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ami: A quantitative approach to software management

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ABSTRACT

The **ami** (Application of Metrics in Industry) initiative was launched with funding from the European Commission in order to raise the profile of measurement in Europe. It comprises a method for implementing measurement programmes based on goal-oriented measurement and process maturity assessment. In this paper we examine **ami** as a case study in software technology transfer. The dissemination of the method is found to correspond well with models of technology transfer appearing in the literature: analysis of **ami** using these models is seen to be helpful in shaping future policy for the initiative.

INTRODUCTION

ami* (**a**pplication of **m**etrics in **i**ndustry), a quantitative approach to software project management, was ESPRIT project No 5494 - one of several initiatives set up by the Commission of the European Communities in 1989/90 to raise the profile of measurement across Europe. The goal of **ami** was to make the best software measurement technology available to software engineers, quality engineers and managers. This was achieved by packaging the concepts of

software process maturity assessment and goal-oriented measurement into a twelve-step method (Fig. 1), set out in the ***ami*** *Handbook*. (AMI Consortium [1]).

ami set out to perform successful technology transfer in software measurement. The first part of this paper will explain the **ami** approach for the use of goal-oriented measurement in project management. In the second part of the paper, we look at the variety of tactics used for dissemination of the approach in response to the needs of today's growing software measurement community, and consider why the **ami** project itself has come to be regarded as an example of successful technology transfer. In the next section we identify three frequently referenced models of software engineering technology transfer and draw some comparisons between the diffusion of **ami** and these paradigms. Finally, we report on how **ami** has been promoted since the project end to ensure continued take-up of the technology it endorses; a significant challenge to be faced by the well-resourced but relatively short-term projects characteristic of today's software quality research programmes.

THE **ami** METHOD

The **ami** approach did not try to re-invent the wheel; in fact, the basic ideas in **ami** were pre-empted by Pfleeger (Pfleeger [2]). Instead the philosophy was to combine existing, well-tried measurement technology to create a complete working method. The core of this method is *goal-oriented measurement.*, that is, measurement which matches the needs of individual organisations as understood by managers. Only by setting business goals can measurement be carried out in a well-directed and well-motivated way. Goals might be to improve productivity, improve product reliability, or simply to improve visibility or communication. Achieving any goal will inevitably lead to the precise measurement of many attributes of IT products or processes.

Measurements are one of the many sources of information upon which engineers or managers must base their decisions. Unless the decision-making process and its goals are well understood, it is likely that measurements will constitute information that is useless or even misleading. Goal oriented

measurement is exemplified in the **ami** Handbook by the Goal-Question-Metric paradigm of Basili and his colleagues (Basili [3], Rombach [4]) at the Software Engineering Laboratory at the University of Maryland. The decision-making process is made explicit by deriving a set of questions, answers to which will provide the necessary information upon which to base decisions. These questions are answered quantitatively by making the necessary measurements. For example, the goal of improving the validation and verification process might involve asking at what stage errors are being detected and what stage they are being introduced. The answer to this question will come from a detailed, quantitative analysis of software defect reports. A mere count of the number of bugs found during testing would not in this scenario, constitute information upon which QC resourcing decisions could be based.

Software process maturity assessment is exemplified in the **ami** Handbook by the five-level Capability Maturity Model of Humphrey (Humphrey [5]) which has been adopted and extended by the Software Engineering Institute. According to this model, organisations producing software can be ranked on a scale of 1 (initial) to 5 (optimising). There is some controversy as to whether this ordinal scale necessarily reflects the quality of the software produced by the organisation concerned (Bollinger [6]). Nevertheless, engineering or management goals must be chosen realistically and process maturity must be assessed for this to be possible. In SEI terms, it is not sensible to aim for level 5 goals if your organisation is at level 1. In fact, experience from industrial trials of the **ami** method show that goal-oriented measurement can be 4 or 5 times as costly for over ambitious goals.

DISSEMINATION OF **ami**

An active promotion strategy was built into the **ami** project from the very beginning. Behind the decision to place such a strong emphasis on this activity lay a simple philosophy: that in order for a project promoting technology transfer to be effective, it is not sufficient simply to make the technology available to users, albeit in an attractive, user-friendly format. Further steps must be taken to ensure that users are continually made aware of its existence.

