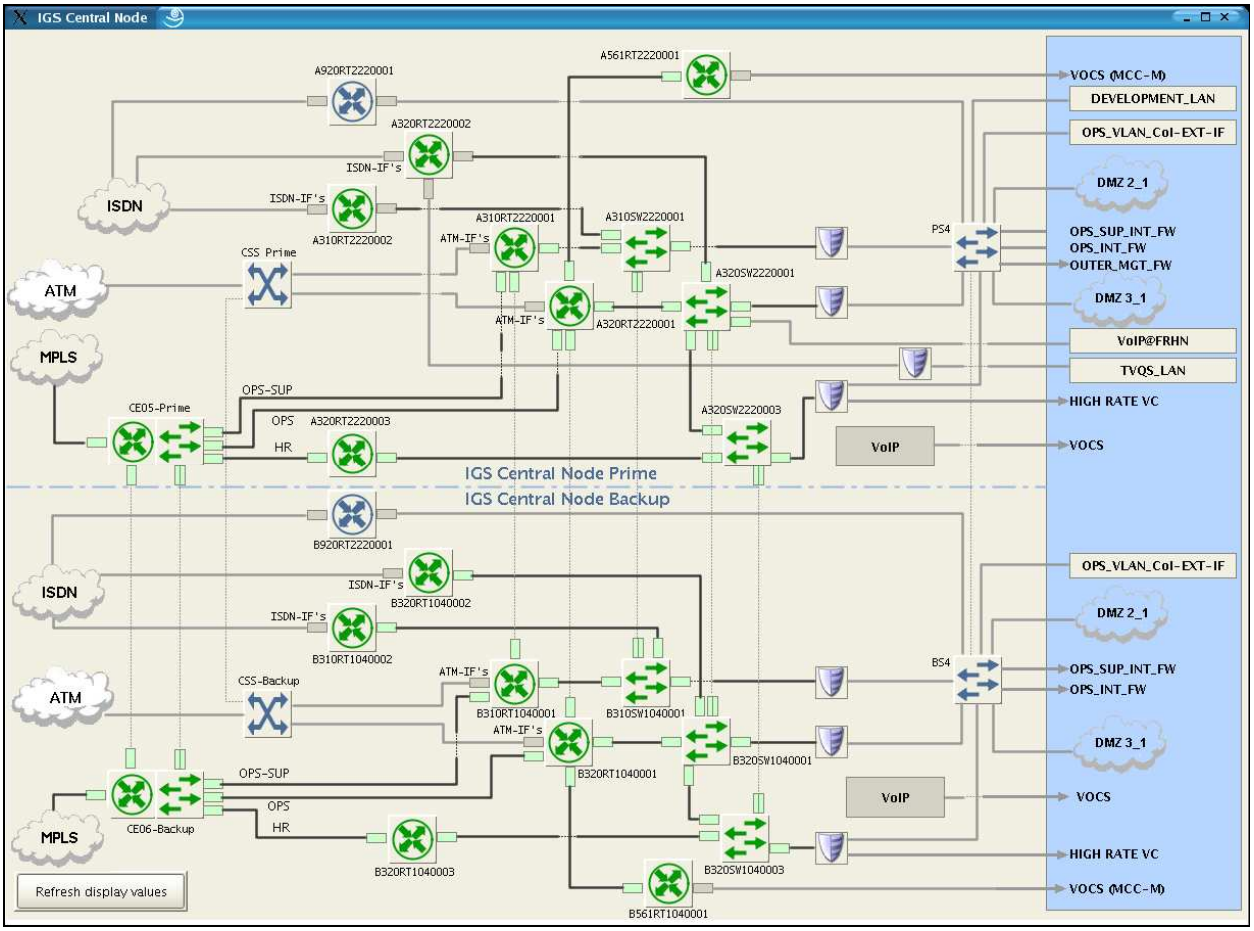

Figure 7. Updated monitoring display of the Central Node at Col-CC reflecting the new MPLS configuration. *Various network devices are monitored and status information is provided to the operator on console. Legend: green – nominal; blue – not monitored; black lines – connected; grey lines – not monitored.*

