



Report on Euro-Argo ERIC links with industry

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EXECUTIVE SUMMARY

Developing a framework to foster collaboration between the teams responsible for the implementation of Argo (the 'users'), and the commercial suppliers who provide the overwhelming majority of the platforms and sensors used by Argo is of high importance for the network sustainability and enhancement.

The task 8.3 of the Euro-Argo RISE project recognises the importance of these links and has explored different ways of facilitating networking, feedback and contacts with industry and identifying the best means to develop stronger relationships. To that aim and despite Covid19 has slowed down this task, a variety of approaches have been used to work more thoroughly with the industry. In conclusion, there is not a unique proposal but a set of means that provide a wide range of opportunities (not limited to the project itself) for users to engage with suppliers.

This document proposes 3 main recommendations for the Euro-Argo community to continue those close collaborations with industry:

- 1- Face to face encounters are the most effective way of sustaining links between users and individual engineers in the suppliers' companies. It is vitally important that European users continue to participate in these meetings where they have the opportunity to do so.
- 2- Even when travel and in-person meetings become the norm, the cycle of single-supplier online calls, opened, but not restricted, to all European Argo implementers should be repeated at suitable intervals: perhaps once per year.
- 3- The engagement of expert user groups in sensor evaluation has been an important European contribution to the international Argo program, and must be continued but such activity requires specific funding after the end of the Euro-Argo RISE project.

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1 Overview

The motivation for task 8.3 has been to stimulate stronger links between the teams responsible for implementing Argo (the 'users'), and the commercial suppliers who provide the overwhelming majority of the platforms and sensors used by Argo.

The original end date for this task was the end of December 2021 but it has been extended until end of March to capitalise on the activities carried on early 2022 as a lot of activity has occurred in the first 3 months of 2022, which is included in this report.

Building strong links with industry will have several benefits, including:

- Suppliers will better understand the present and future requirements of Argo, and in particular Euro-Argo members, and can improve or develop their products to better serve Argo's needs
- Users can inform suppliers of things that aren't working as well as they need to
- Expert users can collaborate with suppliers on evaluation and problem solving
- We will build a better-informed community of users, who will become aware of opportunities and capabilities that they might previously not have known about

A variety of approaches have been used in order to bring about the benefits outlined above, including:

- 1) User engagement with suppliers through ordinary Argo meetings including: European and international user workshops on technical, data and science topics; international meetings of the Argo Steering Team and Argo Data Management Team
- 2) Trade shows: Ocean Business; exhibitions at conferences
- 3) Special projects and investigations, particularly for the evaluation of the RBR CTD (WP2-3), the Deep Argo SeaBird CTD (WP3), new sensors of BGC-Argo(WP4), and ongoing development of ARVOR and PROVOR floats (WP5 and WP6)
- 4) A series of zoom calls in 2021 and 2022 with single suppliers to enable users and suppliers to meet each other
- 5) Specific interactions and meetings to link with manufacturers for novel instrument technologies

In reviewing the different opportunities for the Euro Argo community to form links with industry, we will review all opportunities, not just those provided by Euro-Argo RISE. The overall objective is to have a wide range of opportunities available in order to meet different user needs and different ways that users may prefer to engage with suppliers.

Industry suppliers provide Argo with three elements of the Argo program: platforms, sensors and telemetry. Platforms are the floats, the machines that ascend and descend in the ocean. The platforms carry sensors, which measure ocean properties. A telemetry system is required to get sensor measurements from the float to the data centre ashore. The main industry/commercial suppliers to Argo are shown in the table 1 below.

Table 1: Main industry/commercial suppliers to Argo

Company	Known as	Country	Provides	Well known products used in Argo
CLS	CLS	France	Telemetry	Argos and Iridium telemetry
MRV systems	MRV	USA	Platforms	SOLO float
NKE Instrumentation	NKE	France	Platforms (and sensors, but not within Argo standards)	PROVOR and ARVOR floats
Ocean Underwater Technology	OSEAN	France	Platforms	Mermaid float
RBR Ltd	RBR	Canada	Sensors	RBR CTD
SeaBird Scientific, previously better known as SeaBird Electronics	SBS previously referred to as SBE	USA	Platforms and Sensors	NAVIS float, SBE41 CTD, BGC sensors
Teledyne Webb Research	TWR	USA	Platforms	APEX float
TSK	TSK	Japan	Platforms	

Of these, MRV is a relatively new supplier and has provided only a small number of floats to Euro-Argo partners (UK only so far), but internationally is a major supplier of floats for Deep Argo. OSEAN has not yet provided any floats to Argo, but is interested in doing so. TSK has not supplied European users: TSK customers are mainly in Japan. There are also floats under development in China, but these are not yet advertised or available outside China.

