Deployment of S-Pol at TiMREX

Project Report

1 Introduction

S-Pol was deployed in southern Taiwan from May 15th to June 30th on the of Kaoping River Levee near Sinyuan township in Pingtung county to support the Terrian-induced Monsoon Rain Experiment (TiMREX). All EOL staff that were involved in this project are to be congratulated for their hard work in making this project a very successful field project. This report summarizes the deployment, highlights what went well and what could have been done better, and makes recommendations for future operation and deployment of S-Pol.

2 Project Preparation

Planning for the deployment of S-Pol was done through a series of 13 meetings that took place from November 11, 2007 to March 19, 2008. The notes from these meeting are posted on the EOL web pages [1]. Each meeting followed a similar format, in which updates were presented on the progress of all aspects of the project, and new action items assigned to people. These meetings defined the scope of the work that needed to be done for deploying S-Pol at TiMREX, and allowed all to assess progress in the preparations.

At times throughout the planning process, it appeared as if the requirements for the project kept changing. This appearance was probably mainly due to disagreement between NCAR staff about what standard features (data products, displays, access to external data, etc.) are supplied when S-Pol is requested for a field project. The expectation of what would be supplied by NCAR to support scientists in the field was complicated by this project not being an EOL-wide supported project: CDS and FPS had made it clear before RSF decided to proceed with TMREX that they would not be able to support enhanced functions such as an operations center and complex displays, i.e. beyond what is required to operate the radar in a standalone mode, for TiMREX in addition to T-PARC and VOCALS. Therefore, there was confusion as to whom would provide various services such as access to external data at S-Pol, access to S-Pol data at the project office, and field project coordination.

Recommendation: *RSF must decide on the standard configuration of S-Pol and communicate this configuration to users, so that requests for additional features for a project are clearly identified. In addition, all S-Pol staff associated with future projects must actively review the feasibility analysis that is written for the project to clear up any misunderstandings about what RSF is promising to deliver in support of the field project.*

NSF funding for the deployment of S-Pol (~ $670k) was not sufficient, and additional funding had to be sought by the PIs from Taiwan. There is a strategic danger in fielding EOL instrumentation with budgets from NSF that do not cover the total cost of the project, because PIs for future projects may question why S-Pol costs so much more than a project like TiMREX. On the other hand, there is a risk that S-Pol will not be fielded if NSF has to support the cost of the whole field program. NCAR staff recognize this issue, and often strategically under-bid S-Pol projects to ensure that NSF will fund them, and then look to make up the shortfall with non-NSF funds. It seems that this strategy is fine, if NCAR staff are assured that the total cost estimated in the project planning process will be covered.

Recommendation: *To address this issue, EOL must communicate the total cost of the project to the PIs, and if it is not fully supported by the deployment pool funds, request that PIs find any additional funding. EOL must have assurance from PIs that the costs that are not covered by the deployment pool funds, will be covered. It is recommended that this additional funding be identified and approved before final approval of the project.*

The Central Weather Bureau provided all of the communications and networking infrastructure at S-Pol so that NCAR scientists could be part of the daily planning process and that the data could be accessed remotely. Coordination and planning for the use of these resources would have proceeded more efficiently through direct communication between NCAR and Taiwanese technical staff. Much of the technical planning was conducted through the PIs of the project, but the details the situation were not always clear to the technical staff involved. Direct interaction between technical staff would also have allowed staff to establish relationships with their counterparts which would have made work in the field more efficient. For example, better communications would have helped plan for the networking infrastructure that was installed at the site. With this information, EOL staff could have simulated the networking environment that was created for S-Pol in Taiwan at Marshall which would have helped us prepare solutions for problems that occurred, e.g. the restrictive firewall, space in the SCC for the Taiwanese provided networking equipment (fiber optic converter and high bandwidth switch), and bandwidth problems caused by existing S-Pol network equipment.

