SpaceOps-2023, ID # 648

Development of mission control centres for the 21st Century

Dipl. Ing. Joerg Schmittroth and Kevin Marston

European Organisation for the Exploitation of Meteorological Satellites, Eumetsat Allee 1, 64295 Darmstadt, Germany, www.eumetsat.int

Abstract

This is the journey from EUMETSATs first dedicated single mission control centre through to today's multi mission control centres with a view into the 21st century.

EUMETSAT is an intergovernmental organisation with 30 Member States, monitoring weather and climate from space with ground systems across Europe and corporations across the globe.

It all started with the METEOSAT Geostationary Orbit satellites, which were supported by dedicated ground stations and ground segments. The control centre was built for the program and consisted fundamentally of a single operational environment. Bulky monitor and control computer hardware and CRT screens were fitted into large Star Trek-like, heavy load consoles.

Moving forward to today, EUMETSAT has a wide variety of satellite programs, supported by associated ground stations and ground segments. Archive and distribution of own data and data from partner organisation is monitored and controlled from the two multi-mission Geostationary Orbit and Low Earth Orbit Mission Control Centres.

The implementation of these Mission Control Centres requires a highly flexible setup to incorporate new control systems, additional new or recurrent satellites and satellite sub-systems. At the same time, it is necessary to maximise the usage of the given real estate which will not increase, even as the number of missions grows.

The journey continues, improvements will include the removal of the Geostationary Orbit and Low Earth Orbit floor separation. It will be possible to use all the ovals for any program. With this, a further roll out of video connectivity from our remote monitoring control centres at Spain and Italy could be easily established. Pending security, control could be handed over to other EUMETSAT external sites such as the remote control centres, with a consequent improvement in the associated business continuity model.

The next generation of EUMETSAT and Copernicus satellites will be more autonomous with less need of continues commanding. It will be possible to share the control centre ovals across multiple programs with sophisticated scheduling and login systems.

Acronyms/Abbreviations

EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GEO	Geostationary Orbit

LEO	Low Earth Orbit
MCCs	Mission Control Centres
RMCCs	Remote Mission Control Centres
OECR	Operational Evacuation Co-ordination Room
OSR	Operational Support Room
MEX	Mission Extension Room

1. Introduction

This paper describes the journey that took the EUMETSAT control rooms into the 21st Century, from the identification of the key user requirements, approach to the implementation, lessons learned along the way, as well as the drivers to ensure that the Organisation has a set of modern efficient operational Mission Control Centres that meets the needs for the years to come.

2. EUMETSAT Control Centres History

It all started with the METEOSAT Geostationary Orbit satellites, which were supported by dedicated ground stations and ground segments. The control centre was built for the program and consisted fundamentally of a single operational environment. Bulky monitor and control computer hardware and CRT screens were fitted into large Star Trek-like, heavy load consoles (see Fig.1).

(Fig. 1) METEOSAT First Generation Control Centre @ 1995

The workplaces for each of the different functions (such as spacecraft monitoring and control, ground stations or mission data and product end-to-end monitoring and management), were at fixed locations - the controllers had to move physically to each of the locations for their monitor and control. Hardware and room infrastructure required significant electrical power as well as energy for cooling. Introducing additional satellites or new mission functions resulted in a physical hardware move from one location to another plus the addition of more consoles which was still in 2015 the case (see Fig.2).

(Fig.2) EUMETSAT METEOSAT Second Generation Control Centre @ 2015

Each function had its dedicated computer system, operating system, application, screen resolution, keyboard & mouse and alarming system - hence no commonality.

Instructions and procedures were paper versions, the control of the satellite and systems partially automated with permanent manual commanding. The original METEOSAT satellites were not designed to fly autonomously.

3. Studies and Questionnaires for New Control Centres

EUMETSAT's needs grew rapidly with the introduction of new satellite programmes, the obsolescence of existing operational hardware - the necessary modernisation of infrastructure gave the opportunity to rethink current ways of control centre usage. New, faster, more efficient and advanced technology opened up further ways to change and improve the control centres.