2 Main methods of engagements with suppliers

2.1 User engagement with suppliers through ordinary Argo meetings

Users have the opportunity to encounter suppliers through the ordinary meetings of Argo at both European and international level. These meetings are often the forum in which suppliers choose to announce new developments, but are also the forum in which technical problems with platforms or sensors are first reported, discussed, and solutions announced. It is expected that participants in these meetings will disseminate the material presented to their communities of users.

2.1.1 European workshops

Many of the suppliers take part in and make presentations at European workshops, such as the Euro-Argo science workshop held in Athens (October, 2019). These meetings provide an opportunity for any supplier to present their latest capabilities, and for users to make (1) enquiries about present and future technology and (2) recommendations/specifications on what the instruments should be capable of, in order to meet latest science requirements. This provides a forum for a very wide section of the European user community to participate in the discussions. One limitation of this forum is that while it would be open to any supplier to participate, there has always been more participation from European suppliers than the full international range of suppliers, so Euro-Argo partners whose main participation is in these meetings miss seeing a full range of technological possibilities.

2.1.2 European and international workshops dedicated to particular technical topics

Over the last 5 years, there have been a variety of workshops dedicated to particular aspects of Argo, including :

- Technical workshops on platforms and sensors (Seattle, Sep 2017; Brest, Jan 2020),
- BGC Argo (Seattle, Jul 2018, Virtual, Sep 2021),
- aspects of Deep Argo (Hobart, May 2019; Virtual Oct 2021)
- aspects of data Quality Control (La Jolla, Dec 2018, and several online meetings; mainly users but suppliers also participate)

These workshops did not require any particular stimulation from Euro-Argo RISE to come into being: they have arisen naturally from users in the Argo program recognising the benefit and timing of organising a workshop on a particular topic. Resources from Euro-Argo RISE have however been important for enabling wide European participation, in terms of both staff time and travel funds.

2.1.3 International Argo Steering Team and Data Management Team

Each year the International Argo Steering Team (AST) Meeting sets aside limited time for engagement between suppliers and members of AST. These meetings have participation from every supplier, and are a primary opportunity to establish contacts between suppliers and national programs. Every national program deploying floats is invited to have a representative at AST. Since March 2020, the

meetings have been entirely online (2020, 2021) or hybrid (2022), so any national program can participate even if they do not travel to attend AST in person. These meetings are an opportunity to encounter the suppliers at very high level, often company CEO, or equivalent, and for users to ask direct questions about any topic they are concerned about.

The interaction between suppliers and national program representatives at AST should be a major means of establishing links between users and industry. However, some of the smaller national programs do not always participate in AST, and the passing on of links made at AST into all parts of national programs is more effective on some topics than on others. Participation in AST by Euro-Argo PIs is an extremely valuable means of maintaining links between users and suppliers, but it is not sufficient across the whole of Euro-Argo. In addition, it is somehow difficult for users and manufacturers to fully expose their requests or answers, publicly and in front of all other user groups and other manufacturers. This is why the one-to-one meetings of Euro Argo RISE were helpful.

As sensor manufacturers, SBS and RBR usually participate in meetings of the Argo Data Management Team (ADMT). This provides an opportunity for users and suppliers to discuss issues of data quality and handling of metadata. Most of the platform suppliers do not participate in ADMT meetings, but the methods by which the suppliers provide platform meta data, and the way that floats send ocean measurement data through the telemetry system, are both crucial for the Argo data system. Prior to what had been set up within Euro-Argo RISE there wasn't a regular way for the Argo data system to interact with platform suppliers.

2.2 Trade shows: Ocean Business; exhibitions at conferences

Ocean Business (a technical conference with an extensive trade show held once per two years at the National Oceanography Centre, Southampton, UK). Most of the suppliers have an exhibition stand at Ocean Business or are represented through a European agent. While this is convenient for UK based users, not many Euro-Argo users outside the UK would travel to Ocean Business just to see the exhibition stands.

Many of the major science conferences (AGU, EGU, IAPSO, OceanOBS19) also have traditionally included trade exhibitions. These provide an opportunity for scientist users who attend the conferences to interact with suppliers. This opportunity is suitable for leading scientist users who regularly attend conferences, but is less accessible to users who attend conferences less frequently, such as real-time or delayed-mode data centre workers, and float engineers who prepare floats for deployment at sea.