Recommendation: *Establish direct communications between technical staff when planning field projects.*

It was noted that preparation for shipping of the S-Pol containers was handled excellently. However, PIs did question the cost of the shipping agent that was used, and the number of containers that we needed to ship. The shipping agent is one with whom EOL has worked for many years. We have an excellent working relationship with them, and they have always been reliable. Furthermore, our experience is that they are available 24 hours a day which is especially important for resolving shipping problems in international projects.

These days, S-Pol ships in eight containers. Four of those containers form the support structure for the S-Pol pedestal and function respectively as the fuel container, the transmitter container, the generator container, and a storage container. The S-Pol Control Center (SCC) and the Annex provide space for staff and researchers to work. Container 7 is a storage container that holds large spare items, e.g. a spare air conditioner. Container 8 provide a workbench for technicians and engineers to set up test and measurement equipment to troubleshoot problem subsystems in S-Pol, and also provide space for a large refrigerator for food and water. We have found that the space of eight containers provides for a productive and harmonious environment when in the field.

Recommendation: *Continue to use our current shipping agent to ship S-Pol to international field projects, and ship eight containers.*

Project planning would not have gone as smoothly without the time and input of Brigitte Baeuerle. RSF gratefully acknowledges her contribution to making this project a success.

Recommendation: *Future national and international S-Pol projects not be approved without support from FPS.*

3 Site Preparation

The Central Weather Bureau (CWB) did a fantastic job preparing the site for S-Pol. The CWB had a retaining wall constructed next to the Kaoping River Levee. The space between the levee and wall was filled to create a large enough site on top of the levee for S-Pol. The construction of this extension to the levee was done very well. When S-Pol is deployed on a new site, the ground usually takes some time to settle under the weight of S-Pol. Typically, for the first few weeks, the pedestal must be leveled to account for this settling. The preparation of the extension was so good that the new fill within the retaining wall only subsided by a small amount after the second heavy rain fall event during the project.

4 Setup

This was the smallest site on which S-Pol had ever been deployed and Jeff Bobka did a great job at first planning the layout of S-Pol and then implementing the plan during setup. The containers were delivered to the site on April 22nd. Three RSF technicians (Al Phinney, Mike Strong, and Bryan Gales), Jeffery Bobka and Jose Rivas constructed S-Pol between April 23rd and May 6th (12 working days, two days off). The construction proceeded according to schedule, despite the hot and humid conditions that existed in Taiwan at that time. Before power was established in the containers, ice cold water was essential to remain well hydrated.

The pre-installed networking infrastructure and cabling in the SCC greatly reduced the time taken during setup to set up the SCC. The reduction in computers in the SCC by moving processing machines to the transmitter container also helped. Because of these changes, we thought that it would be an unnecessary cost to rack mount the remaining workstations in the SCC for future S-Pol projects.

The CWB provided two fiber optic network connections and two K_u-band satellite communications links. One fiber optic link was dedicated to the CWB video conferencing system, and the other was dedicated to providing network access to S-Pol to transfer data, access the Internet, and remotely log in to S-Pol from Boulder. Joe Vinson did an excellent job working with the Taiwanese to configure the networking infrastructure for S-Pol. For example, some services such as access to the secure IMAP server at EOL were blocked by the fiber connection through the CWB, so Joe configured the S-Pol networking equipment to route this traffic through the one of the K_u-band satellite network connections. Without his efforts, it would have been difficult to effectively use the networking infrastructure provided to us by the Taiwanese. Because the network access played a large part in the success of the project (see Secton 6, Operations), the infrastructure provided by the Taiwanese and the support from CDS was invaluable.

Recommendation: *S-Pol projects must always have full CDS support. In addition, S-pol projects must have high speed networking access to facilitate coordination between researchers operating instruments in support of the project.*

The TiMREX Project Office also supplied a container and computers for scientist use. The video conferencing system was setup in that container, along with a data server machine through which we transfered S-Pol data and images, CIDD workstations for scientists and students to peruse data, and a WINS client to view CWB data.

