Reality Filtering

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At the German Space Operations Center (GSOC), a new generation of monitoring and control software has been put to operations, as well for the antenna hardware at GSOC's ground station in Weilheim, as for the internal communication network infrastructure of the control center in Oberpfaffenhofen. While keeping operations ongoing and trying to create monitoring tools looking familiar to the experienced long-term operators, DLR also tries to improve operations by innovative concepts. Beside our intention for progress, new concepts have become necessary by the growing complexity of the systems in use and even more by the rapidly increasing amount of monitoring information provided by these systems. This paper describes, how the way to display a complex system has changed with the new M&C-tool, and its impact to operations and operators.

Nomenclature

M&C	=	A system to remotely monitor and control some given hardware equipment on ground.
SpACE	=	A generic M&C-framework developed at GSOC.
WARP	=	Weilheim Antenna Remote Processing, the M&C used at Weilheim ground station as antenna control.
NEMO	=	Network Monitoring, the M&C used to control the IT-infrastructure at GSOC.

I. Concepts Of Operations – Procedures, Skills ans Tools

Any discussion about operations and concepts of operations starts with a broad consensus: The monitoring tool in use shall display “green” as long as the system is nominal, and it must change to yellow or red in abnormal situations. The sheer simplicity of this requirement often leads to the misunderstanding that operations already is defined by this sentence. In fact, it is not for two reasons: First, the requirements for a complex system to be in nominal condition most often do not have hard boundaries. They are soft in the sense, that some deviations are acceptable under certain conditions, they do not play a role for certain actions and so on. The exercise to translate such an interpretation of the system and its current task as a whole into pure logic that can be coded in software and then ultimately leads to a single green or red signal on the top-level display is the Holy Grail of any monitoring system. The second piece missing to precisely define operations is the definition of the operator's reaction in case of failure. This task is not that much a technical problem than a conceptual one. Is failure an option? In other words, does the service to be provided has to be up for 95% or for 99.99%? How is the relation between utilization of the system and spare time for trouble shooting balanced? How much is invested in expertise of the operators and/or in the immediate availability and presence of experts? All these boundary conditions have a significant impact on the needs how a system monitoring tool displays the situation. And even worse, they might differ in time, while the same hardware is utilized for different tasks.

Most often, all of the conditions mentioned above are set externally and can not be changed. The main variables that can be adjusted to match the needs are the procedures handed to the operators and the training of the operators. At GSOC's ground station in Weilheim we are in a fortunate situation that we also can easily adjust the monitoring and control tool in use, named WARP – a short for Weilheim Antenna Remote Processing – as it is based on an in-house developed M&C-framework. In fact it was the invention of this new M&C-system that triggered us to rethink the concepts of operations.

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A. Multi-Mission Operations at GSOC's Ground Station inWeilheim

Weilheim, located about 50 km south of Munich, Germany, performs as ground station for spacecraft operations since 1968. Besides hosting dedicated antennas exclusively in use for a single project, Weilheim ground station operates six antennas in multi-mission context. There are 3 antennas for receiving and transmitting signals in S-band, two of them with 15 m in diameter, the third one with 9 m. A fourth antenna, 11 m in diameter, is prepared to receive and transmit signals in Ku-band, and a fifth of size 13 m works in Ka-band. All of them are full-motion antennas optimized to follow quickly moving targets, they are capable of receiving and transmitting signals, and all can be operated in autotrack-mode. The sixth antenna, a dish with 30 m in diameter, is designed to operate in L-, S- and X-band. This last one at the moment is equipped as a receive-only antenna.

The tasks fulfilled by those antennas range from routine TT&C-operations for LEO-satellites, primarily done in S-band, over LEOP-supports in all frequency regimes for LEO- and GEO-satellites, to IOT-campaigns, the first one in Ka-band successfully completed in March 2014. All these antennas also are used for R&D-work. Especially the largest antenna, the 30 m-dish, is utilized for various test-campaigns, because of its easy access to the feed-system and the possibility to exchange and adjust the connected RF-equipment. Some conditions for operations can be derived from this portfolio of activities:

