Col-CC Voice System Migration During On-Going Operations

Thomas Mueller[1]
Ground Operations Manager

German Space Operations Center (GSOC)
Muenchnerstraße 20
82234 Wessling
Germany

Verbal coordination via voice loops is still an essential part of space operations. This is especially true for human space flight and even more for the highly distributed operations for the International Space Station (ISS). Coordination between on-board and ground and between all operations centres relays to a major extend on voice loops. Consequently the voice conferencing system is one of the most critical systems in a mission control centre.

The Voice System (VoCS) of the Columbus Control Center (Col-CC) supports not only the Columbus operations done from Col-CC, but all European User Centres including the ATV Control Centre and supporting sites are connected via the Col-CC voice system to the International Partner systems/sites.

This paper describes the complex migration to a new voice system at the Columbus Control-Centre (Col-CC) in 2011. This had to happen during the on-going ISS operations with minimal service impact.

After a short overview of the general set-up of voice communications within the European ground segment and a summary of the reasons for exchanging the system after just about 6 years in operations is given.

The different possible migration scenarios with their technical and operational impacts are discussed with the conclusion and explanation on the step-by-step approach chosen for this migration. Problems during the migration, dependencies to systems of other control centres as well as operational dependencies and planning issues are described.

The step-by-step migration implied also a staggered testing and operational validation sequence. The testing had to be carefully planned and integrated in the migration steps. Operational validation had to be done during operations with roll-back possibilities rather then a final validation before a hand over to operations.

[1] Ground Operations Manager, German Space Operations Center GSOC, DLR, Muenchnerstr. 20, 82234 Wessling, Germany, th.mueller@dlr.de

I. Introduction

IF somebody is asked which data is important to exchange with a spacecraft - the answer is obviously : telemetry and telecommand.

If someone is asked about the most famous words in spaceflight, a lot of people would certainly say "This is a small step for man…" or "Houston we've got a problem". Both sentences said by astronauts to the ground teams during their missions live on voice loops.

For manned space missions, beneath telemetry and commands, voice communication is the third data essential to be exchanged between the space craft and the ground. Coordination between astronauts and ground teams, reports of experiments, troubleshooting, private conversation with families (especially very important for long-term stays as in the ISS) and, last not least public relation and educational activities are done to a very large extend verbally on voice loops using sophisticated voice systems.

But not only between spacecraft and ground, also ground to ground, communication and coordination between the ground teams, which very often deployed among various control centers and/or ground stations, happens verbally using voice communication systems. Here manned and unmanned missions are similar. At the German Space Operations Center GSOC we have the experience that even in one single control room it is easier to communicate between the single console positions using a voice system to eliminate cross talks with parallel on-going conversations.

Taking the above into consideration it is obvious that outages of these voice systems have a serious impact on the on-going operations, nearly as dramatic as telemetry outages, or often even more as missions are used to have times of Loss of Signal (LOS) to the spacecraft due to missing coverage of ground stations, etc. But during these LOS the ground teams pre-coordinate next steps. Therefore they might not used to have communication outages.

If outages are disturbing, everybody can imagine that a complete transition to a new voice system is a real challenge to both the operation teams and the ground engineering teams performing this transition.

II. The Set-up of voice Systems for the International Space Station Program

A. The International Ground Segment for the International Space Station

Nome nest Omen. The Space Station is *International* with modules of different participating space agencies. Consequently the ground segment is as well international. Under the leadership of the ISS main control center MCC-H (Mission Control Center Houston) by NASA, control centers of Roskosmos (Mission Control Center Moscow, MCC-M), JAXA, and ESA (Columbus Control Center, Col-CC in Oberpfaffenhofen) for the different modules of the station, plus control centers in the US, Canada, and Europe for visiting vehicles, roboter arms, etc. , plus payload control centers constitute to a worldwide ground segment.

Each major control center has its own voice system interfacing with the other control centers directly and/or via the voice system of MCC-H. MCC-H and MCC-M host the uplink channels to communicate and coordinated with the crew. JAXA does also have own uplink channels for experimental support.

Within all different voice systems, a total amount of way over 1000 different voice loops are configured. These loops contain sets of loops shared among all control centers for ISS operations, loops for different disciplines and cadres, loops internal to international partner networks or control center internal loops. As the ISS mission is a long duration mission, preparation and simulations for upcoming activities (so called increments) or missions have do be performed in parallel to the on-going operations. Therefore a second set of essential loops used in operations are configured as '*Sim Loops*' to be used for training and simulations.