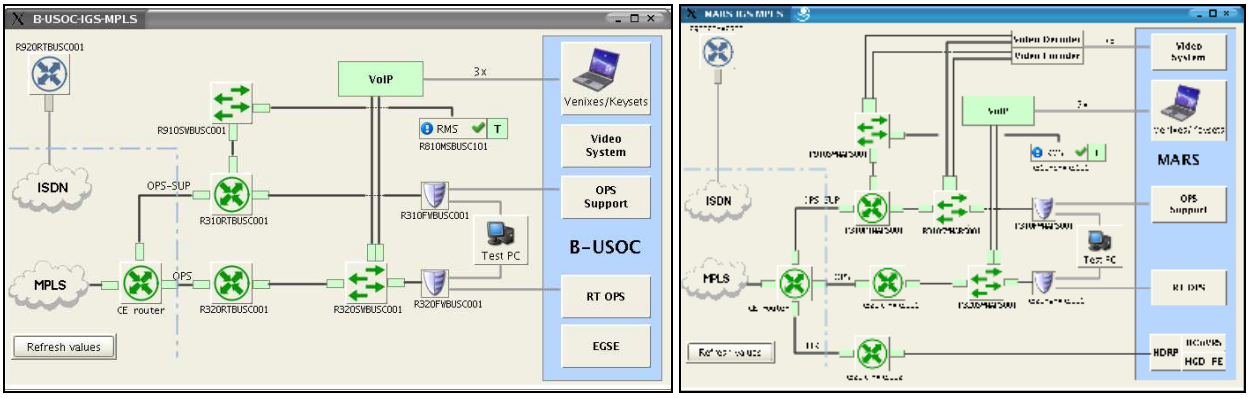

Figure 8. Updated monitoring display of remote sites B-USOC and MARS. *The left display shows the IGS node monitoring of the Belgian USOC and on the right display the IGS node monitoring of the Italian remote site MARS is shown. Legend: green – nominal; blue – not monitored; black lines – connected; grey lines – not monitored.*

As already described the Voice Communication Subsystem (VoCS) was affected by the MPLS migration. The VoCS is operated in order to allow voice communication between Col-CC and remote sites. The voice subsystem was based on ATM and ISDN technology with an underlying ethernet network. After the transition to MPLS which is based on IP the voice subsystem had to be reconfigured.

In Fig. 9 the original and the updated VoCS displays in IMS are shown for the German USOC MUSC. For converting the IP stream of MPLS to an ethernet stream additional devices had to be installed. They are shown in the right display in Fig. 9. For these devices new status information probes were created and added to the IMS displays. The sum parameter of the additional devices is shown as a VoIP box in the general IGS display (see Fig. 8).

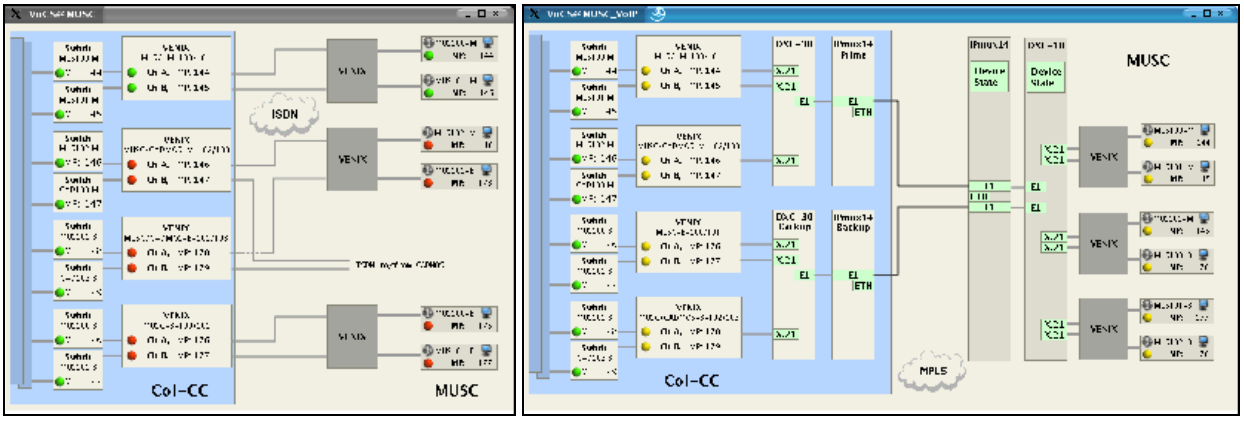

Figure 9. Original and updated VoCS monitoring display of the German remote site MUSC. *The left display shows the original VoCS monitoring based on ISDN; on the right display the updated VoCS monitoring based on MPLS with additional devices is shown. Legend: green – nominal; yellow – standby; red – switched off; black lines – connected; grey lines – not monitored.*