5 Calibration and Pre-operations Testing

Calibration and pre-operations testing was scheduled from May 6 to May 14, but took longer than expected, in part due to unexpected problems, and in part because there was a lack of experience working with the new S-Pol software and hardware. The work on making the radar operational included selecting an operating frequency, tuning the antenna controller, calibrating the radar, implementing sector blanking, implementing an archiving scheme for the new processor data, fixing problems with the processing and display software, configuring real time delivery of data to the operations center, and providing access to third-party data sources.

5.1 Antenna Subsystem

The antenna controller did not boot in the correct configuration after S-Pol was constructed. At various stages during testing, the dual port RAM had to be reconfigured and the encoder definition table reprogrammed. In addition, the previous generation of S-Pol engineering staff had not documented that the spare PMAC card dual port RAM was never fixed which made debugging confusing when trying to use the spare PMAC hardware. Lack of functioning spares could caused a complete failure of S-Pol at TiMREX.

The S-Pol motors that were refurbished and returned only days before S-Pol was shipped performed superbly during operations, but because these were installed in the system after S-Pol had been disassembled at Marshall, we had to tune the PMAC system and servo amplifiers to operate with the refurbished motors in the field. Because this task is always performed before S-Pol is shipped to a deployment, it caused a delay in the pre-operations and calibration schedule.

The refurbished motors also exposed some long standing problems in the scan controller software. These problems included skipped fixed angles in a series of surveillance or sector scans, and repeated sector scans at the same fixed angle. These problems would have had a large impact on implementing data collection strategies in the field. They required at least several days work to fix.

Aligning the dish is a routine procedure for S-Pol, but we found a significant source of error in the traditional procedure that we could not explain. To align the dish, solar scans are used to measure the position of the sun as seen by the radar. This position is then compared with a calculated position and an offset is introduced in the radar antenna controller to force the measured and calculated positions to match. Our procedure of performing this alignment in the morning and again in the afternoon resulted in a 1.4 degree difference in elevation between the measurements when using Jon Lutz's Visual Basic program to calculate the position of the sun: that is, the morning measurement resulted in an elevation offset of +0.7 degrees, whereas the afternoon measurement resulted in an offset of -0.7 degrees. We never did explain the discrepancy between the offset measured in the morning and the offset measured in the afternoon, but we did find that the difference was reduced to around 0.2 degrees when we used Mike Dixon's program to calculate the position of the sun. The previous generation of S-Pol staff likely knew about this problem because similar results were documented in the calibration history for S-pol during Mesoscale Alpine Programme (MAP) in 1999.

In summary, many problems with the antenna controller were known by the previous generation that worked on S-Pol, but the problems were never fixed. Some of the problems that we encountered could have been addressed more quickly if various key technical personnel had had more experience with S-Pol at Marshall.

5.2 Transmitter

During the planning stage of the project, the Taiwanese had provided us with scans of the electromagnetic spectrum around 2809 MHz which is the S-Pol primary operating frequency. These scans showed significant interference at 2809 MHz, and in response, before shipping S-Pol, we tuned S-Pol to operate at 2786 MHz which was a frequency that had been used during MAP in 1999. During testing at this frequency in Taiwan, we found interference at this frequency, and also that there was variation in the transmitted power when scanning the antenna in azimuth. We had noticed this variation when testing in Boulder, but did not have time to investigate because addressing the antenna motor problem was a higher priority. Tests indicated that the variations were being caused by reflections from the rotary joint. To prevent any damage to the system, and to ensure a more consistent transmitted power level, we decided to try operating at 2809 MHz. As anticipated, though, we found that there was far too much interference at this frequency. We then checked for interference at 2803, 2800, and 2795 MHz by tuning the receiver. There was a small amount of interference at each of these frequencies, but it seemed acceptable and the best that could be achieved. For each frequency, we ideally would have characterized the performance of the transmitter, but the schedule limited us to selecting the last receiver frequency attempted (2795 MHz) as an operating frequency for the project. At this frequency, the transmitted power is was about 2 dB less than what the klystron can achieve at 2809 MHz resulting in a loss of system sensitivity. This extra work of selecting a frequency and tuning the S-Pol transmitter and receiver to this frequency caused a delay of around a day in the start of the calibration.