2.3 Special projects and investigations, particularly for the evaluation of the RBR CTD and the Deep Argo SeaBird CTD. Enhancement of the PROVOR float for BGC measurements.

There have been many different initiatives within the timeframe of Euro-Argo RISE to work with suppliers on evaluating new hardware, and understanding existing hardware. These were fostered by the activities undertaken with other WPs (2, 3) and include:

2.3.1 Pressure response of SeaBird conductivity sensors.

The conductivity sensor in the SeaBird CTD that is used throughout Argo is made from glass. It is known that the dimensions of the glass cell vary as the cell is subjected to changing pressure. This effect needs to have a pressure compensation term applied in data processing, with a coefficient known as CpCor (conductivity pressure correction). Since the start of Argo, data from all Argo floats equipped with the SBE41 CTD have had a single value of CpCor applied, based on studies by SeaBird. This single value of CpCor was supposed to represent properties of the glass used to construct the cells.

With the advent of Deep Argo floats, it became apparent that the published value of CpCor was not correct for floats exposed to pressure down to 4000 or 6000 metres depth. There are two CTD sensors in use, the SBE model SBE41 used down to 4000 metres, and the SBE model SBE61 used down to 6000 metres. Analysis of both SBE41 and SBE61 data (WP3 work) showed two things:

- 1) that using the published value of CpCor resulted in salinity data that had a mean bias towards fresher salinity values in the deep ocean
- 2) that there were important differences in the required value of CpCor between cells. The idea that a single value fitted the whole fleet was wrong.

Euro-Argo partners participated in an international working group to consider recommendations for CpCor, collaborating with SeaBird and with other international users. This resulted in shared algorithms from the Euro-Argo users (at https://github.com/ArgoDMQC/DM_CPcor) to enable other users to determine the value of CpCor for their deep floats, and action agreed by SeaBird to do further factory calibration work to determine the CpCor for each SBE61 conductivity cell.

These combined actions will improve the sensors for future deployment, and provide tools for the improvements to be monitored and verified.

2.3.2 Evaluation of the RBR CTD: ship-based and floats experiments

The CTD sensors used in Argo have been from a single supplier (SeaBird) for 20 years of the Argo program. This has made Argo vulnerable to interruptions in the supply chain, to defects in the evolving sensor manufacturing, and has exposed the program to a monopoly supplier, with all the risks that result from that situation

A Canadian company, RBR, has adapted their CTD sensor to enable it to be mounted on Argo floats in place of the SeaBird sensor. Since Argo floats cannot normally be retrieved once they have been deployed (except in special cases of test floats) Argo has required thorough evaluation of the RBR CTD, before committing to deploying large numbers of floats with that sensor.

February 2020: RBR Deep CTDs

Euro-Argo partners have engaged in several collaborations with RBR to deploy their CTDs from ships. In March 2020, 4 RBR CTDs were extensively tested from a UK research cruise, alongside the best available shipboard sensors used in the GO-SHIP program. The CTDs were provided by RBR and tested by Euro-Argo partners (NOC in WP3 activities). Those CTDs were candidates for Deep Argo CTD sensors. This collaboration with RBR revealed a significant response of conductivity to 6000-metre pressure. As a result of that experiment, RBR decided to redesign the sensor and change some of the materials. The next generation of sensors will need to be similarly tested.

December 2020 and May 2021 : Arvor-I RBR experiments

RBR has been working on their CTD offering to core Argo for many years. Among the tests of RBR CTD, Euro-Argo partners worked with NKE to integrate the RBR core CTD on Arvor floats in Euro-Argo RISE (Ifremer in WP2 activities), thus enlarging the Arvor float capabilities from June 2020. Once integrated, Euro-Argo partners deployed 2 Arvor-I floats fitted with RBR CTD in December 2020 in the Canary Bassin (Ifremer and IEO/CSIC in WP2) and 2 others in the Baltic Sea in May 2021 (FMI in WP2 - 10.5281/zenodo.6657340). The evaluation of the RBR CTD accuracy and stability has been started at the European level and common diagnostics are provided through tools shared in the Euroargodev Github (<https://euroargodev.github.io/earise-rbr/frenchfloats>).

Euro-Argo RISE made possible the test of such sensors on European float technology: before Euro-Argo RISE there was no European float equipped with RBR CTD. With the activities carried out in WP2, the Arvor RBR is now available to users for tests and data collection.

