# Incremental Deployment of a Voice Intercom System in a modern Space Control Centre

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**In 2009 an innovative voice intercom system (VIS) was installed at Galileo Control Centre. The constellation currently operated consists of two IOV satellites with two further IOV satellites planned for 2012, and will be expanded to 30 in FOC – operational for some decades. This leads to significant constraints. The VIS needs to be simple to use – since over time a wide variety of operations personnel will have access.**

**The VIS has brought state-of-the-art and proven technology based on voice-over-IP into the space ground-segment. A fully redundant and decentralized architecture solves the single point of failure issue, circumventing entirely the need for any down-time due to maintenance. In addition the hardware is robust and easy to install. It is possible to use the system after a very short training.**

**The initial requirements were for a relatively modest system with 36 keysets – primarily for use in the simulation and rehearsal phase. In preparation for the In-Orbit phases a further 20 keysets were deployed. Since further extensions are expected the Voice System shows a wide flexibility by in line growing with mission augmentations. A high variety of external interfaces should be integrated into the system and an outline is provided for system deployment in stages – incorporating access to relevant external interfaces such as SIP for compatibility with CISCO-based Telephony.**

**This paper reviews the challenges of the outlined system architecture, and discusses the incremental deployment strategy.**

## Nomenclature

| | | |
|---|---|---|
| *VIS* | = | *Voice Intercom System* |
| *VoIP* | = | Voice over IP |
| *LAN* | = | Local Area Network |
| *SIP* | = | Session Initiation Protocol |

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## I. Introduction

During the evolvement of Oberpfaffenhofen's most recent Control Center, the GCC (Galileo Control Centre), the requirement for a state-of-the-art voice intercom system was formulated. The selected solution provides a radically different voice communication system architecture. It uses standard network and computing platform technology to process and transmit digitally converted audio signals for efficient and best-quality voice conferencing. The VIS was installed in a very efficient incremental way that allowed parallel usage of those devices that had been installed. The entire process and order of installation, described in this paper, was coordinated by GfR-DLR.

## II. Background

Previous voice systems have been based on common technology using star cabling and a central node for voice information distribution. All voice stations had to be connected to an audio cross-bar in a star architecture. Any malfunction within this central component obviously had the effect, that parts of the system were impacted.

The voice terminals were dedicated designed devices, produced especially for the use within a voice intercom system. No standard components could usually be used. A requirement was generated that forced the usage of standard hardware to be more flexible at future extensions. In a standard network infrastructure with standard PC hardware, it is not difficult to add devices

## III. Requirements for VIS in Control Centres

A large number of requirements for a state of the art voice intercom system have been defined at the initial stage of the GCC infrastructure. The VIS (Voice Intercom System) for the GCC should be based on Voice over IP technology without any central components. The main goal was exactly to overcome the limitation of a centralized system.

Due to the fact that routine operations require 24/7 availability, a focus was set to maintainability and ease of use. The replacement of a single component must not interfere with the functionality of one other component. It is required to control the system from a central facility in the system, but a failure of this facility must not disturb the rest of the system.

It was foreseen to have powerful MMI technology with touch-screen and the possibility to configure role-based access to voice channels. Full flexibility towards role definition as well as UI design was a basic requirement. This should be combined with most intuitive user guidance. The large amount of people that will use the system over Galileo lifetime require ease of use. Minimal training should be necessary to be able to use the basic features of the VIS, i.e. to speak on a voice channel. Training courses in general are very short. A 20-minute hands-on training for the operators covers the entire operator-usage of the system.

The VIS should be designed to utilize redundant LANs to avoid single points of failure. The use of standard components and Ethernet cables ensures availability at low cost of ownership for a long time.