In addition to changing the operating frequency of S-Pol, the Taiwanese also requested that we implement sector blanking over Pingtung and Linbian because each of these locations has military installations. Using Google Earth, Bob Rilling found coordinates for the assumed limits of each of these areas and based on these coordinates, an S-Pol relative azimuth was computed. Sector blanking was implemented on 2008-05-15.

Table 1: Sectors overs which sector blanking was implemented.

Linbian, east side	22:27:24.6	120:29:52.6	139.4 deg
Linbian, W edge Army Base	22:26:52.1	120:28:44.3	151.9 deg
Ping-tung, W runway edge	22:40:20.6	120:26:52.5	5.2 deg
Ping-tung, E runway edge	22:40:26.5	120:28:42.6	15.8 deg
Ping-tung, E town edge	22:40:13.3	120:30:34.0	26.1 deg

5.3 Calibration

Calibration of S-Pol took place from May 9 to May 13. Frank Pratte prepared very detailed documentation on the calibration procedures for S-Pol. Without these, calibration of the HAWK processor would not have been possible. The calibration procedures are usually implemented over a period of two to three days, but the calibration measurements in

Taiwan took longer than usual, mostly because of lack of familiarity with the new measurement procedures. The calibration procedures developed by Frank Pratte were excellent but the documentation of these procedures must be improved by rewriting them such that they follow a procedural format.

The Automatic Test Equipment (ATE) constant monitoring mode was started only on 2008-05-24. The delay in starting this monitoring was due to a bug in the program which resulted in the passive monitoring mode being disabled soon after the program was started. Frank Pratte had written this program only shortly before S-Pol was disassembled, and therefore had not had sufficient time to test it. Fixing this program was lower in priority than fixing problems in the antenna controller and the HAWK processor.

While the ATE is able to provide real time monitoring of the system, use of these measurements for initial calibration is a manually intensive process. Software must be developed to ingest the ATE measurements and implement the calibration calculations to produce a calibration file for the radar. Right now, the ATE measurements are manually inserted into spreadsheets and the calibration calculations are performed there. This process is very manually intensive and can lead to errors. The benefit of the ATE will only be realized once the calculation of calibration parameters from ATE measurements is automated.

5.4 Processor Software

The new processor software was not fully tested and debugged before we fielded S-Pol in Taiwan. Part of this was due to problems identified with the antenna motors that reduced the amount of time S-Pol was available to software engineers before the system was shipped to Taiwan. Because of the additional setup tasks conducted in the pre-operations and testing phase of the project, and because the processor software was not ready before S-Pol left the U.S., we did not meet our goal of having S-Pol ready for operations by May 15. Luckily, the weather conditions at the start of operations were not favorable to achieve the goals of the project, otherwise S-Pol could have missed critical observations. The processor software delay also caused a delay in setting up the data management procedures (primarily data archiving and real time quality control) during the project.

5.5 Meteorological Products (refractivity, rain accumulation, particle identification)

Calibration scans for computing refractivity were collected on 2008-05-14, 2008-06-07, and 2008-06-08. Refractivity was produced in real time, but staff at the radar only started looking at the refractivity results in depth on 2008-05-19 after Tammy Weckwerth arrived on site. Many problems were identified in the refractivity results and these were never fully resolved throughout the project.