March 2022: RBR Core Argo CTDs

In addition to the float experiments, there were two particular aspects of the sensor that need evaluation: first, the correction required as the sensor is exposed to pressure, and second the time-response of the sensor as it is moved through water of varying temperature. These effects have been known about, and are an intrinsic part of the sensor design. RBR has been working with users to find satisfactory data processing solutions to compensate for the effects.

The best available conclusions from all these studies were brought together for a new test of RBR CTDs on a ship-based experiment. For this experiment, 10 RBR CTD sensors were attached to a single frame, alongside a GO-SHIP CTD, so that they could be lowered from a ship in a controlled way, and any variations or uncompensated errors could be studied. A research cruise for this experiment was hosted by Spain with RBR participation in March 2022, and provided another step towards demonstrating the readiness of the RBR CTD for wider deployment in Argo.

Collaboration between RBR and Euro-Argo partners has been a crucial part of moving the RBR CTD to the point where the global Argo program has a choice of proven CTD sensors.

2.3.3 'Multi-headed' Argo floats to test the RBR and SeaBird CTDs

The testing and evaluation of the RBR CTD has mainly been done with RBR CTDs attached to ship CTD frames or by deploying test floats with an RBR CTD (as in section 2.3.2).

Much can be learned from a float with just the RBR CTD: if the data have defects, those defects may become apparent.

However, a powerful way in which to demonstrate that a new sensor is a viable alternative for an established sensor is to deploy them side by side on the same float in order to show that the data are of comparable quality. The float that carries several CTDs is referred to as being 'multi-headed'.

As a result of Euro-Argo RISE (WP3 activities), a collaboration between Ifremer, IEO/CSIC, RBR and NKE enabled the design and building of Deep Arvor floats carrying several CTDs¹.

¹ More information can be found in the deliverable 3.1 'Deep float experiment design' (10.5281/zenodo.4561734)

One float (called ‘three-headed float’) equipped with an RBR deep CTD, a SeaBird SBE41 CTD and a SeaBird SBE61 CTD, was deployed in the Canary Basin in March 2022 together with two floats (called ‘two-headed floats’) equipped with SBE41 CTD and RBR deep CTD. Data from this float make it possible to compare data from each pair of sensors.

This collaboration has enabled evaluation of CpCor for the two SeaBird CTDs, and to compare the RBR and SeaBird CTDs. The results of a series of test deployments are still being analysed in collaboration with the suppliers, and form part of the process for evaluating the RBR CTD as it becomes more widely deployed by Argo.

2.3.4 Participation in the international RBR Task Team

An international Task Team has been established to evaluate the data from RBR CTD sensors, and determine the RBR CTD readiness for widespread deployment in Argo. The Task Team includes Euro Argo users, international users, and RBR. The contributions from Euro Argo users (ship-based experiments and the multi-headed float) have provided vital data for the Task Team to consider. The Task Team has met multiple times in Zoom conference calls over the duration of Euro-Argo RISE.

In March 2022 the UK deployed two floats with RBR CTDs immediately alongside synchronised floats with SeaBird SBE41 CTDs. These floats were deployed in a part of the ocean with sharp vertical gradients in ocean properties, and are providing a further strong test of the latest version of the correction algorithms for RBR data. The UK is collaborating with RBR and users from the USA on analysis of these data.

In March 2022, the recommendation of the Task Team for the post-processing, data quality flagging and distribution of data from RBR CTDs was accepted by the international Argo Steering Team.

2.3.5 Enhancement of the PROVOR float for deployment of BioGeoChemical sensors

The team at SU has regular contact with the manufacturers of BioGeoChemical sensors: SeaBird, TRIOS and RBR, as well as with the supplier of the PROVOR float, NKE. The SU team combines skills in science requirement, sensor expertise and knowledge of the PROVOR platform. The protocols for best practice with BGC sensors developed by SU have been provided to NKE, and disseminated by NKE to other users. This technology transfer has significantly strengthened the European capability to successfully deploy BGC floats.

The sensor expertise within the European users provides a basis for the future evaluation of new sensors offered by suppliers. In particular, within Euro-Argo RISE, SU tested 2 new BGC sensors from the German manufacturer TRIOS (WP4 activities). Experiments were carried out on OPUS nitrate sensor and RAMSES irradiance sensor (10.5281/zenodo.6669025) to explore less-expensive sensors that may represent an alternative and viable option for measuring the same variables as presently measured with SeaBird sensors.