In order to learn and gain experience of what is available on the market and how this could be used for operations, a small team of operations and technical engineering experts from across the departments visited furniture producers, video system showrooms and various fairs, starting in 2012. This was followed by visits at partner organisations, research institutions and control centres from non-space business companies, such as air traffic control.

Due to EUMETSATs long experience in running operational control centres, a questionnaire for teams actively working in the control centres were undertaken in 2015. The inputs were incorporated into the design, room layout and usage of the new real estate.

In-house discussions with house service and all technical departments framed the options and identified practical limits. There were budget constraints, requests to improve the given real estate without expansion, save energy and to follow the evolving health and safety rules.

In parallel, two companies were asked to provide studies on the realisation of the new control centre concept and to provide further ideas and innovation. The companies were linked to the engineering

furnishing industry and video system manufacturers. The goal was that the overall best concept would be the one which could be technically realised and built. The outcome of the studies showed already the idea of the new control centres with curved consoles, OVALs, and video walls (see Fig.3+4).

(Fig.3) Visual Animation by Vertiv - Knürr Consoles & Bilfinger Mauell GmbH @ 2015

(Fig.4) Visual Animation by Jungmann Systemtechnik GmbH & Co. KG @ 2015

Why OVALS and video systems? It was already foreseeable that EUMETSAT would be getting further satellite programs, new satellite and ground segment systems as well as continuation of already running operational programs but with new technology. All those programs come along with own hardware, software, operating systems and applications with a full variety of unique interfaces.

Therefore, one of the main goals identified was to get a common front end in the control centre, such that it would be possible to swap and adjust workplaces according to the needs of growing or shrinking

programs, without timely hardware rearrangement. The controller teams also needed to have a dedicated work area, independent of the technology in the background.

4. Present EUMETSAT Control Centres and Support Rooms

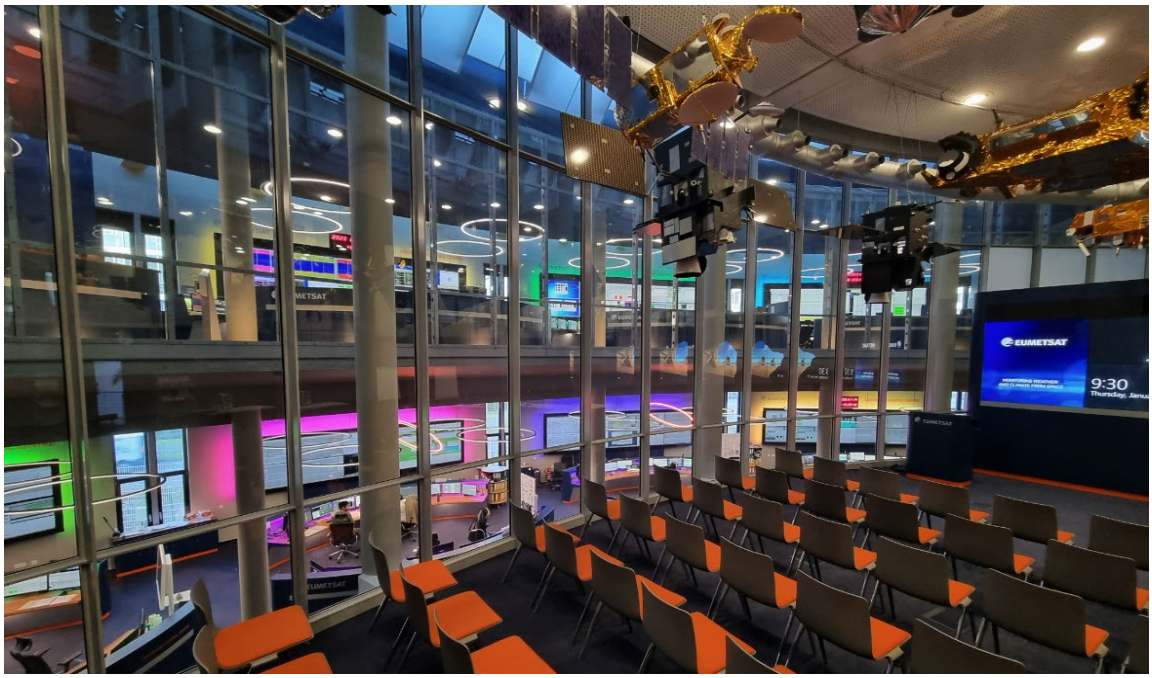
Moving forward to today, EUMETSAT has a wide variety of satellite programs, supported by associated ground stations and ground segments. Archive and distribution of own data and data from partner organisations are monitored and controlled from the two multi-mission Geostationary Orbit and Low Earth Orbit Mission Control Centres.