## IV. High-level Architecture

The VIS can be connected to other sites via different types of gateways. Audio information (voice) is digitized and sent as IP-packets over the IP network (LAN). Standard industrial platforms with touch input devices and Ethernet cabling is used. The redundant LAN architecture ensures high availability. No central node is required and thus a single point of failure is avoided. Digital voice information leads to immediate distribution with latencies of ca. 50ms, producing good audio quality (ref. 2). Additionally the PTT information is transmitted as a part of the voice information and as consequence there is no timing difference as synchronization issue. Signaling information is transmitted over a proprietary protocol for performance reasons. An analogue interface unit controls headsets, PTT, speakers, and other connections.

The smallest unit in the system is a voice station (keyset). It consists of a touch-screen and a computation engine connected to (optionally) redundant LANs. Every keyset is able to combine the information and extract those signals the operator has selected. Thus it is possible to participate in different conferences (loops) simultaneously.

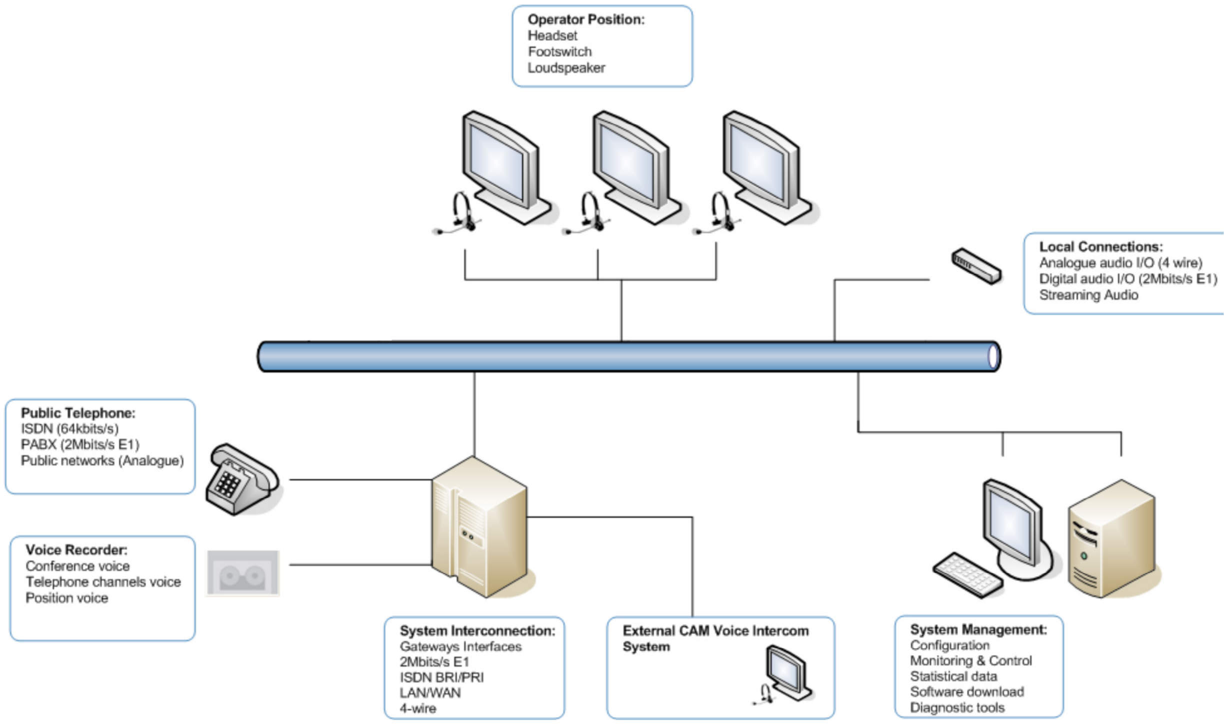


**Figure 1. System Level Architecture (schematic)**

External sites and systems are connected to the VIS-LAN via special gateways. These servers are standard sized components in 1U 19" chassis. They are mounted in a standard rack in the equipment room and are connected to the WAN or the telephone system. Different types are available for the individual purposes:

