PROJECT DEVELOPMENT AND COMMERCIALISATION OF ON-LINE ANALYSIS SYSTEMS

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Abstract

A project team first in the Australian Atomic Energy Commission (AAEC) and since 1982 in CSIRO has developed many on-line analysis systems for the mineral and energy industries. The development of these projects, usually lasting 7-10 years, has followed a common pattern of laboratory R&D, field trials, commercialisation and technology transfer. This successful pattern is illustrated using examples of the development of systems for the on-line analysis of mineral slurries, for determination of the ash content of coal on conveyors, and for determination of the flow rates of oil, water and gas in pipelines. The first two systems, licensed to Australian companies, are used world-wide. They are now the market leaders for radioisotope gauges in their application field. The third, the multiphase flow meter, was licensed in 1997 to an international company. This meter has even greater potential than the other two systems for economic benefit from its use and for numbers of installations.

INTRODUCTION

Radioisotope techniques are the basis of many on-line analysis systems that are now widely used in the mineral and energy industries [1]. These on-line systems are adopted by industry because the speed of response of conventional sampling and analysis techniques is often too slow to meet the requirements of control of mining and processing operations. The cost of the radioisotope gauges is often recovered in 3-9 months due to savings resulting from improvement to the control of operations.

The author initiated Australian research into radioisotope systems for on-line analysis in the early 1960s whilst in the Australian Atomic Energy Commission (AAEC). This led to the development and field testing of a system for the in-stream analysis of mineral slurries that was commercialised in 1972. It is now used world-wide in mineral concentrators.

The research team broadened its interests in the 1970s to include the on-line analysis of coal. The team transferred to CSIRO in 1982. Since then, research has been expanded to cover a wider field of technologies that now includes radioisotope, microwave, ultrasonic, laser and capacitance techniques. The application area has been broadened to include the determination of flow rates of multiphase mixtures in the oil and power industries, and of the particle size of materials in various industries.

The research team, now in the CSIRO Division of Minerals, has built up considerable experience in the research, development, field testing and commercialisation of on-line analysis systems. A successful pattern for the development of these projects has been established and demonstrated in practice.

This paper discusses the pattern for project development and commercialisation of on-line analysis systems. The aims of the projects and occurrence of economic benefits are discussed first. Three examples are then given to illustrate radioisotope systems for on-line analysis.

PROJECT AIMS AND BENEFITS

In the AAEC and CSIRO, systems for on-line analysis are developed to increase the productivity of the Australian mineral and energy industries, and to provide economic benefit to Australia.

The economic benefit sought is predominantly the improvement to the processing of the minerals based on use of the instrument, rather than from its sale. To ensure the early realisation of these benefits to Australia, the AAEC and CSIRO have given high priority to commercialisation and technology transfer of the analysis systems to licensees.

Sales of the instruments discussed and their derivatives have been significant, however, about A$80 million since the 1970s.

ANALYSIS OF MINERAL SLURRIES

On-stream analysis of mineral slurries is required to achieve better control of flotation concentrators. The need is to determine the valuable mineral content of various slurry streams about the plant.

The AAEC, over the period 1963–1973, developed and field tested radioisotope techniques for the on-stream analysis of metalliferous mineral slurries. They were based on several complementary radioisotope X ray fluorescence, and X ray preferential absorption, techniques [2]. The solids fraction was determined by gamma ray absorption. The radioisotope sources and X ray detectors were incorporated into probes that are immersed directly into the plant streams.

The introduction of on-stream analysis has had an immediate impact on control of flotation concentrators. Within a few months of installation, the recovery of valuable minerals is often increased by 1–2% due to better control of the plant.

ASH IN COAL ON CONVEYORS

The on-line determination of the ash content of coal on conveyors is required in a wide range of applications including mine grade control, raw coal monitoring, coal sorting, control of coal preparation plants, product blending, and stockpile management and blending.