The implementation of these MCCs requires a highly flexible setup to incorporate new control systems, additional new or recurrent satellites and satellite sub-systems. At the same time, it is necessary to maximise the usage of the given real estate which will not increase, even as the number of missions grows.

4.1 Mission Control Centres

The new control centres consist now of several oval shaped console areas with each an associated sound system and video wall. The ergonomics have also seen a significant improvement, leading to a much leaner and effective working environment. The functions of the control centres themselves were refined such that only operational activities are executed in those rooms, with all other activities such as validation, analyses and testing moved outside, into operations support rooms. For the control centre teams, the open space makes communication between programs and their shared resources (such as ground stations, ground segment and multi mission elements), significantly easier.

Both rooms are transparent and can be viewed from the visitors' gallery (Fig.5). This allows internal teams, visiting teams from industry and guests to look into the control areas and - via the video wall - follow executing operations, without disturbing by accessing the control areas. The visitors' gallery itself has another video wall connected to both GEO and LEO MCC video systems, limited to monitoring selected channels.



(Fig.5) Look from the visitors' gallery towards the upper floor GEO

and gallery floor LEO control centre.

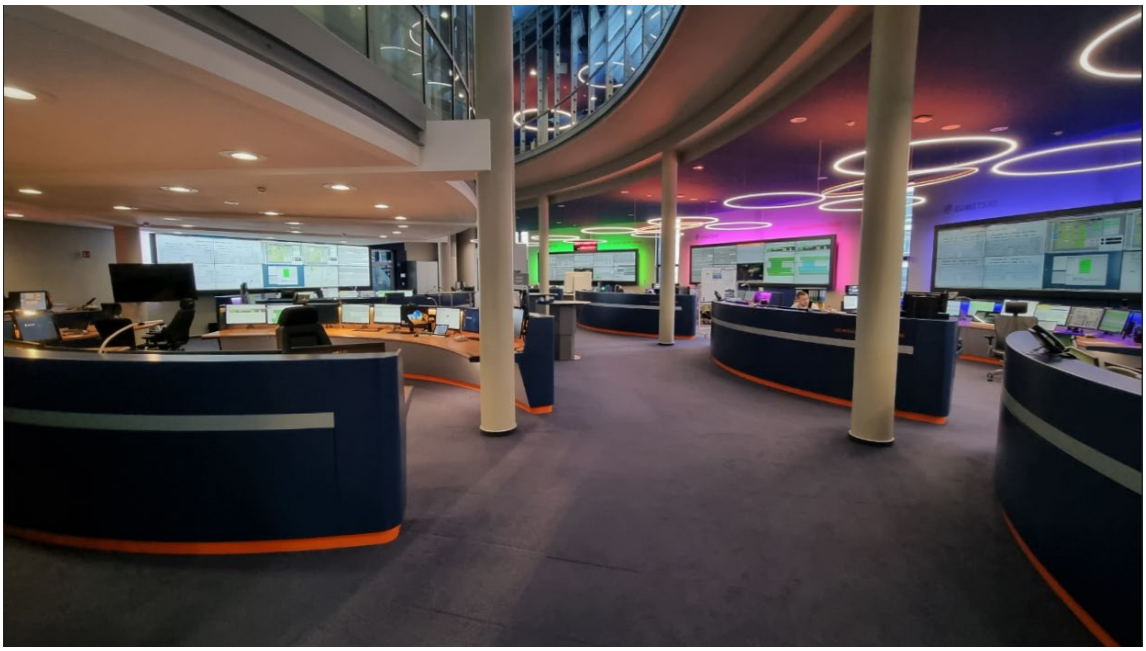
4.1.1 Geostationary Orbit Mission Control Centre

