First year of ALMA site software deployment: Where everything comes together

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ABSTRACT

Starting 2009, the ALMA project initiated one of its most exciting phases within construction: the first antenna from one of the vendors was delivered to the Assembly, Integration and Verification team. With this milestone and the closure of the ALMA Test Facility in New Mexico, the JAO Computing Group in Chile found itself in the front line of the project's software deployment and integration effort. Among the group's main responsibilities are the deployment, configuration and support of the observation systems, in addition to infrastructure administration, all of which needs to be done in close coordination with the development groups in Europe, North America and Japan. Software support has been the primary interaction key with the current users (mainly scientists, operators and hardware engineers), as the software is normally the most visible part of the system.

During this first year of work with the production hardware, three consecutive software releases have been deployed and commissioned. Also, the first three antennas have been moved to the Array Operations Site, at 5.000 meters elevation, and the complete end-to-end system has been successfully tested. This paper shares the experience of this 15-people group as part of the construction team at the ALMA site, and working together with Computing IPT, on the achievements and problems overcomed during this period. It explores the excellent results of teamwork, and also some of the troubles that such a complex and geographically distributed project can run into. Finally, it approaches the challenges still to come, with the transition to the ALMA operations plan.

Keywords: ALMA, Distributed collaboration, Engineering and technical support models, Transitioning from construction to operations

1. INTRODUCTION

In the northern Chilean Atacama desert, the biggest ground based radio observatory is under construction. It is called the Atacama Large Milimeter/submiliter Array (ALMA), an international astronomy facility. It's a partnership of Europe, North America and East Asia, in cooperation with the Republic of Chile. ALMA is funded in Europe by the European Organization for Astronomical Research in the Southern Hemisphere (ESO), in North America by the U.S. National Science Foundation (NSF), in cooperation with the National Research Council of Canada (NRC) and the National Science Council of Taiwan (NSC), and in East Asia by the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Academia Sinica (AS) in Taiwan. ALMA construction and operations are led on behalf of Europe by ESO, on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI) and on behalf of East Asia by the National Astronomical Observatory of Japan (NAOJ). The Joint ALMA Observatory (JAO) provides the unified leadership and management of the construction, commissioning and operation of ALMA.

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When completed, ALMA will offer 50 antennas in its main array, 16 more in the ALMA Compact Array, a variety of configurations, a large number of observing modes (standard interferometry, mosaicing, fast-switching, etc.) and complete frequency coverage of the mm/submm windows up to 1 THz. These antennas are being built by three different vendors, and are assemblied at the Operations Support Facility (OSF), near San Pedro de Atacama, since april 2007. Before being delivered to the Observatory, antennas have to be thoroughly tested by the vendors to accomplish ALMA specifications, including pointing accuracy and dish deformation. Once the vendors and the ALMA supervising institution are satisfied with the performance, the antennas are delivered to the Observatory's Assembly, Integration and Verification team. This team has the responsibility of integrating the various ALMA subsystems, it must integrate and verify correct funcioning of the antennas, its receiver, its back-end electronics and the correlator together with the ALMA Software. Hardware prototype antennas and detectors were tested until December 2008 at the ALMA Test Facility (ATF), at the Very Large Array site in New Mexico, U.S.A.

The ALMA Software is the infrastructure that will control the overall operations of the array, and the later data processing. It is developed by the Computing - Integrated Product Team (C-IPT).[1] Members of this team are geographically distributed in Europe, East Asia and North America. The software is divided into different subsystems that corresponds mainly to different roles inside the system.[2]