Although the main operations loops are quite stable defined, the voice loop set-up of the different voice systems is very dynamic.

- Due to limitations in the number of voice loops to be transferred between different systems, different sets of loops (*voice formats*) to be shared are pre-configured on the system interfaces depending on the mission phase.
- Local or joint simulations and trainings require different formats. Joint simulations are simulations between control centers.
- Maintenance or outages of systems or communication means require re-routing of essential loops by utilizing back-up formats
- …

B. The European Ground Segment Set-up

A subset of the ISS Ground Segment described above is the European/ESA ground segment connecting all European facilities. In order to respect the special ESA set-up allowing each member state to actively participate in a mission, a decentralized operations concept was implemented with transnational active centers of competence in each contributing country.

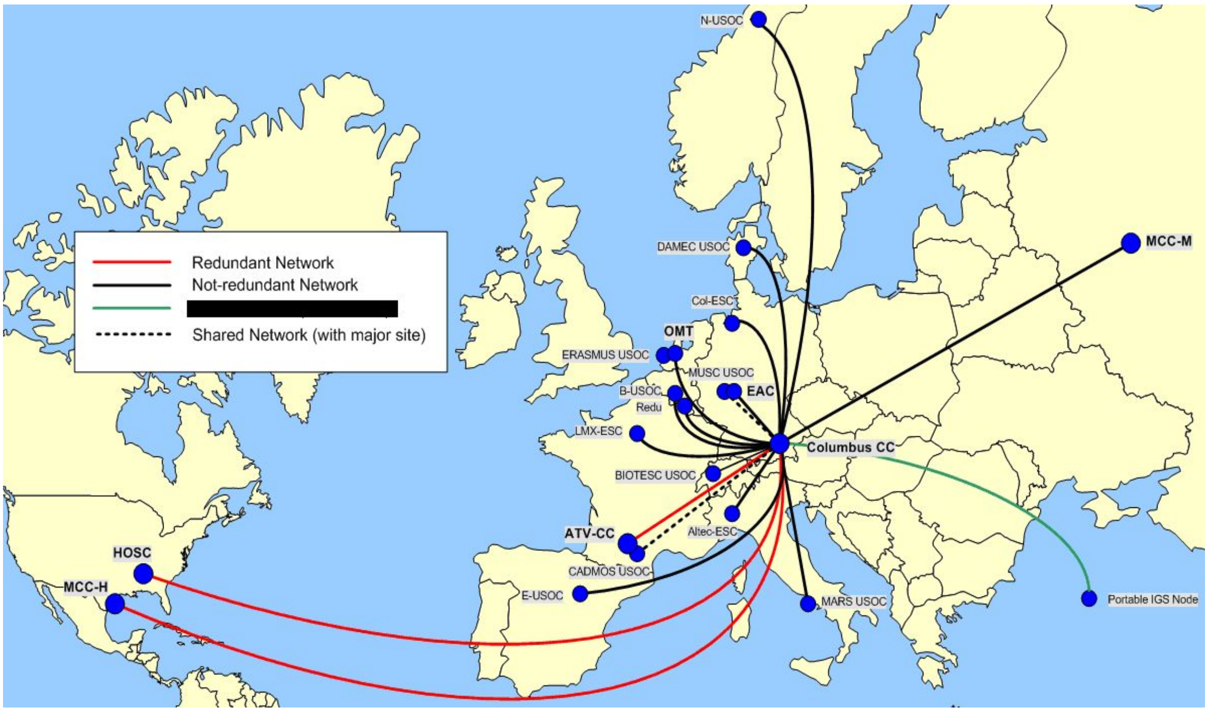

Figure 1: The ESA Ground Segment

As shown in figure 1 above, the ESA ground Segment has a star-like topology with the Columbus Control Center as a central hub. The Col-CC acts as central service provider for data, video, voice and other communication means to all European facilities and as the hub to/for the International Partner sites.