The AAEC initiated research into on-line ash gauges in the late 1970s, and the project team completed the field trials in the 1980s after their transfer to CSIRO. The ash content of coal is most simply determined by dual energy gamma ray transmission techniques [4] that depend on the fact that ash has an effective atomic number greater than that of the combustible matter. Other ash gauges were developed at the same time, but it is the DUET gauge that is now in most widespread use [5].

The net benefits in productivity flowing from the use of the 39 Coalscan ash analysers installed in Australia by 1988 were estimated by independent consultants to be US $130 million over a five year period [6].

FLOW RATES: OIL, WATER AND GAS

Pipelines carry multiphase mixtures of crude oil, formation water and gas from oil wells to production separators. The flow rates of oil, water and gas, from each well, must be measured to provide information necessary for the control and optimisation of oil field production. The oil industry wants to determine the flow rates directly in the pipeline carrying the multiphase mixtures. These multiphase flow meters (MFMs) would replace the current practice of using single-phase meters to monitor the outputs of a test separator.

CSIRO developed and field tested a gamma ray MFM over the period 1989–1997. It is based on use of two specialised gamma ray transmission gauges and pressure and temperature sensors [7, 8].

The potential market for MFMs is very large. World wide, there are about 10 000 wells offshore, and a further 900 000 onshore. The current market is mainly for offshore applications, on platforms and subsea. The applications onshore are expected to be mainly for wells with higher oil and gas flow rates where the cost of the MFM is justified.

The application of this meter should lead to the reduction in capital costs of new platforms and of subsea piping from wells to central facilities, and to better reservoir management, production allocation, and optimisation of total oil production over the field lifetime.

DEVELOPMENT, FIELD TRIALS AND COMMERCIALISATION

The following are the normal stages of a project in on-line analysis, from selection of the project to the successful commercial exploitation of the on-line system in industry:

- selection of specific industries that will gain large economic benefit from use of on-line analysis systems,
- assessment of the key requirements for analysis in the industry,
- a rough assessment of various techniques which may be used for this application,
- assessment of on-line analysis instruments currently being developed elsewhere or in routine use, including their shortcomings,
- preliminary laboratory research and development to gain some experience with the various techniques,
- more detailed discussion with industry of their requirements, best done on-the-spot at their operations,
- soliciting financial support for the project, undertaking the sponsored project which involves laboratory R&D and field trials,
- final reporting of the sponsored project,
- selecting a licensee and negotiation of the commercial Agreement, and
- transfer of the technology to the licensee.

The projects often take 7–10 years to complete because they involve not only the R&D, but also field trials, commercialisation and technology transfer. For example, the MFM project was conceived in 1988 and began in 1989. The MFM was licensed in 1997.

Some of these stages of development of a project are now discussed in more detail.

Selection of specific industry

This selection is not particularly difficult in Australia. The mineral and energy industries world-wide have great need for on-line analysis. These industries in Australia are very large, with annual production of coal, metalliferous minerals and oil being respectively valued at AS 8 (export only), 3.5, and 5 billion. The metalliferous mineral production quoted relates only to those minerals for which on-stream analysis has been proved effective. For example, gold is excluded because it occurs at very low concentrations in ore and analysis is beyond the reach of radioisotope technology.

On-stream analysis leads to the more efficient processing and recovery of minerals. Even though the increase in recovery will be fairly small, a 1% increase applied industry wide in these three industries would lead to savings to Australia of $160 million a year. The realization of this magnitude of savings is the challenge for the Australian developers of on-stream analysis systems and for Australian industry.

Targeting key analysis requirements

The most critical stage of the whole project is the targeting of the key requirements for on-line analysis in the particular industry area. The researcher must understand why these key areas are important, how the analysis system can be used to increase or improve production, and what economic benefit can be gained by industry from their use. Frequent contact with a wide range of people in industry is essential, both by direct contact and by attending industry conferences.

I have found that there may be one, or a few at best, persons in industry who clearly see the key analysis needs of their industry and are prepared to be the industry champion of the project. It takes time and perseverance to find this person. Whilst in the AAEC, I had been working in the field of on-stream analysis of mineral slurries for nearly three years before finding this champion. He understood the real needs for on-line analysis, and I knew the emerging radioisotope technologies that could be further developed for use in on-line analysis of mineral slurries. The project soon became more focused, and developed more quickly.