Such activity would aspire to be perpetuated in the framework of the Euro-Argo infrastructure. SU and LOV, with expertise in floats, sensors and biogeochemical measurements as well as an easy access to the sea at Villefranche, aims to organise these facilities and label it as a Euro-Argo test facility for Euro-Argo ERIC, and create a legal structure to facilitate access to it. The latter could be addressed to industrial or academics for the integration and testing of new sensors.

2.4 A series of zoom calls in 2021 and 2022 with single suppliers to enable users and suppliers to meet each other

The regular or one-off Argo meetings as outlined under sections 2.1 and 2.2 provide vitally important opportunities for users to meet suppliers face to face and to maintain links between those suppliers and groups of users or individuals, and to sustain a vigorous user community who have the contacts to engage with industry.

Within Task 8.3 it was recognised that not all users have opportunities to attend sufficient meetings to establish and maintain personal links. Furthermore, many Argo meetings moved online after the onset of Covid. Online meetings did not provide the opportunities for side discussions that would typically occur alongside Argo meetings, and which form the basis of much effective interaction between users and suppliers.

Task 8.3 therefore initiated a series of dedicated zoom calls to provide a forum for links between users and suppliers.

Between November 2021 and January 2022 as part of Task 8.3 there was a series of 6 meetings on zoom with suppliers who have links to Euro-Argo users: RBR, TWR, MRV, SBE, NKE, OSEAN. These meetings were organised by NOC and Euro-Argo ERIC.

The format was a 1 hour meeting with an optional extension of an extra 30 minutes, with one supplier per session. This provided a chance for suppliers or users to talk about anything that either side wanted to raise. The intention was to provide the sort of discussion environment that might be available at a supplier's exhibit at a conference. The suppliers brought between 2 and 5 staff to the calls, with up to 20 European users involved. In each of these calls, there were new introductions between suppliers' technical experts and users who had not previously had the chance to meet them. The suppliers' teams often included experts who are normally seen at other Argo meetings or the trade exhibitions but also employees that Euro-Argo users are not in contact with (engineers, software developers, etc.).

A common recurring theme was the effort required by DACs to compile float metadata in a format that could be entered into NetCDF files. Some float and sensor suppliers make this easy, some do not. For example, extracting sensor calibration data by re-typing, or cutting and pasting out of pdf files, is time consuming and prone to error. Users also emphasised that when a float engineer changes the format or content of data telemetered ashore, this can have consequences for the Real-Time DACs that the float engineer may not appreciate.

The suppliers all expressed a willingness to engage on this topic with a view to providing:

- machine-readable metadata (minimum requirement)
- machine-to-machine metadata (preferable)
- decoders that provide a DAC with tech and profile data with vocabulary close to what the DAC must upload to the GDACs, and which don't change with minor float firmware revisions.

All suppliers acknowledged the complex decoding that DACs are often required to undertake to deal with these issues and expressed a willingness to work to maintain or improve systems that would

- speed the process at DACs
- reduce errors
- assist DACs to develop vocabularies that appropriately describe hardware and firmware evolution

Some suppliers are already providing data that are relatively easy to use, others acknowledged that they have quite a lot of work to do.

2.4.1 Main action since the series of zoom calls (January to March 2022):

There has been a follow-up interaction with Teledyne to map out a variety of things that would make tasks much simpler for users of APEX floats. There has also been a direct interaction between DAC staff and TWR engineers. TWR have agreed to consider what they can do to improve the situation, and will come back with proposals and new code. In other presentations, NKE illustrated steps they have taken to ensure that the controllers in CTS-5 floats output data with near-to-Argo vocabularies. RBR provides machine-to-machine access to sensor metadata from their web site with a user key.

These are not issues that will be fixed overnight. It will require ongoing investment of staff time in order to gain maximum benefit from these interactions. We look forward to working with all the suppliers to ensure maximum ease of use of their products. Furthermore, we expect suppliers will consider the user requirements, as expressed in this series of calls, in future software and firmware developments.

2.5 Linking with manufacturers for novel instrument technologies

SOCIB has held tele-conferences with senior management and engineers at both Chelsea Technologies Group Ltd. and Valeport Ltd in the UK. Both companies are keen to get involved in our measuring instrument objectives under Euro-Argo RISE. Both companies are aware that there are two overarching aims, one to promote new and novel instrument technologies and the second to increase the diversity of instrument options for Argo float purchasers, so that reliance is not placed on just one or two manufacturers. The two companies are aware that obviously as users we hope diversity will encourage quality and value for money in both manufacture and service, but also that one of the measures of success for the Argo international program will be an increase in the productivity and employment opportunities in marine instrument manufacturing SMEs. SOCIB received a list of current and under-development instruments that both companies would wish to be considered for Argo floats.