This ESA ground segment implements ground segments for two different missions:

- The operations of the European laboratory Columbus attached to the ISS.
  Main control center is Col-CC in Oberpfaffenhofen receiving all (ISS) data from MCC-H, HOSC, and MCC-M. The Col-CC distributes this data further to 10 User Support Centers, Engineering and Training facilities.
- The Automated Transfer Vehicles ATV operated by ATV-CC in Toulouse with data exchange with MCC-H and MCC-M, Redu ground Station and Engineering and Training facilities in Europe.

C. The Col-CC Voice System

For the ESA ground segment described above a central voice system is installed at Col-CC called ***Vo**ice **C**ommunication **S**ubsystem (VoCS)*. Following the star-like topology architecture this Col-CC VoCS acts as the central system (or hub) for 'European' Voice communications in the ISS program:

- The VoCS is connected to the voice systems of the International Partner control centers MCC-H, HOSC, and MCC-M sharing external loops.
- Voice terminals – *local keysets* – connected to the central system/matrix are installed in all control rooms and back rooms at Col-CC. In total about 60 local keysets.
- *Remote keysets* are provided to all European user and engineering sites for Columbus. These keysets are as well directly connected to the voice matrix at Col-CC via the dedicated ESA ground network. This

avoids to have dedicated micro systems at all sites. In total about 80 remote keysets at 21 sites are deployed.

- ATV-CC has a self standing voice system connected to Col-CC system. A small set of remote keysets for this system is deployed among the sites dedicated to ATV support.
- The European Astronaut Training Center has a self standing voice system for training purposes only. This system is either operated for training internal EAC e.g. Astronaut training or for Joint Simulations with other centers. For Joint Simulation support this system is connected to the Col-CC VoCS.

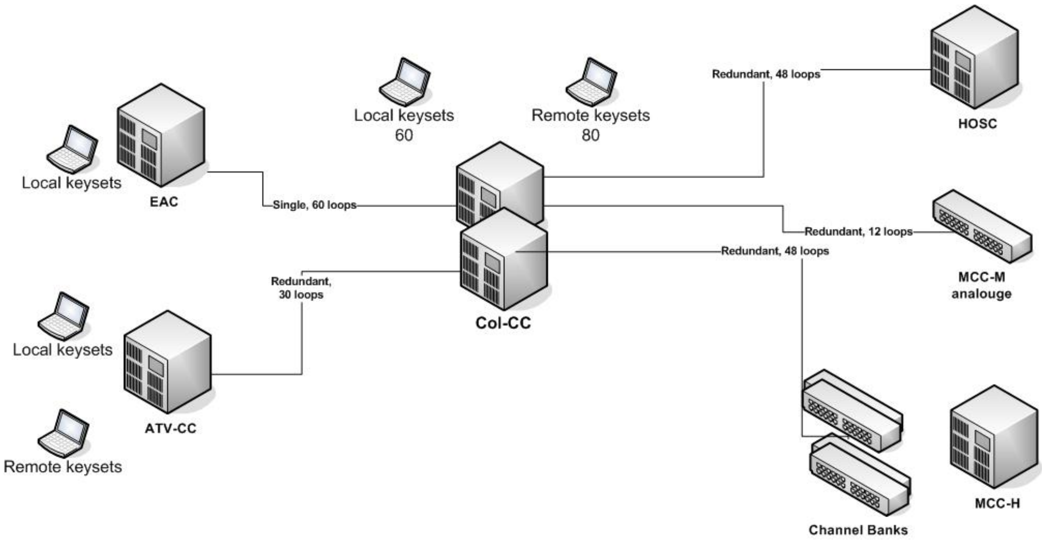

Figure 2: The voice set-up of the ESA Ground Segment

In total, the Col-CC VoCS has about 2020 registered users and 140 terminals. Room for a lot conversation – of course this conversation is not always in parallel and in parallel and has to happen on different dedicated voice loops. There are:

- *External Loops*, loops for communicating with the partners shared over the system-to-system interfaces
- *Internal Loops*, loops for ESA internal communication between positions or centers (mainly via remote keysets) and not shared with the partners.
- A total amount of 404 loops is configured at the moment

The main operations loops are doubled for usage during simulations. As the total number of shared loops used by the operators exceeds the number of voice channels available between the systems (see figure 2), different sets of loops are configured on the system-to-system interfaces for different mission phases. For each interface about 5 different voice formats are pre-configured.

NOTE: All the numbers given in the above section are already for the new voice system of Col-CC and differ in some details to those configured in the old system.