- As used for special tasks in critical mission phases, all equipment is highly redundant and the antenna hardware is designed such, that operation is still possible, even if several parts of the equipment fails. As an example, the up-link chain for transmitting signals is not only redundant in the sense, that two independent chains exist. The signal path can also be crossed from one chain to the other between base-band devices and frequency-converters, as well as between frequency-converters and high-power amplifiers. Therefore the system is robust not only against single failures, but in turn, it is more complex.
- The location in mid latitudes only allows for much less contacts to LEO-satellites compared to ground stations located much closer to the polar regions. This leads to a much less utilization of the station, but in turn allows for longer preparation phases. Thus the focus for operations is laid to reliability in favor over time-efficiency.
- Depending on the orbits of the serviced satellites, there are sometimes periods with ten and more visibilities within few hours, followed by a time-slot of about ten hours without any contact. Such time-slots are used at Weilheim for R&D-work at the antenna hardware. Contrary to routine operation, where the performed action is more or less always the same but only configured for the given satellite, the R&D-work might alter settings never touched before or even temporarily change the hardware setup. Being executed by humans, there is always the risk that the system is not brought back to its nominal setup in terms of hardware and settings. To ensure the desired quality of service under these circumstances, a complete and thorough system-test is needed well ahead the next support, again exchanging time for reliability.

The scheduling for Weilheim ground station usually preserves a time-slot of 20 minutes prior to AOS for setup and testing. For each support an internal data-flow-test is performed to assure the correct settings of the equipment. The sequence to set up the equipment is optimized not in speed but in reliability. Settings are verified in monitoring as well as by functional tests. That way, malfunctions are identified ahead in time of the support. In case of problems, a system engineer can fix the hardware, the support can be run on redundant hardware within the antenna or the whole support still can be completely re-scheduled to another antenna. Such, the main task for the operator is to assure prior to a scheduled support that the necessary equipment does work properly. In case it does not, the operator has to judge which action is needed and he has to initiate this action, either by configuring redundant hardware or by calling in system experts.

B. Network-Control-Operations at GSOC

The German Space Operation Center, GSOC, serves as control center for the European module of the international space station, Columbus (Col-CC), and as ground control center for satellite missions of DLR, missions in international partnership and if needed also as host for projects of external agencies or customers. In addition to the control center for the space segment of a mission, GSOC operates as control center for the whole ground-segment of space missions run by DLR or other partners. As such, the main task of GSOC is to ensure and coordinate the correct configuration of the ground segment, that is to provide real-time and offline connections for data exchange between the worldwide net of ground stations and the satellite control center, be it located at GSOC as well or externally somewhere else. GSOC is specialized to serve as control center during LEOP operations, but it also controls LEO- and GEO-satellites throughout their complete life-cycles, including de-orbiting. GSOC has especially developed unique knowledge in flying satellites in close formation by operating the projects TerrarSAR and TanDEM.

An outstanding feature of GSOC is, that it serves as control center for manned spaceflight as well as for unmanned satellite missions. That way, any mission hosted at GSOC can benefit from the experience and – if allowed by the safety regulations of the missions in question – the existing infrastructure, which was build in accordance with the rigid requirements for ESA's Columbus module at the ISS. To make maximum use of the potential synergies in such a multi-mission environment, GSOC stepwise changes its complete IT-infrastructure from a server-based design to virtual machines. This development has an direct impact to operations, the task to properly manage and monitor the connections of the ground segment. Hardware failures or not-available services on the hardware (e.g. FTP etc.) may now have impact to several missions. From the view point of a network-control operator (NC), now there are two different layers of monitoring to watch: The (mission specific) software running on virtual hosts and the (mission independent) physical host underneath. As pointed out, depending on the regime an error occurs in, the consequences differ completely.

As for ground station operations in Weilheim, the particular setup at GSOC's department for "Communication and Ground-Station" defines the way, NC operations at GSOC is accomplished. It also sets requirements for the tools in use to do so:

- Serving as central node for ground segments with connections to stations all over the world, GSOC has to be available for 24/7, not only for some scheduled passes. Consequently the IT-infrastructure is highly redundant and clustered such, that outages of single elements are covered by automated redundancy switching or alternative routing, and so on.
- Although the operators do have a basic tool-kit to restart servers and services, the main task for the operators is not that much to do trouble-shooting but to communicate the situation. Connected projects and stations might have to be informed about the use of alternative data routing. And even if the service provided by GSOC is still available, system experts have to be called in to bring the system back to full redundancy.