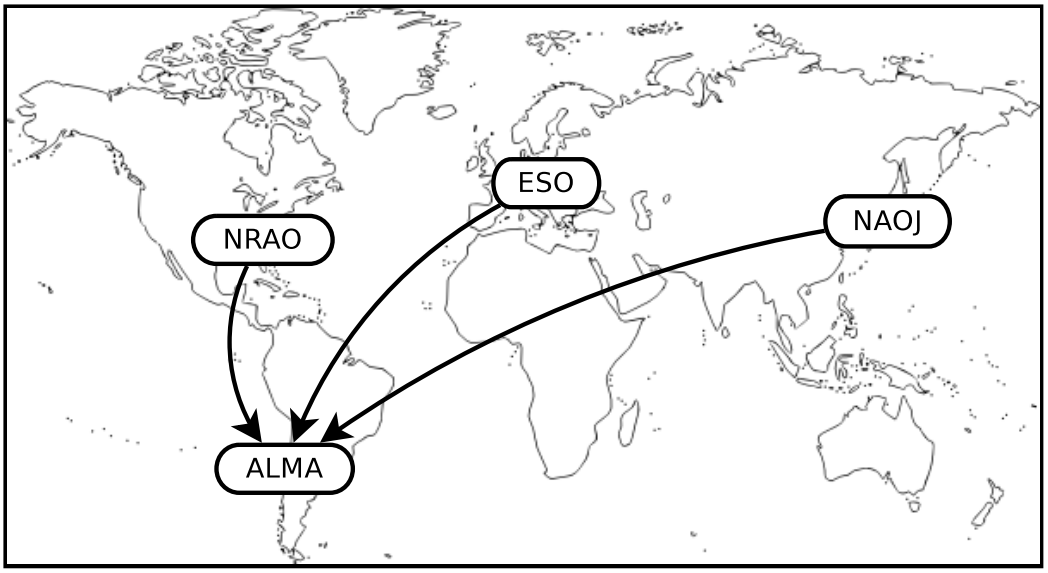

Figure 1. Distributed software development, with central integration point in Chile.

A dedicated team of 15 people, the JAO Software Group, has the role of providing frontline software support for the ALMA software. Among the activities assigned to this team are: problem reporting, troubleshooting and hot fixing of problem if possible, software testing, operations procedure development, software deployment and configuration control. Consequently the group has to interact closely with C-IPT development teams.

This paper explores from the point of view of JSG how the first year of antenna verification and acceptance at the OSF went on, how the road was prepared to reach this point, and what is expected in the near future. It explores the success as also the challenges detected during this year and proposes approaches that might facilitate this work in the future. It also pretends to be a reference for other Software Support groups of large astronomical observations projects which have to interact with geographically dispersed teams to achieve complex goals.

In Section 2, the composition of the JAO Software Group is explained, mentioning some interesting background information which helps understanding the team's good work environment. Section 3 is focused on exploring how the group helped to prepare the observatory to be ready to receive its first antenna for acceptance. Section 4 analyzes the first year of integration and acceptance activities done at the observatory, and on

the JSG role during this time. Based on the gained experience, section 5 explores future challenges. Finally, section 6 concludes what lessons have been learned so far.

2. JAO SOFTWARE GROUP

ALMA Software is developed by C-IPT as part of ALMA construction project. JSG provides frontline support for it. The group is part of the Departament of Technical Services (DTS), which reports to the JAO's Director. In terms of organization the group reports to the head of the JAO Computing Group, who defines the long term strategic planning. The group manager and its deputy define the short term priorities at the OSF. The staff members are divided into three specific areas, according to their main responsibilities: software engineers, database administrators and system administrators. (Figure: 2). By the end of 2009 the team was composed of 14 members.

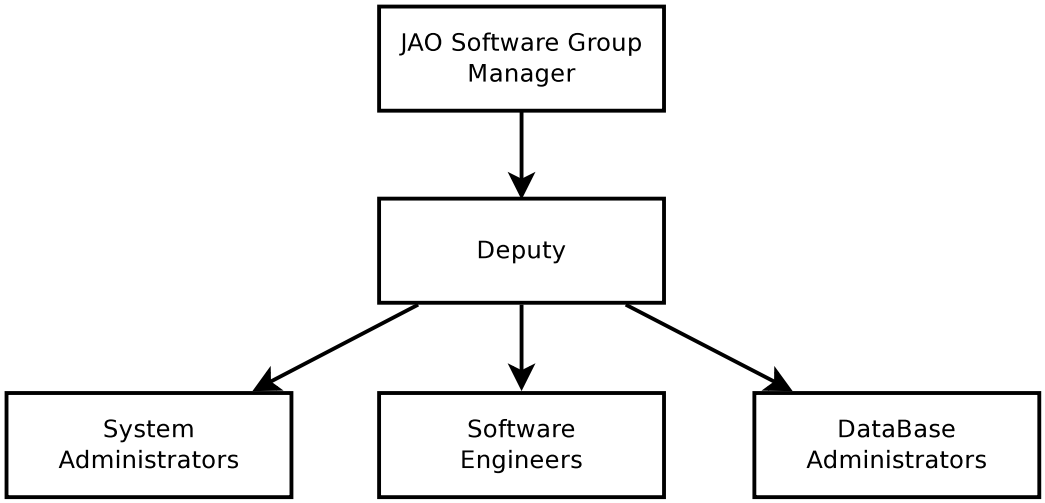

Figure 2. JAO Software Group organization chart.