III. Why to change a running system

The original system was especially developed 2002 for the Columbus and ATV operations and was installed in 2004 at Col-CC. What are the reasons for exchanging such a system after only 6 years of operations? Considering the complexity of such a migration there must be really pressing reasons.

A. Original vendor left the market segment

The procurement of a long-life item for ESA as well as for DLR foresees an analysis of the vendor's economical situation and contractually the reserving of rights for source codes and guarantees for spare part availabilities, in our case for a minimum of 10 years. All these measurements can be treated as carefully as possible, but they cannot prevent the global market to be dynamic.

Already during the installation of the voice system the original vendor was bought by a bigger company and after several company restructuring attempts, the mother company finally decided to leave this, of course very special and limited, market segment of voice communication systems for air traffic control and space flight.

This decision triggered directly or in-directly the following reasons for a system exchange.

B. Complicated and costly maintenance

When a company decides to stop a certain branch, the company will leave minimized resources in this area just to be able to fulfill maintenance obligations towards customers as per existing contracts. Any further maintenance support is either complicated or even not possible, but is certainly very costly.

It is the nature of ESA contracts that timeframes are limited to 2-3 years maximum pending on the council board decisions. This brought us for this system in a situation where the costs for prolongation(s) of the maintenance contracts reached a level of costs of procurement of a new system calculated of approximately two contractual periods.

In addition to this our old system had a reasonable number of third party products. If the main vendor left the market, it is very difficult to get hands on any third party company as well especially if contracts between the main vendor and third parties ran out.

C. End of Life of components

After 6-8 years in operations certain components of the system reached the end of life. As the vendor left this market segment, no further development was made and no qualified replacements were available. Existing spare parts at Col-CC as well as at the vendor site had the same age as the components in use and were not available in a sufficient number.

So the availability of the system could not be guaranteed any longer and the risk increased that particular failures could not be resolved any more.

D. Change of Interfaces to International Partner Systems

NASA decided to procure for all locations a new digital voice system with the consequence that the system to system interfaces for Huntsville and MCC-H changed. Although NASA confirmed to provide the agreed interfaces for some years further, a migration would have been not avoidable. But this migration would have meant a development of new conversion functions, which was not supported by the former vendor any longer

E. Limited capacities

Not only the migration to the above International Partner interfaces were problematic, but also adoptions internal the ESA ground segment e.g. change of the WAN transport technology led to certain instabilities in the long-distance interface to MCC-H, which could never be really solved.

Of course also any extension of either functionality or capacity was not possible any longer after the vendor quit the market.

All the points above finally led to the decision to procure a new system.

IV. Migration Strategy

A. General Concept

As above described the voice communication is an essential service for this mission. Therefore it is clear that the main preamble of the migration to the new system was that the '***transition to the new system is performed with minimal disruption to on-going operations***'.

This is understood as to minimize the impact on real-time operations. A balance had to be found between an impact on on-going and planned activities (real-time and simulation activities) and a cost effective and in-time transition as well as to minimize the risk of the implementation of the new system in regards to schedule, test and validation, etc.

This sounds reasonable and obvious but is also the main dilemma of this migration. In order to minimize impact on operations you have validate your system extensively before a migration but this validation and test activities will impact your interfaces or the entire service and therefore will cause impact on operations.

B. Day X Concept

The easiest approach is to build up the new system completely and then test and validate this system in a representative test environment. During validation or after you should train the operations teams on the new system and then at a day X you switch from the old system to the new system completely.

If the day X is carefully planned and prepared the outage would be minimal, just limited to the switch over and some standard voice tests after.

This is the very common approach in space business and Col-CC is using this for step-ups of other systems like the monitoring and control system as a standard: e.g. Installation of a new version of the M&C system at a test instance, test and validation of the new version with simulators, training and further validation during simulations in a dedicated control room environment and then – at day X – switch over and transition of the operations team to this prepared control room environment.