C. A Common Framework for M&C-Tasks: SpACE

With the need to implement a new M&C software for the Weilheim ground station, it was realized that controlling the network infrastructure of GSOC places a similar set of requirements – similar at least in type. Although the hardware to be configured and monitored differs completely, the setup is always the same as it is sketched in Fig. 1. Information is needed to be collected from the hardware, and must be processed by the M&C in a way that it can be passed to a command instance, be it a human operator or some automated system. Vice versa, the command instance can decide about necessary actions from the available information and pass the resulting commands to the hardware through the M&C. Following this generalization, a generic framework for M&C-tasks was developed at GSOC. Details about this framework named SpACE and the applications build on it, have already been presented.[1]

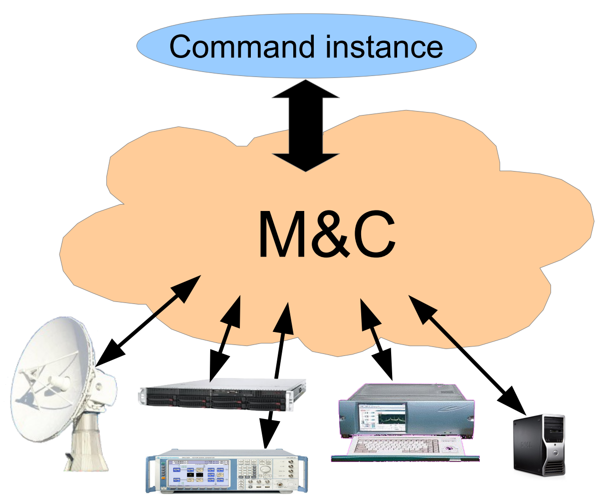

Figure1. The general setup of any M&C-system.

One of the main tasks of any M&C-system is, to process the collected information and thus display a summarized pictured to the command instance. The same is true in the other direction: High level commands or predefined command sequences have to be selected easily by the command instance and the M&C-system shall "unpack" these directives and send the corresponding set of low-level commands to the various pieces of hardware building up the system.

A key feature of the SpACE-framework is not to separate internally between those various layers of information. A low-level value of a single setting at some device is handled in the very same way as a summarized parameter deduced from a bundle of low-level inputs. The first consequence of the fact that all bits of information are treated equally is, there is no information somewhere in the M&C that is not accessible to the command instance. In other words, it is not before the interface to the command instance, that information is filtered. Precisely, if the command instance is a human operator in front of a GUI-application, it is only due to the GUI and the design of its pictures to filter, which information the operator actually sees and which one is skipped. Technically the application "knows" about all details, it is just hiding something in order to allow the user to keep the overview.

D. The Level of Detail – Help or Confusion?

Following the above discussion it is clear that the level of detail displayed to an operator is not a matter of technique, it is a matter of organizing the shift. Here the two variables mentioned above – procedures and operator training – come together again.

It is an important point to realize, that these two variables do not balance each other (see Fig. 2). An operator with excellent expertize is able to work almost independent from any procedure – he or she just knows what to do. But a lack of expertize is not necessarily equalized by good procedures. In fact, a fairly well knowledge of the system potentially creates a conflict between written procedures and the operators intuition. The result is most often an inappropriate reaction. But it is not only the human factor, that is raising the problem here – also an operator, devoted to stick to the procedures, is lost if the procedure is incomplete or unclear.

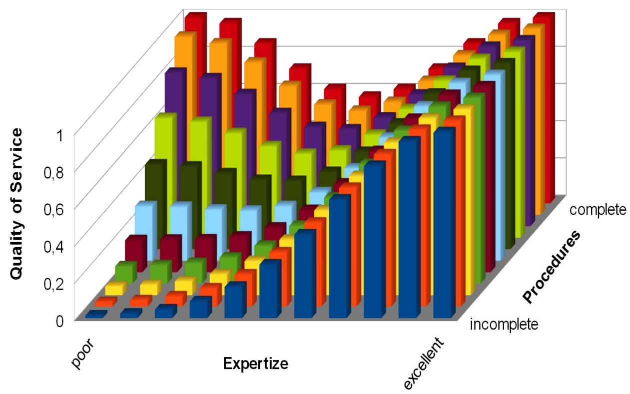

Figure 2. The achieved quality of service with respect to the expertize of an operator and the quality of the procedures handed out.