The team started to be formed in mid 2007. The initial team members were sent to the different locations where software was being developed for training purposes. One team member was sent to ESO headquarters in Garching to work with Archive/ACS teams and the rest spent between six months and a year at the ALMA Test Facility (ATF) in New Mexico, testing and developing the ALMA Software, in an semi-operational environment.[3] During 2007 6 team members were sent for training to the ATF. Beginning 2008 JSG Mannager was appointed and started an agressive hiring rate. During that year the full size of the team was reached, hiring 8 new staff members. Most of them were also sent to the ATF. All JSG team members transfered temporarily to the ATF were integrated into the ATF Support team, with responsabilities similar to the ones that the group would have at the OSF: report and troubleshoot software problems reported to them by other users. Another activity executed by the support team was to exercise the system on a weekly basis by running software regression tests.[4] The ATF was closed by the end of December 2008. All remaining JSG team members who were at the ATF returned to Chile right after that.

During 2008 the main guidelines for the team were established, defining that gaining knowledge of Control, Correlator and Archive subsystems were the first priority to be pursuit. Integration of the software was also highlighted as a very important. In summary the group had to prepare the conditions for upcomming commissioning activities.

3. PREPARATION PHASE

Until December of 2008, the ALMA project had the ATF running at the Very Large Array (VLA) site near Socorro, New Mexico. The ATF was in operations since the prototype evaluation phase. It first started as a facility to test the antenna hardware, but on 2007 the project decided to allow C-IPT to use it mainly to verify

software functionality and integrating the different subsystems. While JSG team members were on duty at the ATF, Control Subsystem tasks were assigned to them. This included mainly the development of software drivers for CAN devices. Many hardware device software drivers are still being maintained by JSG team members. To gain knowledge of other subsystems, team members worked together with colleagues from the Integration, Test and Support (ITS) team, developing utilities to facilitate deployment and development tasks, while others developed applications for the Archive subsystem.

As team members returned to Chile after finishing their training period, they started to prepare the conditions for the upcomming commissioning activities by deploying computing infrastructure and supporting the antenna vendors camp. The interaction with CIPT teams started to become more complex, mainly because CIPT teams were not geographically near the observatory. Many C-IPT members were sent in missions to the OSF to support deployment efforts.

Part of the activities performed by JSG during that period include delivering the Control Command Language for hardware engineers to use it on a day to day basis. Also, three software releases where deployed during 2008, going from Antenna Verification version to ALMA-5.1.1. STEs were deployed at the OSF to start connecting antennas and antenna related elements to them. During this period the first quadrant of the AOS Correlator was deployed at the high site, which required a set of computing infrastructure on site to control it. Network configuration was also defined during this period, aiming for a configuration that would enable an antenna to keep its IP address independently on where it was placed.

Members of JSG participated in many software development proyects, gaining more experience in critical subsystems, such as the hardware device monitoring system. Procedures for the upcomming installation of the 'One Archive' server were established when team members were sent in a mission to ESO headquarters. It was also pursuit to define and implement a project wide virtualization standard, and cooperation with Universities was constantly promoted.[5]

4. FIRST YEAR OF INTEGRATION AND SUPPORT

Starting 2009 computing infrastructure was in place to start antennas acceptance. The first accepted antenna was installed at the Technical Facilities Building during January 2009. Since this antenna already had the detector equipment inside when it was moved, JSG was asked to monitore the diverse electronics equipment inside the antenna as it was moved from the vendor's camp to the OSF pads. This was accomplished by connecting a laptop to the antenna which was running a virtualized STE on it, being this the first field test of virtualization of ALMA SW. In March, Vertex antenna DV01 was the second antenna to be delivered for acceptance, and DV02 followed in April. The year finished with two more antennas being delivered for acceptance: DV03 in September, and DV05 in November.

4.1 JAO Software Group activities

AIV science team, composed entirely by astronomers, is in charge of running tests against the antennas to certify them. The acceptance process is divided in 4 stages, each of them carried out on a different STE, with the corresponding setup. First, antenna control/movement is checked; this includes measuring deformation of the dish and adjusting the antenna panels, and optical pointing accuracy measurements. On station two, the receiver hardware is integrated and the antenna is tested as single dish instrument, such as total power observations. Station 3 corresponds to integrating the antenna with a two-antennas test Correlator, enabling basic interferometric observations. Finally the antenna is tested again at the high site with the real correlator hardware (Figure: 3). JSG provides all software support needed for these tasks. The first antenna was connected to one of the STEs that had been installed at the OSF months before.