This approach sounds too easy to be realized and to be the baseline for this paper…

For a migration of the voice service following the day X approach there are several issues/problems:

- *Parallel installation of the new matrix (main system).* This is a must and actually not an issue. The new core system must be built up in parallel at Col-CC while the old system is still in operations. This requires additional rack space and network capabilities, which should be no issue for such a control center.
- *Parallel installation of Local keysets.* This would mean that all consoles would be equipped with an additional keyset, which creates a serious space problem on the consoles. The alternative is to migrate the back-up control rooms with the new keysets and swap control rooms at day X and then migrate the prime control rooms after. Draw back is certainly to reduce the redundancy of Col-CC during the migration and it is still not avoidable to equip some control areas with double keysets for the sake of redundancy and flexibility.
- *Parallel installation of Remote keysets.* Although some of the external sites would have the capability to split their control rooms to allow a migration in two step as described above, the majority of external sites require to be double equipped with old and new keysets. However this approach requires two travels to all sites: one for the installation of the new keysets and a second travel after day X for de-installation of the old system. Furthermore the installation requires additional network connectivity (as the new system is connected to the WAN completely differently). This means doubling WAN bandwidth.Together with the travelling a very costly approach. The first clear NoGo for this strategy.
- *Parallel installation of System connections to international partners.* The new system requires an interface change for nearly all interfaces to the systems of the international partners as the new system is using a different voice protocol. All interfaces could be implemented much easier than before. However the day X strategy requires a doubling of both the interfaces and the WAN capability. The later one very costly and the first one simply not possible due to capacity limitations at the partner systems. Last not least it was difficult enough to agree and implement the new interfaces – to ask the partners to keep the old interfaces in parallel would have been a challenge in the field of diplomacy. The second and final NoGo.

C. Step by Step Approach

This approach was developed to resolve the draw backs and NoGos from above and to allow a timely migration. A parallel build up of the new system while the old system is still in operations followed by parallel/coupled operations of both systems with a step-by-step migration to the new system.

The following steps were executed:

(1) *Preparation work*
System areas prime and back-up were prepared, cabling including cabling up to the consoles was done before the system arrived at Col-CC. This work could be scheduled with no impact to operations and allowed the actual installation very fast and with minimal impact, especially in the control rooms.

(2) *Installation of the new matrix (main system).*
As above. The main system was installed and tested totally decoupled as stand-alone system locally at Col-CC.

(3) *Cross connect of Old and new system.*
The new system was added as an additional system to the hub Col-CC. By doing this both systems had

all voice loops available in parallel. The number of loops was of course limited by the remaining capacity of the old system. In our case 96 loops at the beginning mainly used for internal loops. For the coupling special conversion equipment had to be rented from the vendor.

(4) *Installation of first set of Local keysets.*
A first set of control rooms and back rooms used for preparation and simulations was migrated to new keysets. To avoid double work and extra costs these rooms were completely migrated with de-installation of the old system. Different sessions and simulations were used to test the system and train the ops teams with the new system. The migration went on in parallel to all following activities in accordance with control room usage plans.
After instabilities of the keysets were detected we tried to migrate as much as possible rooms (more than originally planned) to have as much as possible running keysets.

(5) *Installation and coupling of the system at EAC*
The voice system at EAC was also exchanged. As this system is exclusively used for training and simulation purposes the exchange could be scheduled with the training activities in advance. This system was completely exchanged at this step and the new system was directly coupled with the new system at Col-CC. Voice to voice connections could be tested and all training activities could be supported after the migration with nearly now impact.

(6) *Migration of the International Partner Interfaces*
The most critical step with the most impact on operations. One after the other the interfaces to the partner voice systems were migrated from the old to the new system. For each interface the following steps had to be executed:
   a) De-activation of the loops in the old system and in the partner system to avoid any noise
   b) Cut of the interface old system – external system (preserving roll-back capability)
   c) Configuration of the new interface; this required at some sites new cabling and equipment
   d) Activation of the loops in the new system and first testing
   e) Coupling of freed loops of the old system with the new system and extending shared loops
   f) Clean up

Step e) requires some explanation. As said above the main limitation of the coupling was the number of free interfaces/ports available on the old system. This number dictates the number of shared loops in both systems. During the migration of an interface the loops were cut on the old system and consequently the ports used for this interface were freed. These ports were coupled with the new systems and the external loops could be configured on these ports again. In most cases the old systems had even not to be reconfigured, the external interfaces were just changed from the true external interface to the new system.
Until the new interface was successfully tested a roll-back capability to the old interface was kept as far as possible – and sometimes used…

(7) *Migration of the Remote keysets*
With the migration of the IP system interfaces the new system became the main system at Col-CC and the old system was connected as 'slave'. With the maximum of shared loops the users of the old system were not limited significantly and the deployment of the new keysets to the remote users could be done with adapting their operational needs and constraints.
Each center was migrated at once in order to minimize logistics and cost. The migration included training and required a down-time from about 1-3 days depending on the number of keyset to be installed.