Rain rate and accumulation products worked well throughout the project once we realized that to produce a rain accumulation product, the program needed to be run continuously. Mid-way through the project, we changed the accumulation period from 10 minutes to 7.5 minutes to synchronize the accumulations with the scan synchronization and we started resetting the daily accumulations at 00:00 LST as opposed to 00:00 UTC to match the accumulation product produced by the CWB. We also increased the elevation angle of the scan used to compute the rain products from 0.5 degrees to 1.1 degrees because scans at the lower angle suffered from beam blockage.

The real-time PID product appeared to work well throughout the project.

5.6 Supplemental Data

Mike Dixon configured CIDD to display satellite imagery of south east Asia around Taiwan, and surface station measurements provided by the CWB. S-Pol scientists relied heavily on this data for real-time decision making, and its availability was critical to the success of S-Pol at TiMREX. Without Mike Dixon's help, the ability of the scientists to coordinate measurements would have been severely impacted. Display of additional third-party data at S-Pol was not mentioned in the original feasibility study [2] (note recommendation in Section 2).

Recommendation: *Many of the problems we encountered in this phase of the project could have been avoided by having staff actively use and work on S-Pol between deployments. After field projects, required maintenance should be performed on S-Pol, and then S-Pol should be deployed at our local field site. Also, spares and replacement units must be identified and purchased. The integration plan with CSU/CHILL calls for S-Pol to be actively used between deployments, which should make working on S-Pol between deployments a higher priority. Also, using hardware in common with CHILL will provide a source of spare parts in emergency. Therefore, the integration plan with CSU/CHILL must remain a high priority for the future success of S-Pol.*

6 Operations

The networking infrastructure provided the basis for communications and coordination between the project office in Taipei and S-Pol, and S-Pol and other research instrumentation participating in TiMREX. The CWB offices in Taipei, Pingtung University, and the science container at S-Pol were linked to CWB video conferencing system. The 10:00 LST (02:00 UTC) science meeting and the 14:45 LST (06:45 UTC) daily planning meeting were conduced through this video conferencing system. Participants in the meeting that were not located at one of these sites (i.e. people at the Supersite, the TEAM Radar, and the aircraft operations center) could participate in the meeting through a Skype conference call. Without the networking infrastructure, the level of coordination and interaction between scientists at different sites would not have been possible.

S-Pol did not transition from the pre-operations and testing period to operation on schedule. Development and debugging of the HAWK processor continued into operations. Changes to the HAWK processor were made up until June 16, near the end of the project. Network access to the radar from Boulder was critical in enabling remote debugging of the processor software problems. One of the most serious problems, which caused around 3 minutes of data to be lost periodically, was only fixed on June 04. Other changes which addressed less serious problems caused delays in the production of a final project data set. These problems would have been avoided if the radar had been collecting data in Boulder for several months prior to the project, and software engineers had been dedicated to the software development through this time (see recommendations from Section 5). However, these problems do highlight the critical need for remote access to the radar (see recommendations in Section 4).

To accommodate rapidly changing weather conditions, RSF staff had told PIs that we would only need around a 4 hours notice before the start of an IOP. It turned out that this time was insufficient for staff to transition from working a day shift to a night shift.

Recommendation: *For future projects in which 24 hour manned operations are requested, we must request a minimum of 12 hours notification before an IOP is called.*

Many of the S-Pol staff felt that there was insufficient staff to run S-Pol 24 hours a day during intensive operations periods and the enhanced operations period. The periods required manned operation of the radar, and lasted anywhere from three to eight days.

Recommendation: *S-Pol scientific staff should use students (in this case, Nick and Radian for example), to more effectively staff operation the radar.*

An emergency vehicle was not always available on site. A particular instance cited was when the technicians were required to service the pedestal electronics at night after heavy rainfall. This is a serious violation of UCAR policy.

Recommendation: *NCAR staff must have control of the emergency vehicle for field projects. If a safety vehicle is not always available, the project manager must arrange a vehicle regardless of the impact to the budget of the project.*

During the operations period, S-Pol operated continuously (24 hour/day) from May 15 to June 29 (46 days). In that time, we had one major failure of S-Pol and two minor failures.