The GEO MCC refurbishment started in 2015 and completed in 2018. It consists of three ovals of two sizes with own video wall (Fig.6) and one quarter room space serving as training area. The total amount of room space is 205 m² with a ceiling height of 4.1 m. The real estate is fully air-conditioned, has windows and a partial glass roof for daylight which can be shaded. The room has a dedicated lighting system to ensure sufficient illumination during day and night time. The variety of room and oval light systems, shutters and video wall background can be freely configured and saved as scenarios, pending the ongoing work, time and team present.

(Fig.6) GEO Mission Control Centre @ 2020

4.1.2 Low Earth Orbit Mission Control Centre

The LEO MCC refurbishment started straight after the completion of the GEO MCC 2018 and completed during the pandemic times in December 2021. The main concept from the GEO floor was used as the baseline, with improvements of the audio and video alarm system, data communication system and harmonisation of the oval size. Within a total amount of 258 m² room space and 3.9m ceiling height it was possible to install six identical ovals with their corresponding video wall (Fig.7). A small training area was place in a dedicated area in the corner on the room. As above, the real estate is fully air-conditioned, has windows, a partial glass roof for daylight which can be shaded, a dedicated lighting system configurable through touch panels in the ovals and walls. All control rooms are secured by access control systems.



(Fig.7) LEO Mission Control Centre @ January 2023

4.2 Support Rooms

The decision to concentrate the satellite, ground segment and ground system monitoring and control in the two control centres led to further room function changes and upgrades.

4.2.1 Technical Support Rooms

In order to avoid having noisy COMMS infrastructure and servers in the MCCs, all hardware was installed in a dedicated technical room per floor along with all the video system components and terminals. Those two technical rooms have a higher security, dedicated cooling, sophisticated fire detection and extinguishing system.

4.2.2 Operational Support Rooms

Validation of monitoring and control procedures, simulations or tests with satellite, ground station and ground system, routine and daily checks were moved to nine Operational Support Rooms (OSRs). They are located in the north wing building extension and beneath the control centres. Currently they are installed and configured either for the GEO or the LEO programmes. The restriction is driven by the virtual terminal setup and operational room co-ordination, but is planned to become multi-mission in the future for a better room utilisation.

4.2.3 Mission Extension Rooms

Hardware, software or COMMS problems as well as routine maintenance and fixes require to swap to dedicated rooms which have a similar setup as an OVAL but just without the video system. Those five Mission Extension Rooms (MEXs), one for each of the operational programs are close to the main control centres for an efficient and fast move.

MEXs layout are like OSRs but received the maximum amount of screens and terminals to support operations in the smaller amount of real estate. Furthermore, each MEX is dedicated to a single programme,

such that the teams can use instructions for a predefined workplace usage, store business continuity relevant documentation and co-ordination items in those rooms to ensure a fast setup in case of a control centre relocation.

4.3 External Support Rooms and Locations.

In a contingency case of a partial or complete system outage of the EUMETSAT site, the controller teams relocate to geographically remote sites known as Remote Mission Control Centres (RMCCs). Madrid in Spain is available for the LEO EUMETSAT and Copernicus programs and Fucino in Italy for all GEO programs.