(8) *Installation of remaining Local keysets.*
Until the last remote keyset was installed, Col-CC still kept some old keysets in operations (in the ground control area) for troubleshooting and monitoring purposes.

(9) *Decoupling of old and new system – End of migration*
The end of the migration was the decoupling of both systems at Col-CC after all users migrated to the new system.

V. Planning Constraints

After the migration approach was defined a detailed project schedule had to be developed. This was not an easy task and more-over it was of course a living task on-going until the end of the project.

D. Planning with different parties

This schedule had to take into account various constraints from all the different parties involved.

Internal Col-CC this required planning and harmonization of:

- the different teams like network, infrastructure, WAN, voice engineers
- control room usage and migration activities
- operational activities
- simulation and training activities
- system freezes for other missions
- …

With the international partners the interface changes were discussed and prepared long in advance. The final migration had to be planned taking into account constraints like:

- Shipment, customs, etc of new equipment
- Travel and badging preparations
- Technical resources at the partner sites like cabling activities
- Testing and PA activities
- Operational constraints
- Forecasted outages

The migration of the remote keysets was –compared to the above- quite easy. At this stage the main system was migrated and we could take into account:

- Shipment, customs, etc of new equipment
- Travel planning from our installation teams
- Operational constraints
- Forecasted outages

E. Operational constraints

Main benefit of operating a permanent manned space station is a quite flexible operations scenario. Therefore the entire short-term planning has the priority on on-board operations. All (even long) scheduled maintenance/ground activities have to be coordinated with the operations teams before execution. A certain amount of activities from the voice migration was delayed – even on short notice- due to on-board issues or operational re-planning.

To keep this re-planning to the absolute minimum a good communication and coordination with the flight operation team(s) was essential.

- Every step of the migration was presented to the flight operations responsible in detail
- The changes and impacts were clearly documented in ground planning requests and published to the ops teams in internal and external flight notes (with NASA)
- Close coordination and frequent telephone conferences with international partners to prepare the interface migrations.
- A direct interface between the acting Mission Director (MD) of Col-CC and the migration project manager.
- The fact that one of the two project managers was the ground operation manager was very helpful.

F. ATV#2 Flight

The most significant planning constraint was the flight of the second ATV space craft. All the relevant interfaces to ATV support had to be migrated and moreover validated in time to support the ATV#2 preparation and system validation activities as well as to meet the ATV ground segment validation schedule.

VI. Problems

During the proposal review and discussion with ESA the first version of the step-by-step migration plan was judged as being '*well worded and detailed*'. However everybody new that reality is different and we had to deal this some very interesting problems during the migration, which required some virtuosity and re-planning. But in the end did not have to deviate too much from the principles.

A. Protocol conversion between old and new system

´The old system implemented the G.728 and the new system the G.711 voice protocol. Prerequisite for a successful coupling of the two systems (and therefore the basis for the migration approach) was powerful and good quality protocol conversion between these two standards. We used equipment offered by the supplier of the new system.

A special test set-up with a test system located at the supplier and our old system was used to qualify and validate the conversion equipment at a very early stage of the project – in parallel of the production of the new system.

B. Interface change to ATV-CC

The original design of the new system foresaw a conversion G711 to G728 to the ATV system as well. Consequently above described conversion equipment was planned to be used for this interface as well. Later ATV-CC confirmed with their vendor that the interfaces could be configured to G711 in their system and no conversion is needed.

This happened shortly before the factory acceptance test FAT. The FAT was changed on short notice to include a test directly with the ATV-CC system on G711. Therefore the test set-up to the Col-CC system had to be extended to ATV-CC, the ATV-CC voice system had to be reconfigured, etc.

Why did we include that test in the FAT on such short notice? We had to decide if we change the interface and consequently have to qualify with ATV-CC a complete new configuration and interface in time before the ATV#2 launch or- as originally planned- we leave the interface to ATV-CC un-touched until the ATV#2 mission.