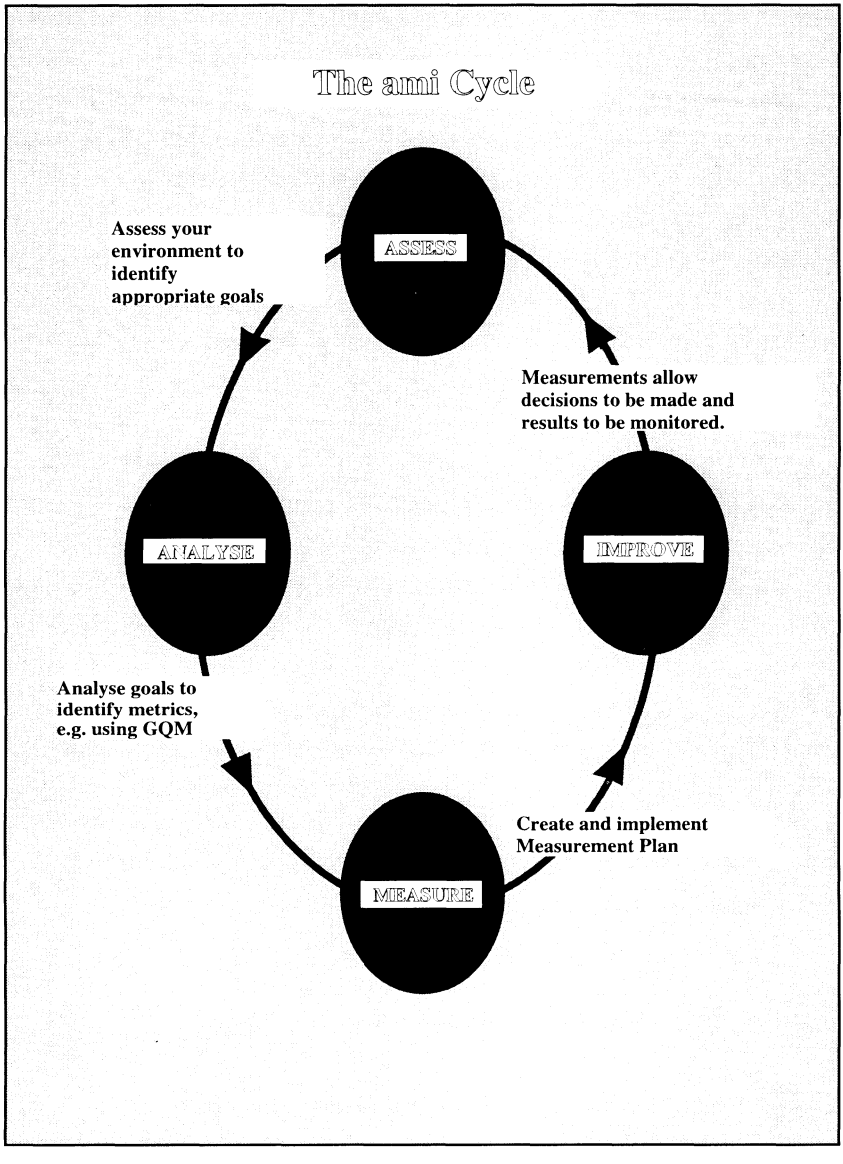

Figure 1

The **ami** cycle

Even then the picture is not complete; provision should be made for the uptake of the technology by means of information, consultancy support and maintenance. These three elements can be summarised as the **3 P's**: *packaging*, *promotion* and *provision* (Rowe and Whitty [7]). Awareness of the **3 P's** should help to ensure continued uptake of technology long after the project has ended; a significant challenge to be faced by the well-resourced but relatively short-term projects characteristic of today's software quality research programmes.

The **ami** project demonstrates all three elements of technology transfer. In terms of *packaging*, the **ami** method brings together into its twelve steps two tried and tested measurement technologies. The **ami** approach is presented in an attractive, easily-understood Handbook, sturdy and spiral bound for everyday use and with plenty of white space for notes.