At the end, there are three quantities that have to be adjusted to each other:

1. **Display** – The operator either must have the expertize to interpret the displays he sees, or those displays must be described in explicit procedures.
   As a consequence, what's neither fully understood by the operator nor covered in procedures must not be displayed.
2. **Procedures** – Everything an operator is supposed to do must be described in procedures. If not, the door is open for arbitrary actions based on guessing.
   As a consequence, what's not explicitly stated in procedures shall not be expected from operators. There should be no such thing like common sense or implicit assumptions.
3. **Expertize** – The operator either must blindly stick to the procedures or he has to fully understand the impact of his action to the whole system.
   The difficulty of this fact is revealed if it is formulated the other way around: The operator has to realize the point at which he must stop trying to do the best. It is not easy to step back and do nothing else than inform others while the system display alarms and the next support is coming close.

II. Viewing the Same From Different Perspectives

With the growing complexity of the ground segments nowadays it is constantly getting harder to maintain the overview. In fact, it is almost impossible to know for any single malfunction at lowest level the impact to the system as a whole. Progress like virtualization and the usage of the same hardware for multiple projects in different context add more and more dependencies to the system. Because of this tendency, we decided at GSOC to take the opportunity of the implementation of a new M&C-system to re-define the working point in terms of displays, procedures and expertize.

A. Sorted by Device versus Sorted by Service

Traditionally, combining information to higher level summaries, is often closely connected to the hardware setup of the system. At a ground station for instance, all the detailed information of an HPA is gathered to a single device state and furthermore the device states of HPA, frequency-converter and base-band equipment is summarized to a high level information about the up-link chain. Following this logic, dependencies between the devices are hard to be implemented.

An example: The HPA might not show a low or missing input signal as an error. In fact, adjusting the output power to the desired level can be a combined setting at the HPA and some attenuator prior in the chain. On the other hand, a low or missing input signal will force any gain-control to drive into its limits. Depending on the type of HPA, this can cause severe damage to the hardware.

Of course, such dependencies can be added "artificially" to the next higher level. In our example the combined up-link chain would be colored in red signaling the improper configuration, but all underlying devices would be green as none of them reports an error. As a result, the displayed error can not be traced to its cause and the situation can only be solved, if the operator is experienced enough to understand that it is the combination of two devices displayed as "green" that leads to the error.

A better way to handle the same situation is, to choose a sorting for the displays that includes the dependencies between devices from the very beginning. This is realized in WARP in the following way: The up-link chain is not understood as the sum of its devices but as a tool to fulfill a certain task – in our example: Provide an RF-signal with a given power level. Now the top-level display summarizes all requirements to be met, in order to deliver the expected result. If an alarm is raised, the operator knows instantly which functionality of the system is concerned and the navigation from the top-level alarm brings the operator to the list of requirements. There he can read off which condition is violated, in our example a missing output at the frequency-converter.

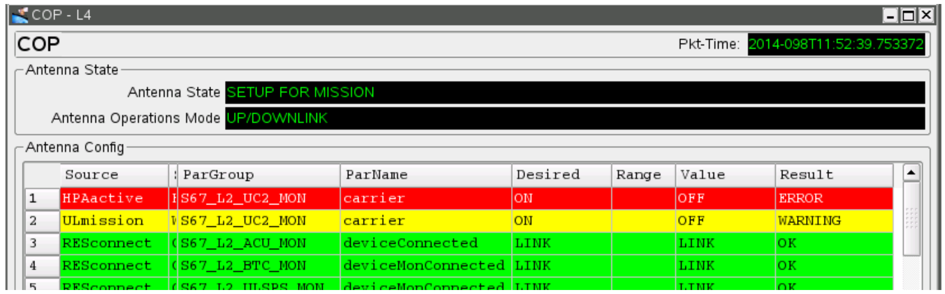

Figure 3. The List-Display of WARP. *In this example, the HPA is supposed to be active ("Source") which requires the carrier at the UC to be ON ("Desired"), while the actual setting is OFF ("Value"), reported as ERROR ("Result").*

Being used to a pure graphical display showing the hardware components of the antenna, the newly invented list display is uncommon to the operators. Right now we are discussing several ways to provide a much more intuitive graphical representation of an antenna and its services. But even with the list representation, as shown in Fig. 3, the interpretation of an occurred error is much more straightforward since a pair of information is given: The parameter that deviates from its normal setting ("UC carrier") together with the impact to the system ("HPA is not active"). It is exactly this combination of cause and consequence, that generates the improvement against the legacy system, as for the previous M&C, TIGRIS, it was up to the operator to know (or look up) the impact of an alarm.