1. BRI gateway for connection to telephone system over basic rate interface
2. PRI gateway for connection to telephone system over primary rate interface
3. SIP gateway for connection to telephone system over SIP (voice over IP)
4. IP gateway for interconnection of two VIS over WAN connection
5. Remote keyset gateway for the connection of remotely installed keysets
6. 4-wire gateway for connection to four wire audio cables

A central configuration facility (redundant layout is foreseen) in the LAN allows editing the configuration that, once deployed is valid on each keyset. The configuration server is not required for subsequent operations. Recording is performed on a voice recorder which is mounted in a rack in the server-room. The recorder is configured to record specific voice loops. The number depends on the number of gateways gateways (30 channels per gateway).

Designed to be used in very intuitive way, the effective operator training sessions are usually completed in 20 minutes. An operator normally is able to use the keyset without any documentation or training. Bearing in mind the large number of operators that will be involved at e.g. GCC over Galileo lifetime; this is a very important aspect.

Preventive maintenance tasks can be kept in a small dimension. The keyset works without any moving parts, thus no fan has to be cleaned and no restart is required for long time-spans. Only gateways have to be checked for dust ingress.

The requirement for exhaustive monitoring is fulfilled by the voice tools that are part of the VIS installation. From configuration of the system to monitoring of individual devices – a number of tools are available and used at the current system at GCC.

A diagram of the VIS is shown above schematically demonstrating:

- Voice Stations
- Network Backbone
- Telephone Access
- Supervision & Configuration Units (System Management)
- Gateways (IP, BRI/PRI, SIP, Remote Keyset, 4-wire)
- Recording

Remote sites are connected to the VIS with remote keysets using IP connection. This technology provides the same comfortable usage with identical MMI layout as local keysets. This approach was already developed in the mid-nineties (ref. 1). Due to intensive development on this topic, the current devices allow remote stations that cannot be recognized by the operator as external devices. Voice information is compressed on basis of G.711 (ref. 4) for transmission to remote locations. Any other standard is possible and simply has to be configured for usage. The advantage of a remote keyset compared to a telephone that dials into the VIS is obvious. Each configured (based on role permissions) loop can be selected and all functionalities of voice keysets can be utilized in the same efficient manner. A telephone on the other hand can dial into one loop only.

## V. 5. Components descriptions

The VIS comprises a set of components building the functional system. The basic unit is the voice station, usually called keyset. Inter-connected by network-cables these keysets form the main part of the voice intercom system and form as such already an internal system. The keysets consist of a 1U 19” backend unit that is designed to be mounted in a standard rack or standard cabinet brackets. The lack of moving parts makes the keyset absolutely silent and thus allows it to be placed to the control room desk cabinets. The second part forms a 10” touchscreen with a VESA mount interface at the back for easy installation to standard console arms. Those devices are inter-connected with standard cables for transmission of power-, USB- (only for touch information), and graphics information. The backend-unit is connected to the LAN(s) via up to two standard Ethernet cables.


**Figure 1 Connectors**

**Figure 2 Touchscreen mount**

Headsets are plugged to the RCU which is connected via Ethernet cable to one of the three headset sockets in the back of the backend unit.

This system referenced in this article connects to the outside world (external sites) by the use of three types of gateways.

Telephone Connectivity is available over the SIP gateway. It supports connectivity to a telephone system and will be connected directly to the SIP telephone system (call-manager) via IP on a copper Ethernet interface. With the SIP gateway capability the voice system supports call management for external loop connection with predefined telephone numbers and also the ability to call partners on a call-by-call basis with manually dialed numbers. The second option allows the most flexible use of telephone connections.

An account on the call-manager is set-up with a corresponding telephone-number (account-name (equal to telephone-number) and password). The SIP gateway registers at the Call-Manager with this information. With this setup the SIP gateway will be reachable from outside on the specified number.

The VIS utilizes information available from the SIP Dial-up Protocol to identify the calling number (CLI), which is checked by the system using the data provided by database configuration files to determine a valid caller. Should this number not be recognized then the system will not process the incoming call any further except to disconnect-connect the calling line. Incoming calls with no Caller ID will be rejected. These features are configurable on a line-by-line basis.