Some 45 person-months were projected for the **ami** *promotion* work package at the final proposal stage. In real terms this amounted to two members of staff in the UK (one full-time and one part-time) working solely on **ami** promotion activity for the final 16 months of the project; other members of the consortium were responsible for further promotion within their own (and or neighbouring) territories. The role of the staff in the UK was two-fold, consisting of managing promotion activity in the UK and other EC states which fell beyond partners' territories and coordinating the efforts of the other members of the consortium outside the UK.

A highly intensive promotion effort was thus effected relatively easily across a wide geographical area. Promotion activity, defined by a UK marketing plan, was divided into three phases: pre-Handbook launch, Handbook launch and post-Handbook launch. Each partner outside the UK was visited by a member of the **ami** Promotions Team in January 1992, and own-country marketing plans subsequently drawn up, focusing on the three phases of promotion. The audience targeted in the marketing plan included directors, project and quality managers and senior software engineers within industry, consultancy, standards bodies and national agencies and academia.

Promotion mechanisms have included direct mailshots, events, press coverage, publications and literature, as well as a limited number of other promotional products. Most importantly, perhaps, personal contact has been made with a number of key parties, including professional organisations and specialist interest groups such as the Quality Forum, the British Computer Society Software Quality Management Specialist Group and the Centre for Software Reliability in the UK, the IEEE in the USA and GUPFI in Italy.

Provision has taken the form of tools, case studies and supplementary guides and training materials. Prototype tools have been produced within the **ami** consortium to automate the creation of goal trees and metrics plans. As use of the method becomes widespread, a set of case studies is planned to help new users learn from others' experience. Training is also an essential element of **ami** support and materials for one and three day courses have been produced. A key component of these materials comes from a further ESPRIT project "Metrics Educational Toolkit (METKIT)" (Bush [8], Russell [9]) which has developed complete ranges of measurement courses both for software engineers and managers and for university students - the next generation of managers. The ***ami*** *Handbook's* concepts and technology are consistent with the METKIT materials; in fact the Handbook has been requested by almost 7% of known METKIT contacts.

The question which follows is not difficult to predict: can such a large-scale promotion effort demonstrate tangible results? The **ami** Handbook was launched in the UK in March 1992 at the GEC-Marconi Research Centre, Chelmsford. Over the next eight months, subsequent launches were held in Italy, France, Ireland and Germany and **ami** was being promoted at an average of one event a week throughout Europe. By the time the project was drawing to an end in October 1992, over 10% of the 3700 'sites' which had been exposed to **ami** held a copy of the Handbook. 74% over those sites which had shown interest in **ami** (eg by attending launches) had requested a copy of the Handbook. Companies committed to adopting the **ami** method already included GEC, British Telecom and Racal in the UK as well as other members of the consortium in Europe.

Although at that time the **ami** consortium was concentrating on evaluating its past efforts in order to meet formalities for completion of the project, it was becoming increasingly evident that **ami** itself could not be 'put out to graze'. Members of the consortium, and particularly those concerned with dissemination, were convinced that continual evidence of self-sustaining promotion could not be ignored; it was clear that a growing community of users had been introduced to software measurement and that **ami** had played some part in this. Thus, with support from the Department of Trade and Industry and the European Commission through its VALUE[1] programme, the **ami** User Group was born at the beginning of 1993. The overall objective of the User Group is to continue to promote and support the uptake and use of software metrics, and in particular the **ami** method, both within and outside Europe.

The activities of the User Group are currently coordinated by the Centre for Systems and Software Engineering at South Bank University, in consultation with the **ami** User Group Policy Board consisting of members of the former **ami** consortium. At present, the User Group provides a range of products and services including the ***ami** Handbook,* quarterly editions of the **ami** Newsletter ***DE FACTO***, and the **ami** Tool. Its members also participate regularly in workshops and seminars. Most of the major European organisations which have installed the **ami** Tool have initiated software process improvement programmes based on the method and tool.