B. Color Coding and Time Dependent Monitoring

Another major change for operations is that the displayed colors have different meanings in WARP compared to its predecessor. For TIGRIS, the previous system, the definition of "green" was the configuration expected during a (successful) pass. As a consequence, for most of the time, the displays were showing a rich variety of colors (See Fig. 4). It was up to the operator to know the differences between a pass configuration and, let's say, a data flow test prior to the pass. In fact, during a DFT there had to be many alarms as the needed injection of simulated data to the down-link is something definitely not wanted during a pass.

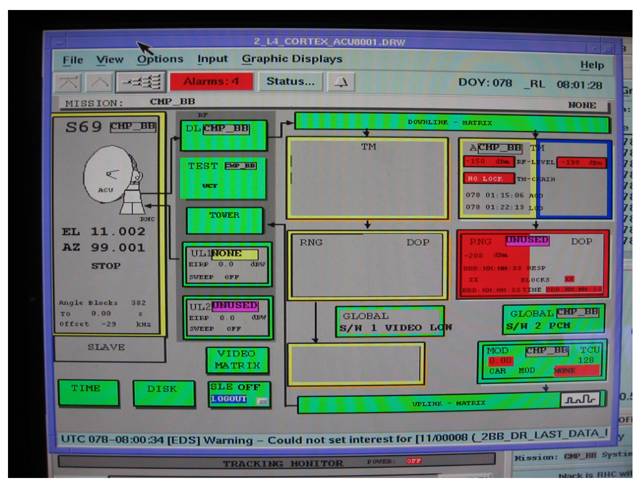

Figure 4. Example Display of TIGRIS. *Due to the color philosophy to define "green" as the valid pass configuration, the main antenna display shows many alarms although being correctly configured prior to a pass.*

Now for WARP, the definition of colors has changed in the way, that "green" indicates the configuration expected in the context of the task currently carried out. To specify the context, WARP has a state-machine included that keeps track on the command sequences run, and hence "knows" what the antenna is prepared for. In Fig. 3 this is displayed in the two upper most lines above the table: The antenna is "Setup for Mission" and prepared to provide up- and down-link. One step necessary to configure the antenna in such a way, was to power up the HPA as it is needed for up-link. Therefore WARP is aware that the HPA is active and can start to watch the relevant settings to keep the device safe. In the example above, that is WARP checks the carrier state at the up-converter.

If the antenna would be operated for down-link only, the HPA would remain off, the antenna state would be aware of that and therefore the state of the carrier at the up-converter was irrelevant. This is the formalism utilized in

WARP to vary the display over time and raise alarms only if they are relevant. As a consequence, colors at the GUI do no longer non-ambiguously correspond to a distinct setting at the hardware, but displayed alarms in turn always are serious.

C. Bottom-Up versus Top-Down

Even more essential is this way of service-oriented display for the other M&C-system based on SpACE, the NEMO application at GSOC. Started at the beginning as a pure network-monitoring, it has quickly grown to a complete system-monitoring and -control. Fig. 5 shows a part of the covered hardware. Currently, NEMO monitors about 200 servers, physical hosts as well as virtual machines, and about 150 network elements such as switches, routers, firewalls and so on. Beside the monitoring, NEMO enables to actively configure the hardware, for example stop a service on a host and start it on a different one.