Who initiates the project?

Conventional wisdom is that industry should initiate projects because only they understand their priorities. However, research groups have a better grasp of emerging technologies, and have a better understanding of what is technically feasible. Who initiates the project does not matter. It is critically important that the industry requirements, the emerging technologies and the understanding of technical feasibility, are all incorporated.

In most of my projects, I have made the first approach to industry because I have sensed the importance of newly developing technologies. Industry followed up my approach with input of their critical needs, their enthusiasm for the developing project, and their ideas for, and support during, field trials.

Planning the project

Once the key analysis problem is identified, preliminary R&D are often required before the main directions of the project can be defined. This work may take 3-6 months, and is nominally funded by the research organization.

The research organization then prepares a more detailed plan of the project, including both laboratory R&D and field trials. There is frequent interaction with industry during this planning stage. The detailed plan is then submitted to potential industry sponsors, especially to those who would have a strong vested interest in the successful development of the analysis system.

During planning, I estimated that the MFM project would take six years to complete. The project was set up in three two-year stages. The first involved only laboratory research, and included gaining more experience with the oil industry. The second and third stages involved both laboratory R&D and field trials.

Funding the project

Funding sources for the three analysis systems

The source of the funds to support projects has changed greatly during the period covered by the development of the three analysis systems discussed in this paper. In the 1960s, the AAEC directly funded the R&D of the mineral slurry analyser. Industry part funded the costs of the field trials, the AAEC covering the scientists' salaries and overheads. In the late 1970s/early 1980s, the AAEC and CSIRO funded most of the R&D of the ash gauge, with significant additional funding being supplied by NERDDC, a Government body for funding energy research based on competitive bidding. In the 1990s, CSIRO directly funded about 50% of the $4M total cost of the MFM project. Oil companies and ERDC (a successor of NERDDC) funded the other 50%. They directly funded part of the CSIRO R&D, and essentially all of their and CSIRO's costs in field trials.

The royalties later gained from commercial sales of the analysis systems have not been included in the above sources of funds. The royalties from ash gauge sales, shared between the AAEC, CSIRO and NERDDC, were about $1.3 million. Based on MFM sales predictions, CSIRO could receive about $2M over the first five years. This would cover the total CSIRO cost of development of the MFM, and further royalties after 2002 would provide a positive return on the investment. Under internal financial policies, the project team has had no access to such royalty streams in the past, and apparently will have no access to it in the future.

Funding for the MFM project

There was no previous contact with the oil industry and hence funding the MFM project was a challenge. The Australian Mineral Industries Research Association Ltd. (AMIRA) was approached. This company, set up by the mineral industry, provides links between industry requiring research to be undertaken and research organizations that could undertake it. It does not itself undertake R&D. It has an excellent record of achievement with the metalliferous mineral industry, and were then expanding their efforts, and had contacts with, the petroleum industry. Finance was sought from the oil industry and AMIRA coordinated the research project.

To enhance the chances for gaining financial support, the project was deliberately set up in three two-year stages. After the successful completion of one stage we sought financial support for the next. This reduced the financial risk to sponsors and provided better direction for subsequent stages. From the beginning, the oil companies were told that it would take six years to develop the MFM. The total support requested for the first stage was only $120 000. This covered some laboratory R&D. We gained experience with the oil industry, and felt we gained the confidence of our sponsors. The bulk of the funding was required for the second and third stages that included the field trials.

Ownership of intellectual property

Intellectual property (IF) in these projects usually consists of patents and know-how. There was limited patent cover for the three analysis systems described above: for one of the XRF techniques used in the mineral slurry analyser, none for the ash gauge, and for a specific part of the MFM. However, know-how was extremely important for the mineral slurry analyser, sufficiently important for the ash gauge to give the licensee a five-year lead on the world market, and is very important for the MFM.