The **ami** User Group places great importance in collecting dissemination statistics. They offer an objective measure of technology take-up and can help in identifying trends in the usage of **ami**. According to figures based on the **ami** User Group database, in October 1993 (ten months after the formal end of the project) over 1000 different organisations or sites (e.g. differently located British Telecom sites) held a copy of the **ami** Handbook (Source: AMI Handbook Survey, ***DE FACTO* 6**: October 1993). This represented an overall increase in site distribution of over 140% from figures collected in October 1992, which indicated that over 400 sites had obtained **ami** Handbooks, with the vast majority (over 65%) being in the industrial sector. The 1993 figures showed the consultancy sector in a strong second place with almost 20% compared to 54% in the industrial sector. Academic institutions came third at 14%. This is an

important trend since it means that the **ami** infrastructure of consultancy and training is growing to support the industrial user base. However, the largest single increase in Handbook take-up was among agencies (primarily government departments and standards bodies) where the number of Handbooks had quadrupled over the year. Agencies are seen as a key factor in 'technology push' since they exert influence over contractors, particularly those involved in the safety-critical and military domains.

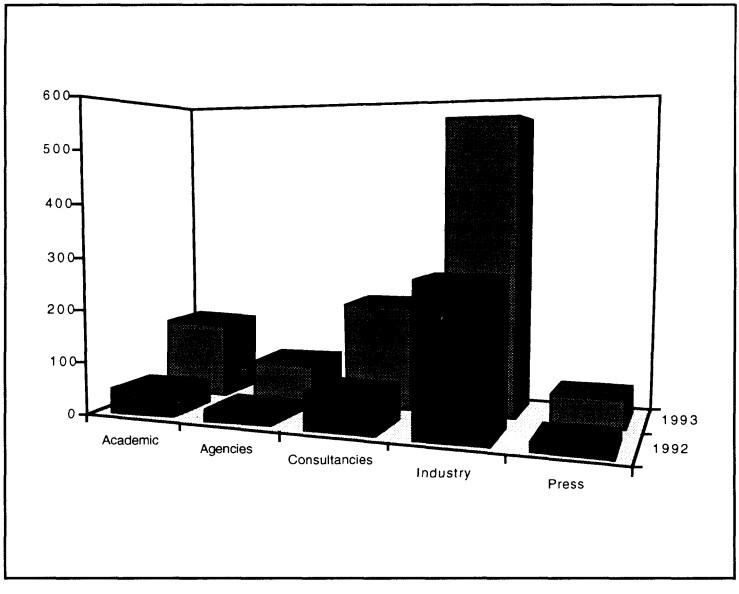

Figure 2.
Increases in each of the five sectors monitored by the **ami** User Group.

Whilst there are some 2500 members of the **ami** User Group on the Contacts Database held at South Bank University, other contacts are known to members of the consortium outside the UK, themselves critical players in the promotion/support infrastructure. Several sites throughout Europe are expressing a high level of interest in **ami** and have begun to consider implementing measurement using the approach.

MODELS OF TECHNOLOGY TRANSFER

Two of the most frequently cited models of technology transfer are those of Raghavan and Chand [10] and Buxton and Malcolm [11]. Raghavan and Chand focus specifically on software engineering technology transfer while Buxton and Malcolm propose a generic model which can be related primarily to the transfer of discrete software process technology, ie a new method or toolset.

Raghavan and Chand define diffusion as "the process of transferring technology from those who develop it to those who apply it". Within the software development process, diffusion is more than a complement to innovation; it is key to the success of software engineering as a discipline. To enable further understanding of the diffusion process, Raghavan and Chand propose an adaptation of Everett Rogers' framework (Rogers [12]) for diffusion of innovations to the software engineering context. A comprehensive framework that can be used descriptively or prescriptively, this has four main elements: innovation, the communication process, the adoption process, and the social system. The third of the these elements, the communication process, is said to involve innovators, diffusers, potential adopters and the communication channels that identify them, and results in the transmission of information about innovations. Rogers identifies two types of channel: mass media and interpersonal, which are of particular interest to the authors of this paper. Mass-media channels, such as newspapers and trade publications, are important in generating awareness of innovations to a large audience. Interpersonal channels are direct communications between two or more people through face to face meetings and interactive media, and are more effective in persuading people to adopt new ideas. Rogers suggests that successful diffusion requires a balanced use of both channels.

His classification of adopters and the resulting innovation-adoption S-curve are well known. The categories (innovators, early adopters, early majority, late majority and laggards) reflect the order in which these people will adopt innovations. The S curve occurs because people differ in their propensity to adopt innovations.