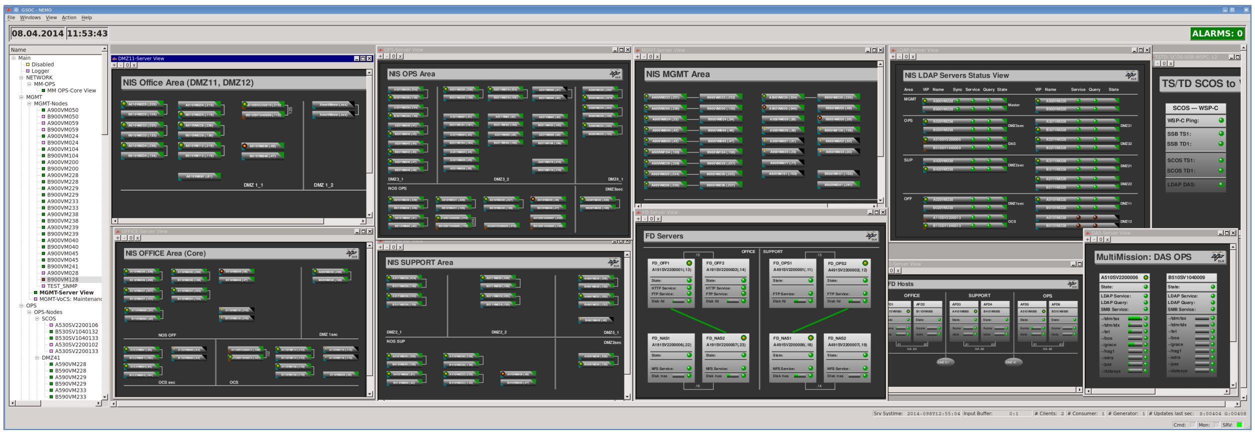

Figure 5. Overview of a part of the IT-infrastructure as monitored on device-level by NEMO.

The complete system at the moment is mapped to about 16.000 parameters with about 500 updates per second. Most of these parameters represent the system on hardware-level. As such, NEMO is used by the system-administrators to analyze problems and trace errors in time. Since NEMO provides command access, this tool is also used to do trouble-shooting by the admins. Commanding can also be done by operators, but only using predefined command sequences, so called work-flows, to reconfigure external interfaces.

In terms of monitoring it is clear, that a display as shown in Fig. 5 serves well for experts, but it is inappropriate for real-time operations. The NC-operator has a completely different view to the system and this view is provided by a dedicated graphical representation.

Here again, the service-oriented approach is chosen. The essential information needed about the network is, whether the end-to-end connection between ground station and satellite command system is available at all, and if a redundant data path is available in case of problems. Such an end-to-end view is realized as shown in Fig. 6.

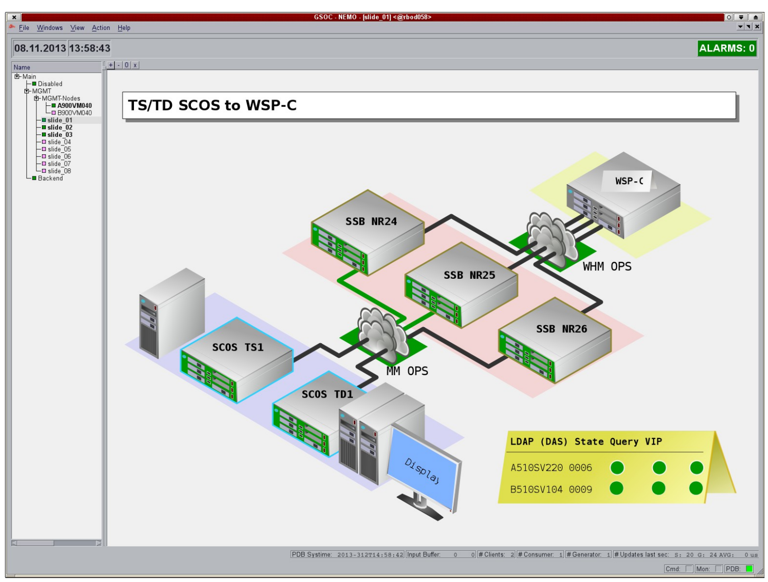

Figure 6: End-to-end view of the connection between SCC and ground station as displayed by NEMO.

At the right-hand side, the WSP-C is the SLE-service-provider[2] hosted by the ground station, here Weilheim. From the GSOC point of view, the SLE-service has to be reachable, but it is not under control of GSOC. Therefore there is just a single WSP-C displayed, the active one. The middle row of devices are the SLE-user hosted at GSOC, the so called SSB. They are setup in a threefold redundancy and as they are locally running at

GSOC, all three of them are monitored and displayed. Finally on the left, there are the hosts running the satellite command system, SCOS, in the displayed example for the satellites TerrarSAR and TanDEM.

Concerning the network, the WSP-C is located in an operational LAN at Weilheim, while the hosts for SSB and SCOS are located within GSOC's multi-mission LAN-segment. In the display of Fig. 6 the particular data path through the network components is completely hidden. Again, the important information is the availability of the service.

In the regime of network infrastructure, it is almost impossible, to deduce the essential high-level information (Is some host reachable?) from the various low-level information of the relevant components. Any operational LAN-segment is internally highly redundant and there is an exponentially growing number of possibilities to route an IP-packet from one host to another (see for example Fig. 7).