Since the ATF was closed by 2009, the integration of hardware and software was only possible at the OSF. Thus it became necessary to be able to maintain under control the stability of the software that was being deployed at the OSF and to test it against real hardware. An strategy for testing the software on a weekly basis was accordingly established. These tests were based on the tests performed back at ATF. They considered different tests, depending on whether there was a new release being deployed or a new iteration of an already deployed release being tested. New iterations were deployed releases are installed at OSF STEs whenever there

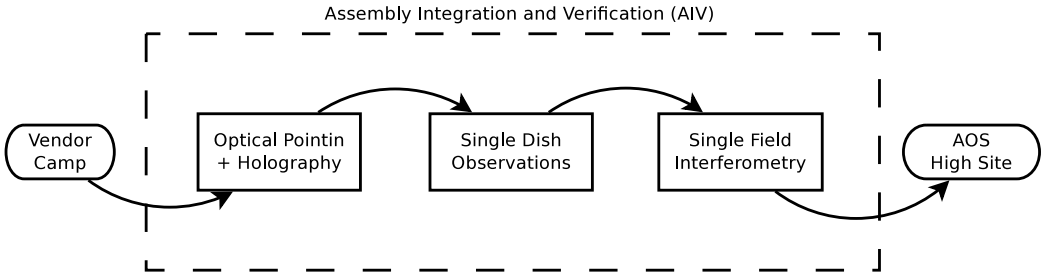

Figure 3. AIV verification stations.

had been a significant amount of patches. Normally, the amount of patches accumulated during a week justify to deploy a new iteration. The strategy implemented by JSG was to deploy a new iteration every Wednesday, and to test this new iteration the same day. If all test passed, all STEs were aligned to that software iteration. Testing strategy at the OSF is not the only software testing policy in place. The Integration, Test and Support (ITS) team is continuously testing the software in many different ways. Nevertheless, they have no access to real hardware, which makes its end to end tests dependent on how well the simulation for certain devices is implemented. Also, daily unit testing is performed by this team, which helps developers to find out very quickly if there has been something wrong with a recent improvement to their code. Thus, testing strategy at the OSF is complementary to tests done by ITS. During 2009, JSG also implemented a 'build farm' in order to have access to daily builds of the current software version, and monitor the build health periodically. During April, using ALMA-6.0.1, the first astronomical fringes at the OSF were achieved on planet Mars, marking an important milestone for the project.

During September, the first antenna was moved to the Array Operations Site (AOS), at 5.000 meters altitude. The purpose was to commence tests using the real ALMA Correlator. On November, first dynamic fringes at the AOS were achieved with the very first two antennas at the high site, marking another important milestone for the project. JSG adapted to the more intensive work activities at the OSF: an on-call service was implemented, providing coverage for night time problems and adapting working hours to be present at the control room for 16 hours in a row.

During the last months of 2009, the preparations to deploy ALMA-7.0.0 at all OSF STEs were started. This was the first release that was not tested before at the ATF. The new release required a change of the STE operative system, from RedHat 4.3 to 5.3. This implicated that the prototype optical pointing telescope, which had been used until then for AIV station 1 verification, could no longer be used because the hardware drivers were not supported on the newer OS. Also, the Oracle Database version of the Archive server had to be changed from 10g to 11g, as the plan was to have one single archive server for all STEs called the 'One Archive'. Tests for this deployment started by the end of August, and the final deployment was done during December. In order to have the One Archive database server installed at the OSF, the server room at the Technical Facilities building had to be finished. This was accomplished during October. During this month, all STEs and the One Archive computers were installed, task done by JSG members and Archive subsystem colleagues.

The AIV science team also requested JSG to support their verification tests during this initial period of antenna acceptance. Since functionality at this stage of the project is not as friendly as it will be when the development finishes, the only way of controlling the system from an end-to-end perspective is through hand-made python scripts, using the Control Command Language (CCL) interface. These scripts, now called science-scripts, would be developed and maintained by astronomers. Nevertheless, JSG is constantly supporting their development through troubleshooting, mainly because it is not clear from the error messages if the error is due to a problem on the script itself or because there's a deeper problem in the software (or even a hardware failure).

One important portion of information to properly operate ALMA is the data corresponding to the weather conditions at the site where the antennas are operated. This data is collected by several weather stations provided by a specialized company. The selection of the hardware to be used as weather stations was assigned to the Science group, and as a consequence CIPT was not involved in the development of the software modules for these

devices. This task was eventually picked up by JSG team when the hardware for the weather stations arrived to the OSF. Thus, during 2008 and 2009, the module was developed and integrated into ALMA Software, and subsequently the weather stations were deployed at the OSF and the high site in order to allow the Science team to commission it.