The instrument manufacturers need more details (roadmap), for example, practical aspects about how and where they have to interface with the electronics in the floats; many of their modern instruments have clever dedicated firmware to optimise performance for a digital serial rather than analogue connection. For this reason, a meeting was held between NKE, Euro-Argo and SOCIB, Non-Disclosure Agreements (NDA) had been signed all round. This has allowed negotiations to progress with these industries.

- **Valeport Ltd.:** SOCIB arranged a meeting between NKE and Valeport Ltd, to explore the possibility of interfacing Valeport instruments on Argo floats in the future. In addition, a meeting during Oceanology International in London in March 2022 was proposed.
- **Chelsea Technologies Group Ltd.:** Chelsea are continuing development of their Micro-STAF instrument and will negotiate new discussions with NKE, when that is finished. There was a significant increase in interest from NKE, once it was pointed out that near direct primary production measurement was of great importance to the BGC community.

In summary, what is clear is that there is opportunity for Euro-Argo science users to make science based introductions between manufacturers of novel instrumentation and the established manufacturers of Argo float platforms. Supporting the scientific arguments for novel instrumentation, and instrumentation using alternative technologies, is important when making these introductions. Furthermore, the one to one interaction inherent in these introductions is often critical



for the instrument manufacturers, who will not want the risks of sharing too many Intellectual Property (IP) details that attendance at more cosmopolitan workshops or trade-shows naturally carry.

3 Telemetry

One aspect of interaction with industry that wasn't planned to receive much attention in this WP is the question of telemetry. The majority of data from Euro-Argo floats is sent from float to shore using Iridium satellite calls. Some floats still use the lower-bandwidth ARGOS system. The main supplier to Europe of Iridium services is CLS, who host an Iridium RUDICS server to receive float data and enable new or changed mission commands to be sent to floats.

Working with CLS to ensure robust and cost-effective Iridium service that meets Euro-Argo needs should be an ongoing activity for Euro-Argo. The increase of the number BioGeoChemical (BGC) floats means that data demands will evolve in the coming years. BGC floats send back more data than a Core float, so telemetry costs will inevitably increase. Through the Euro-Argo ERIC, Euro-Argo has provided a focal point for procurement of floats and sensors. Consideration should also be given to whether Europe-wide procurement of telemetry services would benefit the Euro-Argo program.

There is the possibility of other telemetry technologies becoming available on floats in the coming years. Euro-Argo should invest resources in identifying and evaluating any new telemetry technology offered, in order to make recommendations to the Euro-Argo partners.

4 Summary and Recommendations

4.1 Summary 1

Participation by Euro-Argo users in recurring and one-off Argo meetings (Argo Steering Team, Argo Data Management Team, international and European technical, sensor and data workshops) is a vital part of sustaining Argo technology and links with the industry of Argo suppliers. Euro Argo users make important contributions by evaluating Argo technology and providing feedback to suppliers. These meetings are an important conduit for suppliers to notify Argo users of developments, problems and their solutions.

4.1.1 Recommendation 1

Face to face encounters are the most effective way of sustaining links between users and individual engineers in the suppliers' companies. It is vitally important that European users continue to participate in these meetings where they have opportunity to do so.

4.2 Summary 2

International technical workshops provide a wide forum for dissemination of technical information, and ensure participation by suppliers, especially US-based suppliers. But they are not always accessible for European users. Dedicated technical workshops held in Europe provide easier involvement for European participants. One consequence of the increased use of online discussions was users' readiness to participate in zoom calls. The series of single-supplier zoom calls meant that anyone who wished to could invest an hour to meet with the suppliers' hardware and software engineers who are developing and building floats and sensors.

4.2.1 Recommendation 2

Even when travel and in-person meetings become the norm, the cycle of single-supplier online calls should be repeated at suitable intervals: perhaps once per year.

4.3 Summary 3

In order for new technology to be adopted into Argo, it has to be thoroughly evaluated by Argo science users. The direct interaction between users and suppliers can reveal aspects of sensors that need further development by the supplier (eg the RBR CTD), or lead to procedures for handling the data from a new sensor that can be adopted by the Argo program (eg the CpCor investigation for SeaBird CTDs).

4.3.1 Recommendation 3

The engagement of expert user groups in sensor evaluation has been an important European contribution to the international Argo program, and must be continued.