Also the video subsystem at Col-CC (MVDS – MPEG2 Video Distribution Subsystem) was affected by the transition to MPLS. Various equipment could be used only for ATM and ISDN connections and had to be replaced. Similar to the voice subsystem several devices could not be used with the MPLS technology and became obsolete both at Col-CC and at remote sites. The MVDS monitoring displays in IMS had to be updated to reflect the new MPLS configuration.

The Web Export functionality in IMS offered to various remote sites is available also for the MPLS network. The IMS Web Export displays were adapted and are accessible for remote sites with the new MPLS configuration of the IGS network.

IV. Roll-out of the new MPLS configuration

In the beginning of the MPLS migration project at Col-CC a test facility was established in order to test the MPLS technology on a dedicated network and evaluate if subsystems have significant problems with it. After successful tests a roll-out plan was prepared. The roll-out plan determined the order of substitution of old devices with new ones and the order of migration of the different Col-CC subsystems.

The main challenge was to implement the MPLS technology in parallel with real-time operations. It was essential not to interrupt data lines currently in use and coordinate required interruptions with all parties involved. For IMS it was important to provide to the operator on console in parallel both monitoring of the old ATM/ISDN network and of the new MPLS network. The actual transition period of IGS nodes at Col-CC and remote sites was roughly half a year, in which successively remote sites were migrated to MPLS. For the entire transition period the Central Node at Col-CC had to retain all interface types towards the remote sites: ATM, ISDN and MPLS. So the IMS display for the Central Node was adapted in a way that monitoring of both ATM/ISDN and MPLS equipment was provided. With this configuration it was possible to detect potential failures in IGS network concerning all utilized devices. In Fig. 7 the main elements of the parallel monitoring of ISDN/ATM and MPLS are still shown since ATM is still used for MCC-M. The transition of MCC-M to MPLS is not yet finished.

In the ISDN overview display (Fig. 5) the monitoring of the ISDN lines was successively disabled and marked for the operator as “not in use”. Furthermore the buttons for bringing up and down ISDN lines were deactivated.

After completion of the MPLS transition all affected ground control procedures had to be adapted to the new configuration. Especially the extended monitoring of network devices (CE-router and associated data lines) required new procedures for the Ground Control Team (GCT).

Via a dedicated message display in IMS it is possible to show messages to the operator on console. After the MPLS transition the message display was adapted to receive notifications from the new MPLS devices. So it is possible to provide to the operator the content of messages which are sent from MPLS equipment in case of errors or malfunction (so-called SNMPtraps).

V. Conclusion

This paper presented the main aspects of the adaption of the Integrated Management System (IMS) due to the migration of the Col-CC Ground Segment from ATM/ISDN to MPLS network technology. The Integrated Management System allows the Ground Control Team (GCT) to monitor and command various subsystems in the Col-CC Ground Segment including the network between the Col-CC and the remote sites. As a result of the change of the network transmission technology several devices in subsystems had to be replaced and network equipment had to be adapted. For the IMS this implied the adaption of its monitoring displays in order to provide to the GCT a correct and reliable monitoring tool. A challenging task was to provide to the Ground Control Team a parallel monitoring of ATM, ISDN and MPLS during the transition period.

In the course of the paper several examples of graphical user interfaces (GUIs) were given to illustrate IMS displays before and after the MPLS migration.

A possible enhancement for the MPLS monitoring in the Integrated Management System would be to set up a more detailed monitoring of the CE-routers (Customer Edge routers) in order to improve the monitoring of these devices. Furthermore is it planned to implement a warning or alarm status in IMS if at a redundant remote site a double failure of two CE routers occurs. Currently the reporting functionality in IMS is updated in order to allow the generation of statistics on MPLS usage, traffic and availability of the IGS network.

References

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[2]Maly, S., “From ATM/ISDN to MPLS – Transition of the Columbus Interconnection Ground Segment Network”, Proceedings of the SpaceOps 2010 Conference (to be published).