The network itself is operational as long as there is still one possible way to connect the two hosts to communicate. Instead of checking all possible ways from low-level information, it is much more efficient to simply check if the target host is reachable by a Ping. In fact, if some of the ports potentially used for a connection are down, it would be overkill to issue a warning, as it has no impact to operations. Such permanently ignored warnings only lead to the bad habit to also ignore warnings that are indeed severe.

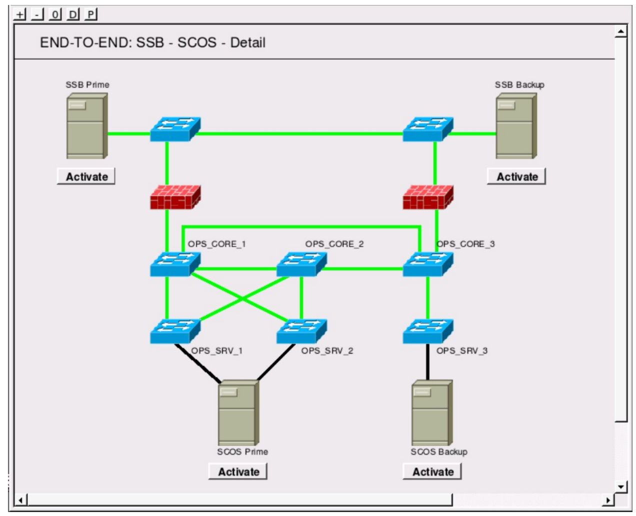

Figure 7. Detailed View of the Network-Structure between SSB and SCOS.

Nevertheless, having the more detailed information available in the system enables the system-administrators to realize if the system slowly degrades, long before it finally fails. In case of a real failure, it also serves perfectly as starting point for analysis, as it enables the admin to localize the breakdown.

D. Specialized Monitoring Tailored to the Projects Needs

There is a small feature in Fig. 6 easily to be missed. The end-to-end view includes more than the infrastructure provided by GSOC in the multi-mission context. It also includes at the end-points of the chain hardware hosted by the ground station and the projects. A picture like Fig. 6 might look alike for any mission, but the hardware at the mission specific end-points is always different.

Also different for any mission is the specification, what a project wants to have monitored. By now a large variety of probes has been developed for NEMO. Among the standard probes for all the typical properties monitored on servers and customized probes dedicated to match special tools in use at GSOC, there is also a native file-based interface that enables to feed any piece of information thought of importance into the system. That way, every project is free to define, which information is monitored by the shift-operator.

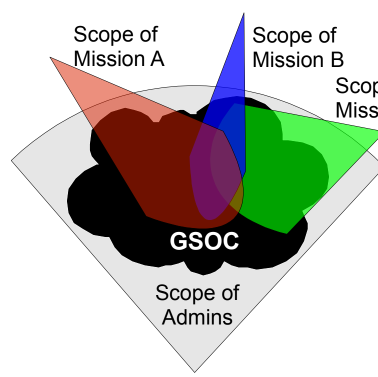

Figure 8: Mission Specific View of GSOC's Network-Infrastructure.

Apart from the real-time TM/TC-connection discussed above, we are in the process to include also offline services. In the sense of service oriented end-to-end views, such an offline-monitoring includes the complete chain from the first FTP server delivering the data down to the final data storage. Fig. 8 sketches the various scopes, different projects put onto GSOC's IT-infrastructure.

Because the antenna M&C WARP and NEMO are based on the same framework, SpACE, inventions for one of the systems can be used for the other without any effort. For instance, the time-dependent monitoring based on a state-machine developed for WARP could also be utilized within NEMO. Potentially the "state" can be connected to the scheduling, altering the mission dependent monitoring with respect to the visibility of the satellite. Also offline activities like data synchronization between redundant storage areas, may creating additional load to network connections, could be taken into account. The huge potential of this development is revealed by the fact that typically it is more a project's problem to precisely define their needs than to realize the technical implementation.

III. Automation and Automated Error-Correction

Operating a ground station has, except for a few critical phases like e.g. a LEOP, become routine. Ground systems are hardened such, that there is no more need to have experts for all devices around all the time. Therefore, a consequent step to more efficient operation is automation. An analysis of all passes supported by the Weilheim ground station in September and October 2013 has shown, that 95 % of all supports have run smoothly without any human interaction for trouble-shooting needed. It's rather easy to have this fraction of passes run automated. But as discussed in Section I, GSOC is devoted to provide a successful service even if failures do occur, hence our aim is not only automation, it is even more automated error-correction.