The RMCCs main functions are the satellite and ground station monitoring and control to ensure that the EUMETSAT assets are secured. Fucino MSG program has an image processing facility which does automated level 1.5 data processing and distribution back to headquarter if the systems are still available. A small archive also secures the MSG data locally.

The co-ordination of business continuity activities is performed from the German Weather Service site at Offenbach, called Operational Evacuation Co-ordination Room (OECR). From this site, OECR teams organise the travel and shift for the remote sites personnel, broadcast information to the EUMETSAT user community and interface between operations, infrastructure, house service and EUMETSAT management.

4.4 MCC Infrastructure and technology

A bonus of the entire control system and house infrastructure modernisation is the major reduction of energy consumption, which brings both financial and environment savings. It allowed the removal of the extinguisher systems, sensors take over the monitoring of the house infrastructure and ensure health and safety. Less energy consumption results as well in less air-conditioning needs, it becomes quieter and results in less disturbing air flow.

The OVAL workplaces can be re-configured in minutes for a program or specific operations. This means, for instance, that the needs of any programme during the various lifetime phases (LEOP, commissioning, routine, critical operations), can be configured dynamically with a single button press. Using the advanced video system, screens can be swapped and returned to the former location in seconds. The control team can rearrange their workplace and bring the information to their location. Visual and acoustic alarm system indicate which system need attention, coloured screen, oval and video wall backgrounds support the identity of the program.

4.4.1 Operations using an OVAL and Video Wall

The standardised OVAL consist of two sides; each side has ten 24'' screens to display from a pool of 240 virtual terminals (see Fig. 8).

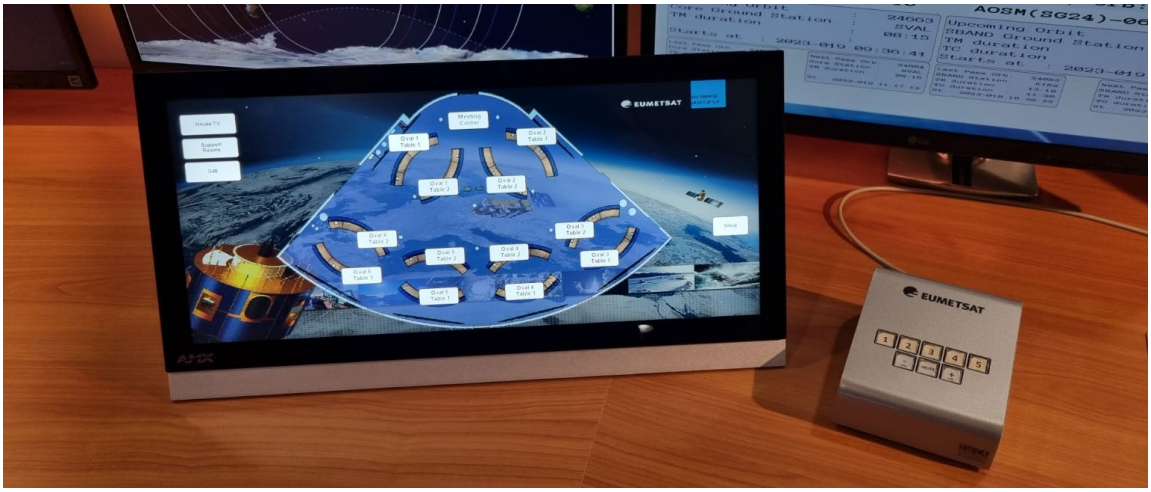
Each OVAL has two cordless and two wired telephones, two mobile phones for contingencies, two voice communication system (VCS) with preconfigured lines and permanent active voice recording.

Furthermore, there are secured USB inputs sockets for mission essential authentication activities.

External laptops can be video connected as source and displayed on the oval screens or video walls. In the other direction, it is possible to stream control centre displays into dedicated in-house rooms and into the EUMETSAT private network for monitoring from the office. One workplace is reserved for the on duty controller office terminal which is not part of the video system.