The ownership of the intellectual property is negotiated at the beginning of the project when its value is uncertain. Some of the technology will have been developed by the research organization prior to the commencement of the project, but more will be developed during it. Ownership is usually a contentious issue. I consider that the research organization should retain the IP rights because

- to ensure success in commercialisation, rights usually must be exclusively licensed,
- usually only the research organization has sufficient knowledge of the product to transfer the technology to the licensee, and
- the loss of the IP rights may limit the contribution the research organization can make to applying the technology to other fields of application and other industries.

The issue of ownership of intellectual property is often resolved by advising the company who wants it that they can have it but must pay the total cost of the background knowledge, the project itself, and technology transfer. The company then takes on the whole risk of the project. My experience with on-line analysis projects is that companies will not take on this risk. The AAEC or CSIRO retained ownership of all the intellectual property developed during the three on-line analysis projects described above.

Field trials

Field trials are essential to all on-line analysis projects. They contribute vital information on the state of development of the system, and may indicate where improvements are necessary. They determine the accuracy of analysis achievable in industrial conditions. This is of particular value to the project sponsors, as they can then plan with confidence the installation of the future commercial on-line system. The researchers learn much about the industry during a field trial, and may find new application areas for the system and bring to light new analysis-areas for future research.

There were six field trials of the system for the in-stream analysis of mineral slurries. This large number was essential because of the range of elements to be analysed (iron, nickel, copper, zinc, tin and lead) and the range of different XRF and XRA techniques that had to be developed and proved. These radioisotope X ray techniques were new to the mineral industry, and an important part of the field trials was proving that the systems were practical.

CSIRO proved the ash gauge in trials at one pilot plant and two coal washeries. These demonstrated to the coal industry that on-line ash gauges were sufficiently accurate and reliable for their routine use.

CSIRO tested and demonstrated the performance of the MFM in three field trials, two on offshore oil platforms and the third on an island fed from oil platforms offshore. Each trial led to further laboratory R&D, improving the technology between each trial. The last trial was on the West Kingfish platform in the Bass Strait. The MFM has been in routine use there since completion of the trial in 1995. The MFM was further tested in 1996 at Texaco's multiphase flow loop near Houston [8] to gain experience with a wider range of flow conditions. Further loop trials will be undertaken to improve the calibrations for liquids and gas flows.

Commercialisation

This Section covers the areas of when should the prospective licensee be introduced into the project, the selection of the licensee, checking the intent of the applicant for the license, and negotiating the commercial agreement. The whole process of selection of the licensee to completion of commercial agreement is slow. In my experience, it has never been achieved in less than one year, and often takes considerably longer.

When to bring in the potential licensee?

Conventional wisdom is to bring the licensee into the project soon after its commencement. This should add value to the project by having the licensee influence the course of its development, and allow the licensee to gain experience in manufacture of the instrument to be used in field trials. It was not known a potential licensee prepared to commit their own funds to a significant extent in the early stages of projects. The risk for them is too great. They have committed funds to the research organization after the analyser has been proved in field trials. The best was to keep potential Australian licensees informed about the setting up of new projects and progress in their development. This has given them time to make an early assessment of the market.

Selection of licensee

The key requirement in selection of the licensee is establishing its capability to develop and exploit the market for the on-line analysis system. The licensee should have established good contact with the industry where it is to be used, and preferably have experience with the technology being exploited.

Amdel and Philips Industries were chosen in 1971 as joint licensees for the mineral slurry analysis system. Both had good contact with the metalliferous mineral industry in Australia, and Philips had considerable experience with X ray techniques and with the development of instrumentation. The basis was that Philips would manufacture the system, and Amdel would be responsible for installation and calibration. The potential sales to the Australian market were high because of the large number of mineral concentrators here. It was intended that the experience gained in Australia would be used later to develop the world market.

Mineral Control Instrumentation Ltd. (MCI) was chosen as licensee for the ash gauge. Since three MCI staff had previously worked at Amdel, MCI had considerable experience in radioisotope and nucleonic instrumentation technology. They had no experience with the coal industry, but formed links with a firm of engineering consultants to the coal industry. The Australian coal industry is large and the experience gained first in Australia again was later used to develop the world market.