As for the interface to human operators, the key decision to be made for connecting an M&C to an automated command instance, is the decision on the level of abstraction used, to signal errors by the M&C. A granularity chosen too fine results in a vast number of possible error conditions, impossible to be handled automatically. On the other side, too much abstraction leaves not enough room for a proper reaction and will flag too much of the hardware as non-operational in case of error. A lesson learned is, that the device level – where information is grouped along the physical separation of hardware into various devices – is not well suited to define the desired level of abstraction. Especially failures of the kind discussed in Section II, resulting from the dependencies between several devices, could never be solved automatically that way.

The state engine integrated to WARP seems to be a much better starting point. It provides several features making it possible to respond to abnormal conditions appropriately:

- The signals can be individually adjusted to the needed level of abstraction. They can be connected to single alarms raised by one hardware component as well as to a combination of many low level inputs.
- Well known features can be handled individually, the reaction can be a real error-correction. Only if a correction of the error is not possible or not (yet) implemented, the system has to switch to redundant hardware.
- The state engine can be used as a single interface, providing all information needed by the command instance for error handling. Therefore all failures are reported by the state engine in a single format.
- In case the automated error correction does not succeed, the remaining failure is signaled within its context and the corresponding functionality. Thus the next instance to address the problem, a human operator, knows immediately, to which extend the system is affected and which parts are still operational.

At the moment, we do a systematic long term analysis of operations at the ground station Weilheim. Based on this data – precisely the occurred problems, how they were displayed and the operator's reactions to resolve the situations – we are moving forward towards automated operations at Weilheim.

IV. Conclusion

Bringing the newly developed M&C-tools to operation at GSOC and its ground station at Weilheim has triggered a significant change in the way operations is performed. Trying to replace a display of "what is there" by a monitoring of "what is needed" has lead to a complete change in the way information is displayed at all. On one side, the growing complexity of the systems in use produce an increasing amount of data. This is even accelerated by the fact that the new M&C-tool has access to parts of the system, not included in the monitoring before. On the other hand, available information is much more rigid filtered to give the operator a chance to identify severe problems while suppressing less important information.

At the Weilheim ground station, we were able to create a time-dependent monitoring based on a state-machine within WARP. This has lead to a different way to display deviations from the nominal configuration such, that source and impact of the deviation are shown as once. Besides helping the operator to evaluate the situation, this was the key to finally include dependencies between different hardware devices in a consistent manner. It was this change that allowed us to start not only the implementation of automation but also to realize automated error correction.

At GSOC, NEMO has become a powerful tool as well for system administration as for routine 24/7 operations. By replacing the monitoring of a bunch of servers by dedicated views tailored to display the services needed by the various projects to get their work done, NEMO has demonstrated its power to summarize the essential information. It is now possible for the same shift operator to monitor a much larger amount of hardware than before. Also the problem to distinguish between real and virtual hardware has vanished by concentrating the monitoring to what a hardware is used for. As for the ground station, the evaluation of an alarm has become much easier because this alarm does no longer come from some hardware, instead it is raised within the context of a service. The increasing acceptance by projects to define precisely what they wish to have monitored and the integration of those needs into NEMO proves the huge potential of this new tool.

Appendix A
Acronym List

AOS	Acquisition of Signal
COP	Configuration Observation Processor
DFT	Data-Flow-Test
DLR	German Aerospace Center
ESA	European Space Agency
FTP	File Transfer Protocol
GEO	Geostationary Orbit
GSOC	German Space Operations Center
GUI	Graphical User Interface
HPA	High Power Amplifier
IOT	In-Orbit Testing
IP	Internet Protocol
LAN	Local Area Network
LEO	Low Earth Orbit
LEOP	Launch and Early Orbit Phase
M&C	Monitoring- and Control-System
NC	Network-Control
NEMO	Network-Monitoring, the new IT-infrastructure M&C at GSOC
RF	Radio Frequency
SSB	SLE-Switch-Board, the SLE-user in use at GSOC
SLE	Space-Link-Extension
TM/TC	Telemetry and Telecommand
TT&C	Telemetry, Tracking and Command
UC	Up-Converter, Frequency-converter to RF
WARP	Weilheim Antenna Remote Processing, Weilheim's new M&C-system
WSP-C	Weilheim Service Provider for Cortex, the SLE-provider in use at Weilheim

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