(Fig. 8) OVAL with alarm indicating video wall

To avoid the desk overload by keyboards, only two keyboards per side are available. One keyboard controls five screens, which are selected by a key pad (see Fig.10) or via the landscape touch panel (see Fig.9). The selected control is indicated by a yellow LED strap mounted under the screens.



(Fig.9) Touch Panel (Fig10) Key pad

There are different ways to monitors alarms triggered by the satellite and ground systems. Each OVAL screen has its internal speaker for the audible alarm from the displayed terminal. The applications have as well colour codes to provide visual alarms. The video wall indicates alarms via a red LED Strap (see Fig.11) above each of the upper row of screens and below each of the lower row of screens. This is for the visualisation. In addition, the audible alarm is coming from the speaker in the corresponding OVAL. The

alarm system is configured so that visualisation and audible alarms follow where they are displayed. In the event that terminals are not displayed an any of the OVAL screens or video wall, the sound gets routed to a generic speaker installed in all ovals. The touch displays (see Fig 9.) has as well a summary page to show alarming terminals.

(Fig.11) LED strap indicating an alarm on video wall monitor

4.4.2 Terminals and IP based Video System Components

In order to reduce the hardware components in the control centres, only the Video System decoders are built into the OVALs and hence less space, noise and heat.

Terminals, COMMS routers and switches, Video and Audio System Controllers and other components are installed in the dedicated technical support rooms. Tables 1+2 give an impression of the amount of main hardware installed in the technical rooms. For the LEO MCC ten * 2.1m height and 19'' wide rack space (see Fig. 12) is needed for the spacecraft and ground segment and station monitoring and control virtual terminals, the entire video system, audio system and COMMS network.

(Fig. 12) LEO MCC Video System, terminal and COMMS network

The GEO and LEO video systems are currently not connected and (for now) will not be connected to keep the redundancy, such that if one system fails the other system is unaffected. Installed LEO video system components are in the gallery floor such as the LEO control centre, and GEO video system components are in the upper floor such as the GEO control centre. Both video systems have dedicated terminals which can access the servers in the technical infrastructure building. Currently there is a logical separation between LEO and GEO terminals, from the COMMS side they are already migrated.

List of main hardware components for GEO and LEO control centre.

Table 1. GEO Control Centre main Video System Components for the 3 OVALs

70	24'' LG 16:9, HDMI screens for OVALs
30	55'' LG 16:9, HDMI video wall monitors
120	Shuttle Terminals
120	AMX Video over IP Encoder
92	AMX Video over IP Decoder Control Centre
34	AMX Video over IP Decoder Extern Rooms
6	AMX Quad Wall Processor
2	AMX Video-Controller
6	AMX Audio-Transceiver
2	AMX Master-Controller
3	AMX I9" Panoramic-Touch panel
4	AMX 10" Touch panel
2	QSC Core Audio Controller
6	QSC OVAL speakers
3	Yamaha active speakers video wall
6	Extron USB extenders

Table 2. LEO Control Centre main Video System Components for the 3 OVALs

120	24'' LG 16:9, HDMI screens for OVALs
60	55'' LG 16:9, HDMI video wall monitors
180	Shuttle Terminals
180	AMX Video over IP Encoder
180	AMX Video over IP Decoder Control Centre
40	AMX Decoder Extern Rooms
12	AMX Quad Wall Processor
2	AMX Video-Controller
6	AMX Audio-Transceiver
2	AMX Master-Controller
6	AMX 20,3" Panoramic-Touch panel
7	AMX 10" Touch panel
2	QSC Core Audio Controller
12 + 6	QSC OVAL speakers
6	Extron USB extenders

4.4.3 Alternative Control Centre Display Broadcasts

Both control centres broadcast six display channels each into the EUMETSAT office network for monitoring only, by using a standard video player on any office laptop. This streaming is called **House TV**, limited to EUMETSAT premises and secured as there is no control function and the selection of input channels is performed only from the control centres.