The licensing of the MFM was considerably more difficult than for the other systems. At least part of the problem was the need to address both international and Australian markets at the same time. Unlike the other two systems, the local market was insufficient to use as a base for subsequent world sales. In addition, the nature of the oil industry makes it a global business, not a regional one. A limited number of major companies dominate the oil industry.

CSIRO policy is to give preference where possible to licensing Australian companies. Two attempts were made to do this with the MFM, both involving the linking of an Australian company (one had no previous experience in the oil industry) with a large international instrumentation company already servicing the oil industry. This linkage was essential to exploit the international market. Both attempts failed. The first probably failed because the overseas company felt uncertain about tying up with a technology and manufacturing operation based in Australia. The second failed because of a takeover bid and subsequent policy changes in the overseas company at a critical stage of discussions with them.

Learning from the above experience, CSIRO Minerals accepted that the MFM should be directly licensed to an international company that services the oil industry. With the benefit of hindsight, this is a more appropriate route to exploitation of the MFM. Two international oil services companies, both potentially very good licensees, expressed immediate interest. It was licensed to one of them, Kvaerner FSSL of Aberdeen, in 1997. Kvaerner service the oil industry world-wide, have experience in the development of instrumentation for the oil industry, and are one of the few companies world-wide who have expertise in subsea engineering.

Is the licensee applicant serious?

Companies express interest in taking up the license for various reasons, including serious intent, the desire to gain information in an area of their interest, and in rare cases, I suspect to gain the license to keep the analysis system off the market. The applicants are entitled to some information on the system to enable them to make a better assessment of its viability for successful commercial exploitation. The companies must decide whether the product fits in with their immediate objectives, if the timing is right for their company, and are the decision-makers in the company enthusiastic.

Once the research organization has decided to proceed further with a specific applicant, it is sensible to test the seriousness of their intent. One way to do this is to offer them priority right to negotiate for a set period of time in exchange for a sum of money that is refunded on successful conclusion of the license agreement.

Negotiations

The developer and potential licensee have many interests in common. Both want to see the technology transferred rapidly to the licensee, to see the gauge developed quickly into a commercial product, and to see it gain widespread use in industry. These common interests drive negotiations towards success.

It seems that the best approach to commercial negotiations of on-line analysis systems is similar to the best practice of negotiations in many other areas. Find out what are important needs for both parties. Discuss these in detail to see if agreement is possible. Make sure that these are jointly acceptable before detailed negotiations of terms take place. Do not put forward conditions that the other party cannot accept, but be prepared to have to seek another licensee if agreement on fundamental issues cannot be resolved.

Contentious issues are often financial, both in the immediate funding of technology transfer and further system development, and in royalties. At this stage, the research organization may no longer have access to funding from industry sponsors, and requires finance to cover the costs of technology transfer and further development of the analysis system. The licensee has a negative cash flow whilst taking on the technology, modifying it to ensure a marketable product, and marketing it. The licensee usually prefers to fund the research organization from royalties on sales. This limits its risk, but transfers some of the risk to the research organization if future sales are overestimated. Both parties must be prepared to take on some of the future risk.

The costs of the transfer of technology are considerable and are mainly covered by the licensee. After licensing, the research organization usually undertakes further R&D to simplify the analysis system and to extend the range of its applicability. This may be covered, at least partly, by having the licensee fund the research organization from an extra margin on the sales price for the initial sales of the system (if the system is successful).

Royalties are a complex issue and depend on many factors including patent cover, the value of the know-how, the availability on the market of competitive systems, the extent to which industry needs the product, and the savings resulting from its use. Royalties are usually decided on a specific case basis.

Comments on negotiations with licensees

The negotiations for a license for the mineral slurry analyser were complex because four parties were involved in the Agreement. The negotiations would have been much simpler if only the AAEC and one negotiator, representing both Amdel and Phillips, had been involved.