4.2 Main challenges

The main complexity of the daily work of the JAO Software Group is to be the central interaction point for most of the activities at the OSF. As all system users are most of the time interacting with software pieces to access hardware devices or do observations, most of the problems are normally first reported to JSG. In this sense, JSG team members have an additional role, as they have to act not only on software problems, but also diagnostic problems in other areas, and call the people in charge, if necessary. Therefore, Computing is normally the middleman between hardware engineering, commissioning scientists, operators and other users (Figure 4). It is important to consider that users at this point of the project have also a wide knowledge of the underlying system, and are therefore able to handle complex information about it. That means, in this middleman role, the software support communicates directly with the involved parts, unifying different points of view. Further, for general coordination of OSF activities, there is a daily coordination meeting, involving all the before mentioned system users.

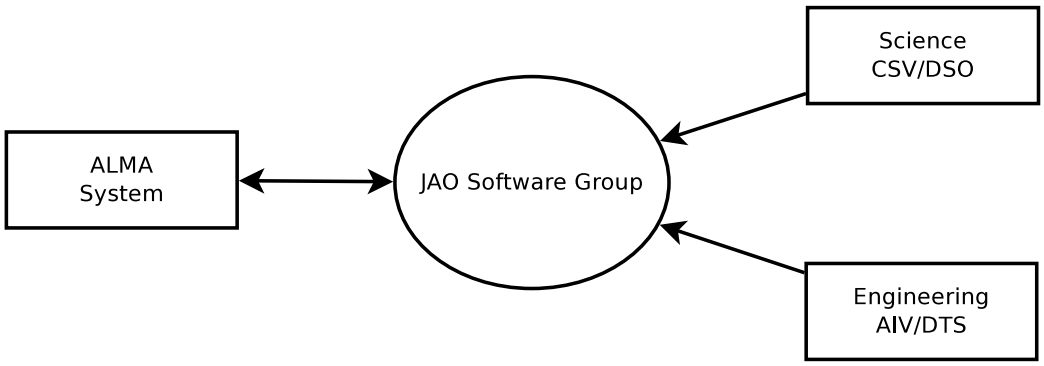

Figure 4. JSG support interaction with Assembly, Integration and Verification, and Science Commissioning groups.

Also during ALMA 7.0.0 deployment it became clear that an exclusive and continued access to real hardware to integrate the software with it was neccessary, in order to detect problems on time. Since the ATF is no longer available, it has been requested to have such an access with the OSF two antenna correlator.

Regarding cooperation with CIPT development efforts, members of JSG participated during this year actively in the refactoring of the implementation for hardware device monitoring functionality, the extension of the Control code generation framework for Ethernet devices, and continued to develop hardware devices software drivers for Control subsystem. Monitoring implementation work continued all around the year, first iteration started operations during August, last details were worked out during December prior ALMA-7.0 release. In general terms, the Observatory is the physical place where all subsystems come together. This is also the reason for CIPT to send regular missions to Chile. JSG has therefore also a unifying role in terms of software deployment and testing.

Once antennas started to arrive at the OSF it was clear that there was a necessity for being able to move the antennas from one pad to another without having to reconfigure all the devices in an antenna that had an associated IP address to it. Therefore, a plan was elaborated which changed the initial design of the network layer for the antennas and made use of virtual networks supported by the installed switches. This plan was finally approved during early 2009. The design of the new network for antennas was tested by JSG during February, and until now has showed that facilitates enormously the configuration tasks executed by JSG staff. To make the deployment effort even easier in terms of network configuration, it was proposed during mid 2009 that each antenna would have a class C network instead of the original class B. This has effectively isolated the antennas, avoiding the need to handle unnecessary broadcast messages.

During this first year of integration a couple of problems were uncovered: the project relied until this point on one single CVS server, which was located in Germany. Since activities at the OSF were increasing, and because of the distributed locations of the development teams, having one single CVS server became a bottle neck. It became clear that a replication solution for the CVS server was required. This was implemented during mid 2009, and on May a replication solution entered operations at all four locations of the project. In Chile, because of network limitations, the replication server was put initially in Santiago, once the network bandwith to the OSF was improved, the server was moved to its definitive location at the OSF.