Second option of broadcasting display channels from the control centre is a direct steaming to the visitors' gallery video wall. The concept is the same as for the House TV with full control from the control room and no commanding functions.

The third from security authorised method or software is called Cyber Ark and allows access from inside and outside of EUMETSAT. Control Centre support teams use the Cyber Ark Remote Access Tool to monitor and control terminals and servers in the control rooms and technical building.

All three systems enable the option to support control centre operations without accessing the real estate, which became a necessity during the pandemic. Although the tool would permit control activities, satellite operations are explicitly excluded and only possible from the control rooms.

5. Challenges, decisions and lessons learned

5.1 The challenges to refurbish

The first control centre refurbishment was the GEO floor and went as planned and was completed within the time and budget limits. All video system, furniture and house infrastructure hardware and software were delivered on time. Requested manpower from various companies for the jobs were available when needed. At that time, only the METEOSAT Second Generation (MSG) program was on that floor, the legacy METEOSAT First Generation having been decommissioned beforehand. MSG legacy hardware migration onto new IBM blade servers was successfully completed, allowing to use small terminals with virtualisation software.

Fortunately, as there was sufficient control room space, the existing real estate was divided in half and a dust and noise protection wall in the middle of the MCC was built. After completion and validation of Phase 1, OPS moved to the new OVAL and refurbishment Phase2 took place.

Inspired by the good experience with the GEO refurbishment, the positive feedback of the new OVAL concept and the flexibility which was more needed by LEO, the decision was taken to clone the GEO concept but introduce changes from the lessons learned. The main upgrades where the COMMS data distribution to allow a duplication for the LEO hardware amount and the alarm system sound concept changes from a full room alarm sound distribution to an individual OVAL alarm distribution.

The work started in 2019 with a higher complexity due to two running programs, EPS and Sentinel3, in the LEO area and one program shortly before launch, Sentinel-6. The project was divided into three phases with the same idea of replacing everything from the control centre and protecting the operational space with dust and noise protection walls.

And then came COVID, the pandemic with all known issues.

Despite all the challenges introduced due to the pandemic, the project was completed only half a year later and the budget within limits.

The leading contractor showed a high work flexibility and also a good contact network ensuring that the remaining components were available before deliveries problems started.

5.2 Decisions before the refurbishment

Control centre use by control team only! This is due to the fact that EUMETSAT does not get further control centres, with the increasing number of programmes. With modern technology, improved usage of real estate, new satellite concepts and longer satellite autonomy, it is possible to concentrate all program monitoring and control in the already available real estate. The control centres are open rooms to allow communication between the control teams. Discussions between big teams during e.g. validations would distract the others in the room.

Why not moving operations outside of the control centre? The EUMETSAT control centres are 24/7 physically secured, all real estate used for operations including hardware rooms are on dual power and backup systems. All data routing is duplicated with dual signal cabling in all rooms. Teams can help each other immediately on site when needed, no lonely person in a remote place. A variety of phone systems ensures contact to the on call specialists.

5.3 Lessons learned

Especially during the pandemic times, the restricted onsite presents of the control centre teams caused a lack of communicating the new features and work ways available to use. There is currently no need to modernise further without using the already given options and features. The implemented systems have many more capabilities to improve operations and use further, and so far we have only scratched the surface. Only after a good understanding what the system can do we shall continue and improve systems.

Hardware obsolescence comes faster than hoped. The first video system components from the GEO modernisation have already received the End of Life notification. This means for approximately another year the factory hardware and software warranty or maintenance is available.

There was a natural human response to be reluctant to such a significant change to the overall operations philosophy. The project team had quite some challenges with the users of the just handed over

new OVALs and user concepts. There was an "age" consideration, as the younger controllers in particular rapidly assimilated the ideas of the new systems, and identified further advantages of the new technologies. After an initial period of training and practical use, the teams adopted the new way of working and finally agree that the new way is a significant improvement.