The negotiation with MCI of the agreement for the ash gauge was much simpler because only CSIRO and MCI were involved.

The negotiations with potential licensees for the MFM took place over a three-year period, and were successful only after CSIRO decided to negotiate directly with an overseas company. The negotiations with Kvaerner FSSL Ltd. of Aberdeen were made somewhat more complex because of distance. Considerable telephone and written discussion took place before it was possible to schedule the first meeting that was held in Houston. However, the communications then became rapid because of use of email. Even so, the first meeting was held 14 months before the signing of the contract. A greater number of face to face meetings may have speeded this up, but again the cost and complexity of arranging such meetings increase with distance.

Technology transfer

The time and resources needed for technology transfer depend on the complexity of the analysis system, its stage of development, and the licensee's experience with the technology. Licensees usually underestimate the time and resources required to transfer the technology. From the experience, it has been achieved best when technical staff of the licensee work with research organisation staff on the project for a few months, and jointly undertake either a plant trial or the first commercial installation. The following summarises experiences in technology transfer with the above three on-line systems.

Amdel

The mineral slurry analyser was Amdel's first involvement with radioisotope techniques and with the development of instrumentation. An Amdel physicist spent one year at the AAEC laboratories, undertaking both laboratory work and field trials with AAEC staff. This was critical to the success of the technology transfer. The AAEC had proved the on-stream analysis technology in field trials using laboratory equipment. Amdel and co-partner Philips Industries Ltd. designed the industrial system. The AAEC had to supply backup support on technology for about five years after the first commercial sale to industry. The experience Amdel gained with the on-stream analysis system led to Amdel becoming the world market leader in radioisotope on-stream analysis of mineral slurries. Amdel have introduced solid state detectors into the radioisotope X ray system, and broadened the application area to include analysis of dry powders, solutions, and coal slurries. Total sales exceed AS 50 million. Amdel undertake their own R&D into new analysis systems.

Mineral Control Instrumentation (MCI)

MCI obtained the license for two on-line ash gauges in 1982. They had considerable expertise in on-line analysis and radioisotope techniques. CSIRO had used laboratory electronics in the field trials. MCI had to design electronics and mechanical equipment suitable for long-term industrial use. Although the license agreement was signed in 1982, CSIRO continued R&D and proving of the ash gauges until 1986. The technology was transferred over a three-year period. MCI now market two models of the ash gauge as the Coalscan 2500 and 3500 ash monitors. They have installed over 210 monitors world-wide, with total sales exceeding AS 30 million. The monitor is the world market leader in on-line ash gauges based on gamma ray techniques. MCI now successfully undertake their own R&D into new coal analysis systems.

Kvaerner FSSL

CSIRO commenced transfer of the multiphase flow meter technology to Kvaerner FSSL Ltd. in December 1996. A Kvaerner staff member visited CSIRO at Lucas Heights in two separate visits for a total time of about 6 weeks. Otherwise, contact has been by email and by telephone.

The transfer of the technology was greatly simplified compared with the previous cases because, in the period 1985–1995, CSIRO Minerals had developed considerable expertise in the electronic and mechanical design of industrial gauges. The CSIRO MFM was at a far greater stage of industrial development than the previous instruments because, for field trials, the MFM had had to meet the unusually high standards of safety mandatory on offshore platforms. The transfer of mechanical and electronics design was in the form of engineering drawings.

A CSIRO scientist took part with Kvaerner in the setting up of the first MFM they manufactured and in the first loop trial at the National Engineering Laboratory, Scotland. CSIRO is continuing to transfer technology to KFSSL and to undertake R&D into the MFM calibration for liquids and gas flows.

CONCLUSION

The AAEC and CSIRO have over the last 35 years very successfully developed on-line analysis systems for use in the mineral and energy industries. The development of these systems has led to the establishment of Australian technology in the forefront of on-line analysis systems for the world market. The successful pattern of laboratory R&D, field trials, licensing, and technology transfer developed has been discussed in relation to three analysis systems developed.

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