Another problem that showed up during 2009 was the unintended side effect of connecting all STEs at the OSF to the same archive server. Original design didn't include this scenario usage, however the operational requirements pushed into this direction. This is still an issue, and will have to be solved in the near future.

5. FUTURE CHALLENGES

During 2010 there have been already many new achievements at ALMA which involved JSG. The most important one corresponds to the start of Commissioning and Science Verification (CSV) activities. CSV is the latest step of verification prior ALMA can start scientific observations. Its goal is to verify, test and refine the various telescope observing modes and to demonstrate the ability to attain the scientific goals of the instrument. It is expected that this should be achieved during the present year. During the second semester of 2011, Early Science Operations are planned to commence, needing 16 antennas available at the high site, fully commissioned and with at least four receiver bands installed. Nevertheless, CSV activities will continue during this period until the official inauguration of the ALMA Observatory, which is planned for the end of 2012. As for antennas, during this year three more antennas have started their commissioning process. PM02 and DV04 were delivered in February, and DV07 in May.

CSV requires at least ALMA release 7.0.0 to operate, but unfortunately, since optical pointing tests are a must have for acceptance activities to go on, problems with the new production Optical Pointing Telescope (OPT) forced JSG to downgrade one STE to run with ALMA-6.1.1, to be able to use the old prototype OPT, for which there is no support on newer RedHat versions. This triggers the concerns of how stressed deliveries of new hardware have become, and to better understand the consequences that failures like this can have for normal operations. Also, there have been problems with Oracle's Real Application Cluster (RAC) solution, mainly because of the high load that the Archive server was under because there are too many STEs connected to it. Interim solution has been to disable RAC and to separate components in different Archive servers. This is something that should be solved in the short term.

The software testing suite at the OSF has received many improvements in recent months, mainly because of involvement of the ITS team. New end to end tests have been included, and also science scripts testing has been added. Nevertheless, maintaining test cases up-to-date is a time consuming task, and a plan is being elaborated to automize the execution of these tests. ALMA Software release 7.1.1 is about to be deployed, and OSF test cases have proven to be very useful to discover unreported problems while doing preliminary tests for deployment of this latest releases.

On the hardware side, currently used single board computers (Antenna Bus Master) are no longer available in the market, thus three new boards have been tested live at the OSF by a CIPT colleague. It seems that a decision has been made about what board will replace the existing ones, and thus, in the near future all antenna boards should be replaced by the new one, bringing some new features and eventually some difficulties for the new future.

During 2010, it has been decided that because the only place to have access to ALMA hardware is at the OSF, exclusive testing time will be provided to CIPT development and integration tests in a daily basis for the coming year. Moreover, it has been established that for these tests a two antennas Correlator, currently installed at the OSF, and at least two antennas (also called the OSF Interferometer) will be available to perform these tests. Reservation of these time slots has been coordinated between CIPT Software Engineering and JSG.

6. CONCLUSIONS

In the period from when the first antenna was handed over to the observatory till now (mid of 2010), there has been a major change in JSG activities. Prior to 2009, main activities of JSG included preparing computing infrastructure in order to be able to handle the coming commissioning, as well as integration of antennas and their equipment. Recently, the most important role has shifted to provide user support to astronomers, in order to allow the continuity of their commissioning activities. Software support consists of problem troubleshooting and analysis, and in some cases debugging and code fixing. This requires an overall knowledge of the system, and it is therefore very important to have experts on each subsystem on-site. Most times, permanent code fixes are requested to responsible developers of the failing module. Therefore, interaction with CIPT development teams is essential to fulfill JSG main goals. The fact that many team members spent extended periods of time working at the ALMA Test Facility and visited ESO headquarters in Garching, facilitates personal communications. Getting to know each other in person helps to clarify misunderstandings in a much easier way.

Besides support activities, all team members have been involved in cooperation projects with CIPT subsystems. This cooperation has taken different forms, including development of new functionalities, or participating in testing and development of procedures to be used at the OSF. These activities have required most of the times assigning involved team members for short missions to visit the corresponding development site. It has also converted the participating team member into experts in the corresponding functionality of the ALMA Software. A key to achieve this has been the establishment of accurate goals by JSG management, in order to accommodate preferences of the different team members.

As a matter of fact, the horizontal structure of the JAO Software Group helps to create a healthy work environment. This structure makes it also easy to interact directly with the group management and allows the team members to have a clear view of the overall team goals and interests, which are also enforced through periodic conferences and trainings attendance. This ends up in having a strongly cohesive group, with a very positive attitude and a cooperative approach to face problems.

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