The connection between recorder and gateway is based on E1 (ref. 5). Each gateway is able to connect 30 channels. The number of supported channels in total is depending on the recorder model. This number can be increased as required by adding additional gateways. Since only real voice information is recorded, the amount of storage required is limited to a modest amount

## VI. 6. Deployment

The deployment of the GCC VIS was performed in several short steps. Since the voice system is optimized for rapid deployment strategies it was possible to use short time-slots to install the individual components.

Keysets are the most flexible part in the mounting process. Depending on the environmental constraints the keysets were mounted vertically in the console cabinets or horizontally underneath the desks right at the table top. The devices do not have power buttons but are remote controlled from a centralized management unit. Thus it was possible to mount the keysets as close as possible to the desk. The dimension of all backend units and gateways is industry standard 19”. Backend Units can thus be rapidly mounted with 4 screws to the cabinet brackets or mounting bar. The standard format further allowed the usage of the available racks for the integration of gateways and recording unit.

The VIS touchscreens are mounted on swivel arms on top of the consoles. Equipped with a VESA mount the integration was a matter of minutes. Each touchscreen is connected to the keyset backend unit with standard USB cables, DVI cables and a 4-pin power/loudspeaker connection.

The system configuration had been established for the entire basic expansion state. Thus it was possible to install keyset per keyset without affecting the performance of the installed devices. Depending on the configuration, any available keyset can be used. A keyset appears in the system once plugged in.

### A. Initial Phase I

The first installation comprised the mounting of keysets in all control rooms plus recorder and gateways in the rack of the server room. It was performed within one week. Those components already formed a fully operational voice intercom system at this early stage. Together with an IP gateway, a voice recorder with dedicated recorder gateways for the connection of the VIS to the voice recorder completed the first batch.

In primary control-rooms the keysets were mounted in the console cabinets. The consoles had been pre-equipped with one RCU (Remote Connector Unit – for user headsets) and two mounting brackets each in the under-desk cabinets. Thus the backend-units could be mounted vertically in the cabinet.

Swivel arms were mounted in the primary control rooms for the keyset touch-screens. To guarantee a seamless integration, the same model was used as the one that holds the screen of the operator-workstation. Since not all consoles were equipped with a keyset at that time, only the relevant consoles received a second RCU for headset connection.

All cables were tied in the console cabinet construction as well as to the swivel arm to avoid unintended unplugging. Each cable was labeled unambiguously at both ends.

Secondary control rooms are equipped with normal desks. The lack of console cabinets forced the installation of the backend unit in horizontal position underneath the desks. Fixed to an indirect mounted Aluminum bar, the keyset could be mounted in a way that no part is in the way and able to interfere with the operator in an unintended way. The touch screens in both control rooms are mounted on a heavy stand and can thus be easily moved on the desk. Cabling again could be integrated into the desk’s existing infrastructure. Each desk came with a channel in the backside. The mounting of the second RCU completed the installation process in both control rooms.

### B. Phase I b

This phase only consisted of the installation of two additional keysets in dedicated operator positions.

### C. Phase II

The second phase completed the existing building's equipment stage and comprised another set of keysets that were integrated into those consoles that had been omitted during the first phase. All areas have been affected. This phase was completed within a week including the integration of cable outlets in one control room as well as setup of additional roles to mirror the layout for the operational phase.

### D. Phase III

In September 2011 the VIS was extended by the integration of a second SIP gateway that was installed into the VIS rack to work in cold redundancy. In case of a failure in the first gateway, the second one can take over within seconds.

Further a remote keyset gateway was installed together with a set of remote keysets. Those are foreseen to build the interface at remote sites. The devices are configured at the GCC and then distributed to the remote sites. From that point on, the configuration will be performed from the central configuration unit (Management Unit) at the GCC in the same way for local keysets.