6. Winning Awards for EUMETSAT GEO and LEO Control Centre

Winning an award for the achieved work is always a good motivation to continue but mostly a recognition by internal and external professional, that the achieved work was something special.

The GEO Mission Control Centre won the **Prolight + Sound Sinus Systems Integration Award 2019** (see Fig. 13) for its work on EUMETSAT's new control room. 'The control room incorporates the latest technology to provide a more flexible, energy-efficient and secure workplace that is also more dynamic and productive for spacecraft and ground segment controllers'.

The LEO control centre won the **ProAV Avard 2022** (see Fig 14) in the category 'Best Control Room & Security Integration'. This price recognizes the best implementation of video and audio systems.

(Fig 13) The Award Winner 2022

(Fig. 14) Sinus Systems Integration Award 2019

7. Future Control Centres and Support Sites

The journey continues, what comes next? EUMETSAT operational control centres have been modernised, validated and finally handed over for operations before and during the pandemic times. Fortunately, the interfaces allowing to stream control centre displays out of the control centre were procured and installed beforehand. Security discussions for opening up the control centres to the outside world ended with the agreement to keep the control inside of EUMETSAT, but to allow timely display streaming outside of the control centres.

In future those interfaces will be expanded and standardised and web connectivity may be permitted. Pending security, control could be handed over to other EUMETSAT external sites such as the remote control centres, with a consequent improvement in the associated business continuity model.

Other improvements will include the removal of the Geostationary Orbit and Low Earth Orbit floor separation. It will be possible to use all the ovals for any program. With this, a further roll out of video connectivity from our remote monitoring control centres at Spain and Italy could be easily established. Those RMCCs get activated in case of physical access problems or complete system outages at the EUMETSAT campus. In order to increase the prime site autonomy either those RMCCs will get equipped with image and product processing facilities to ensure the continuation of product dissemination to the users, or the facilities software get outsourced to secured cloud backup solutions which install EUMETSAT software on demand, start the facilities and take over the processing if needed until the local site returns as prime.

One of the big challenges is to educate the operations teams in the control centres regarding the available tools. The installed video system supports lots of features which are currently not fully utilised. One example is the monitoring of systems that are not in a display pane. Whenever they alarm they could automatically be brought up in front of the controller.

Improvements and training have to be implemented under operational constraints, noting that long running legacy programs with a proven high availability can be conservative when considering innovation and improvements. The already established Video System Validation area for maintenance is a good candidate to support better hands on training for the operational teams. The RMCCs backup centres infrastructure is another place were teams can be trained, either locally at the remote site or via video system or display access software at EUMETSAT premises.

Control centres in the current design are for the 24/7 operational use and focus on the needs of the controller and controller support teams only. Development, validation and integration can be undertaken from operational support rooms and - with new technology – even from the manufacturers site if necessary.

Paper procedures and schedules are still part of the control centre; improving the supporting software and making hardware more reliable should support the swap to a paperless environment. Likewise, paper logbooks have already been replaced by electronic versions, with a consequent improvement in the usability and access to information. The transitioning to electronic logbooks was accelerated due to the pandemic. On call and interested operation teams can read and do analyses now remotely without accessing the control room and optimising their worktime.

The next generation of EUMETSAT and Copernicus satellites will be more autonomous with less need of continuous commanding. It will be possible to share the control centre ovals across multiple programs with sophisticated scheduling and login systems.

One point is already clear - the hardware lifetime of the current system is already ticking and the replacements will be faster, higher resolution, with better human communication including picture and better applications, and will be more intuitive to use.

If all the current possibilities start being used to their full extent, another round of lessons learned will highlight what is needed for the next generation of control centres. However, we are now in the fortunate position that we have a set of control rooms that are fit for the 21st century, and with the potential for further improvements in our overall operations in the years to come.