6.1 Major system problems

S-Pol down from 05:00 to 14:48 on June 05 during the enhance operation period (EOP) because water leaked into the pedestal electronics (slip rings) causing us to lose elevation control. The timing of this event was unfortunate because it occurred during the heaviest rain during the EOP.

6.2 Minor system problems

The following problems occurred, in addition to the problems mentioned above.

- The PMAC antenna controller was replaced with the original on May 23. S-Pol was down from around 00:00 to 07:24 UTC. We discovered that the spare PMAC controller caused volume and scan numbers to be corrupted. Unfortunately, the previous generation that worked on S-Pol knew about this problems, but never had the spare PMAC controller fixed.
- The mechanical fast alternating polarization switch started to fail sometime during operations, and was replaced with the spare on May 29. S-Pol was restored to operation after one and a half hours.
- Missing data segments in scans due to a bug in the software that transfers scan information from the VIRAQ processor to the HAWK processor, and also due to a bug in the software that passes data between processing stages.

7 Tear Down

The conditions during tear down were extremely hot and humid so the tear down crew (Alan Phinney, Jonathan Emmett, Kyle Holden, Jeff Bobka, and Jose Rivas) did an excellent job managing the tear down schedule, despite reducing their working time to around 6 hours per day to alleviate fatigue from the heat. Staff found that the time estimated for tear down (and setup) were good estimates because it built in time for delays such as rain or shipping delays. The extra days are especially essential for international projects.

Recommendation: *We should investigate a bar coding system for automatic inventory preparation because the inventory requirements associated with a CARNET/TECRO are very time consuming.*

8 Logistics

EOL staff stayed at the National Citizen Hotel in Kaohsiung during setup. Technical staff (engineers and technicians) continued to stay there during the remainder of the project, but scientific staff moved to Pingtung University. The National Citizen Hotel was basic, but comfortable. The hotel provided a good breakfast and the staff very very helpful and understood English. The hotel was conveniently located next to the freeway which provided easy access to route the site. However, since the hotel was not located downtown, staff often used taxis to go to restaurants downtown to eat. Despite the requirement to use taxis at night, the location of the hotel was good because the alternative (that the hotel was located downtown) would have added a significant amount of travel time to and from the site. The Pingtung accommodation was functional, but not comfortable. Staff that stayed there would have preferred access to kitchen facilities or at least breakfast, and would have preferred to be closer to the site. Students involved in the project also stayed at Pingtung, and S-Pol staff did enjoy the ability to interact with them.

Apart from some inflexibility in only having one shuttle at each accommodation site (see below for the discussion on transportation), separation of technical and scientific staff reduced the camaraderie associated with other projects,and at least once, caused some staff to miss out on a sightseeing trip. These were not serious issues but should be considered when planning field programs.

Recommendation: *If possible, staff should be co-located to minimize logistical issues and give everybody a sense of common purpose.*

Transportation was provided by the National Technical University during setup, and then by the National Citizen Hotel shuttle. The hotel shuttle worked well when the schedule was fixed during operations, but did not cope well with variations in the schedule such as late night repairs, IOPs called on short notice, staff working late, or travel into town to fetch parts to repair the system. For many of these instances, use of the National Citizen Hotel van was either not available during the day or caused a significant delay in travel. Also, it was noted that at times there were 13 people in a 10 seater van which is not safe.

Recommendation: *The project manager must ensure that NCAR has control over transportation vehicles and that there are sufficient vehicles for the needs of the project. Project PIs must not be responsible for organizing vehicles for staff.*

9 References

[1] http://www.eol.ucar.edu/deployment/field-deployments/field-projects/timrex/timrex-documents

[2] http://www.eol.ucar.edu/deployment/field-deployments/field-projects/timrex/timrex-documents/f_TAMEXII.pdf