The test was successful and both control centers agreed to migrate the interface before ATV#2 because the interface was much more simplified. Consequence for us was a major change in the migration sequence.

C. Keysets problems

During the installation of the first set of local keysets at Col-CC we discovered some issues and instabilities. These problems were not detectable during the FAT as they occur after some days of usage, or during installation.

In order to gain more experience with the keyset (problems), we decided to change the deployment planning at Col-CC and to install as much as possible local keyset as early as possible. This helped to analyze and solve these issues before deploying the remote keysets.

D. Interface migration with MCC-H

NASA's announcement of procurement of a digital voice system and in consequence the change of the interface to our system was one of the major drivers for our system exchange and our system was selected to be compatible with the new interface. Therefore it was an interesting situation that due to the fact that our (in comparison to NASA) small project was much faster and due to some project delays at NASA we were faced with the fact that MCC-H could not provide us the new digital interface in-time for our migration.

Fortunately MCC-H found some additional conversion equipment to support our new digital interface- the same conversion equipment used internal MCC-H for their migration. The installation of this equipment had to be folded into their migration schedule and was therefore a big unknown and actually happened on short notice. Consequently the entire migration of our main ISS interface was done on short notice with numerous coordination activities between the Ground Operations Manager and the Columbus Mission Director, some happen after hours via mobile.

This interface was also the most complicated; it took several runs to configure the conversion equipment, historic channel banks and our new system. We did testing on the back-up interface to minimize impact on on-going operations on prime.

The migration to the final interface is still not done at the time this paper is written.

VII. Testing and Validation

A. Factory Acceptance Test

Was done accurate and extensively. However the main problem with a FAT is that the test set-up is just a test set-up and not the final environment, with the final network and distribution and with the final operation condition and system load. The consequence is that a lot of problems occur later after installation at the site. This is especially true for such systems as the voice system where simulation equipment or test generators cane be barely used.

B. Site Acceptance Test Campaigns

The standard is that after a successful FAT a new system is installed on-site and an extensive site acceptance test is performed followed by an operational validation using simulations etc before the system is activated for operations. With the step-by-step approach selected for our system this is of course not possible as the new system is nearly seamlessly step-by step activated and used for operations.

The system validation followed also a step-by-step approach. There was a first site acceptance testing done to the most possible extend with the stand-alone system after installation. Then every migration step was followed by a certain amount of tests verifying and validating the specific migration step. At this point it had to be ensured that all testing was not intrusive or destructive and that impacts were limited to specific areas and not to the system at a whole.

Final system load tests and fail-over tests were done via joint simulations with as much as possible participants. These tests were of-course carefully scheduled with on-going operations. It is clear that it was not avoidable that some of these final system tests had impact on operations.

C. Site Acceptance Review

The final site acceptance was done by a formal site acceptance review, where all the self-standing tests and the first SAT were carefully reviewed and analyzed. Open outstandings were documented and a closure plan was agreed.

It should be noted that the new system had an operations readiness review as well. But this review happened much earlier at a point of the migration when the system became the master of the Col-CC voice systems with start of migrating the main external interfaces. This was of course to some extend an artificial milestone.

VIII. Conclusion

To exchange a heavy used and single sourced system like the voice system during on-going operations with minimum impact was a real challenge. It required some deviations from standard processes established especially in space missions. It is here not very easy to find the right balance of deviation and flexibility to keeping or at least adaptation of well-established processes.

Thanks to the excellent coordination between the Ground Team and the Flight Operations Team at Col-CC and the flexibility and understanding on both sides this challenge became a success.

Appendix A
Acronym List

ATV	Automated Transfer Vehicle
ATV-CC	ATV Control Center
COL-CC	Columbus Control Center
FAT	Factory Acceptance Test
FCT	Flight Control Team
GCT	Ground Control Team
GSOC	German Space Operations Center
LOS	Loss of Signal
MCC-H	Mission Control Center Houston
MCC-M	Mission Control Center Moscow

MD	Mission Director
SAR	Site Acceptance Review
SAT	Site Acceptance Test
VoCS	Voice Conferencing System

Acknowledgments

The Author would like to thank the entire system engineering team and the ground control team at Col-CC for their outstanding effort to make this transition smooth and nearly seamless. Special thanks to the VoCS-R team, the task force for this migration.

And a big thank to our flight operations team for their patience and understanding.