### E. Phase III b and Current Stage

This phase was only a small modification consisting of a software update. The desired addition of an intuitive control for customizable loop levels that can be accessed from the operator interface was implemented. The new limit of more than of 64000 loops in the system guarantees full flexibility for any further extensions.

### F. Planned

The VIS system has no limitations in adding keysets or other components coming along with needs for mission evolutions or building extensions. It is expected, that further keysets will be added to the VIS in the scope of a building extension.

## VII. Experience reports from Users

Ulrich Bellenberg, member of the infrastructure department at GCC and head of the VIS describes the installation as follows: "The CAM VIS installed in the Galileo Control Centre Germany is operational since two years now. The VoIP system has supported the satellite tests with all needs for voice communication. Communication on internal voice loops have always been clear and of best quality without any noticeable audible delay. Several external entities respectively voice communication systems have been involved in these tests as well. The different gateways enable the VIS to connect any other type of voice communication system (e.g. IP based, SIP or standard telephone lines, audio interfaces and remote keysets). Thus external voice loops have easily been routed into the VIS being made available to the operators for voice communications. The quality of external loops is completely depending on the quality on the link. Volume control for each loop enables the operator to adjust all his accessible loops.

One major maintenance case has rapidly been solved in less than due time. One failing keyset has been replaced and configured without affecting any system functionality or not even system downtime, just the operator position was affected. The configuration unit of the VIS provides a high flexibility in defining loops and assigning them to roles and defining the layout per role as well as grouping platforms to rooms or per function. So we were able to configure the system for parallel activities.

At the milestone the first Galileo launch in October, 2011 the VIS has been interconnected with several external entities. It has presented itself as a very robust and reliable system. Now the system is in continuous use for parallel applications as Galileo operations and upcoming satellite tests. It is maintaining its high performance with absolute reliability and flexibility."

## VIII. 8. Maintenance History

The VIS is subsequently monitored from the central management unit, all devices are controlled on a monthly basis. Since most devices are in daily use, the functionality is verified continuously. In the time since the first installation 2½ years ago, two corrective maintenance issues had to be processed. The SIP gateway had to be rebooted after the telephone line was impacted by a wide-bucket excavator in the next village. This problem was solved by a reboot of the device after an outage of half an hour. One keyset had to be replaced because of a defect network interface. The device could be replaced within minutes after the problem was identified. This was possible due to the spare concept with additional keysets as well as gateways of each type available on-site.

These incidents led to a projected MTBF of about 490560h per keyset to date.

## IX. Conclusion

Modern control centres require state of the art voice intercom systems that are easily maintainable with short replacement times and standard infrastructure. The experiences with the VIS at GCC suggest that the usage of a mature VoIP system with decentralized architecture made of standard components offers highest flexibility and perfect comfort.

Mainly for operational environments where a smooth operation has to be guaranteed, a system like used for VIS is the perfect solution. No component is influenced by the installation of other devices. The system can be used and further devices integrate seamless in the system. All configuration issues are managed from a central unit without operational relevance. Extremely short exchange times are an essential feature to guarantee seamless usage of a voice intercom system in mission critical environments.

Although SIP connectivity via Telephone systems shows good performance and smooth integration into the VIS, a usage of IP-gateways to connect two VIS of the same type is suggested. Since no telephone calls are required in that case, the running costs can be reduced and the connection can be established without the latencies caused by the telephone network.

## Appendix A

## Acronym List

| | |
|---|---|
| **FOC** | Full Operational Constellation |
| **GCC** | Galileo Control Centre |
| **GSOC** | German Space Operations Centre |
| **IOV** | In Orbit Validation |
| **LAN** | Local Area Network |
| **PTT** | Push To Talk |
| **RCU** | Remote Connector Unit (headset interface) |
| **USB** | Universal Serial Bus |
| **VoIP** | Voice over Internet Protocol |
| **VIS** | Voice Intercom System |
| **WAN** | Wide Area Network |

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