Buxton and Malcolm define innovation as the use of an invention in real industrial production. They suggest that technology transfer is one aspect of innovation (Rothwell and Zegfeld [12]): innovation as a "process of communication" and identify four phases in innovation within an organisation: awareness; assessment and choice, adoption for real use and assimilation into a new organisational orthodoxy. They also identify a number of roles "which need to be present and to participate in the process of transferring a new technology into industrial use": technology supplier, technology gatekeeper, top management, middle management, educators and workers. Our experience with the diffusion of **ami** - a quantitative approach to software measurement - fits well to these roles and will be further developed in the next section of the paper.

Harding [14] argues that while Raghavan and Chand acknowledge the importance of social determinants on technology transfer they have a "tendency to reduce technology transfer, organisation and even communication itself to a narrow mechanistic preoccupation with information transmission". In Buxton and Malcolm's work, she recognises the identification of worker resistance to innovation, but suggests that "there is, however, no critical conceptualisation of the role of technology (or indeed knowledge) as a material or symbolic resource in the reproduction of power relations". She also suggests that in making the assumption that most technology transfer problems are really communication problems which will be resolved when the 'message' as to the benefits of the technology is fully appreciated, they are failing to recognise a key issue: the possibility that even after understanding the 'message' fully, the potential users may well either reject the technology as inappropriate to their needs or "may seek to negotiate its cultural significance, how it is to be used, for what purposes and by whom". As an alternative model Harding suggests the notion of "technology-as-text" (after Woolgar [15] and Woolgar and Grint [16] - applying a radical social constructivist approach to the study of technology transfer. Her key point is that communication involves far more than the transmission of information, and that "although information, its circulation and availability to different groups, is obviously vital to the technology process it is only one aspect of it.....communication is also a social process of meaning production, exchange and negotiation".

A useful comparison can be made between our experiences with the diffusion of **ami** and these models. The most noticeable parallels occur with the innovation roles proposed by Buxton and Malcolm. **ami** can also be classified under the Rogers framework suggested by Raghavan and Chand. Without a full-scale survey of the impact that **ami** has made upon individuals and the communication process (an activity envisaged for the near future) it is more difficult, however, to make comparisons with the Harding model at this stage.

As the producer and packager (though not, as has already been emphasised, the inventor) of the technology behind the **ami** approach, the **AMI** Consortium* is clearly the *technology supplier* in Buxton and Malcolm's model. The *technology gatekeeper* for **ami** diffusion is typically the quality manager, project manager or person in the organisation with a 'watching brief' on metrics. As Buxton and Malcolm suggest, this is "the single most important role in take-up" - the individual or team of people who are able to filter ideas and take a proactive role in endorsing a technology and promoting it to the company. This individual might order the first copy of the **ami** Handbook and subsequently receive the **ami** Newsletter on a regular basis; alternatively he or she might attend an event and seek further information about the approach/support tool and so on. The gatekeeper is frequently in touch with a peer group which is "a most important mechanism for refinement of choice" (hence the emphasis placed on personal contact with professional organisations and specialist interest groups).

Top and middle management have played a key role in the uptake of **ami**. One of the main reasons for this is that the approach, based as it is on goal-derived measurement, calls for management commitment from the outset. For example, **ami** was used during the implementation of a software process initiative for a group of 300 software engineers involved in the development of various telecommunication network systems (Debou, Kuntzmann-Combelles, Rowe [17]). This initiative was divided into three main phases: a preparation phase, an assessment phase and an action phase. Over a two-month period, the preparation phase, during which the **ami** cycle was run with the help of the consultant, management played a key role in the definition and analysis of top business goals for software improvement. During the assessment phase, which ran for three months, management was closely involved in the organisation and

analysis of 100 interviews which produced several key recommendations, eg to define a software process model for the company and guidelines to adapt it to various customers' frameworks. From these results, a detailed management plan was prepared for the action phase (still underway at the time of writing); this included customisation of these five recommendations to the different software departments, estimation of resources and schedule for each individual action. Furthermore, the consultant helped the software improvement programme manager to validate the five recommendations against the business objectives selected at the end of the first phase. Early results show real exchange of know-how, procedures, techniques and tools.

The METKIT training materials are a frequent source of measurement *Education* for **ami** users. The experience of Stephanie Bacon, Metrics Project Leader at Provident Mutual Life Assurance Association, supports Buxton and Malcolm's point that "The gatekeeper will have a role in commissioning education and probably in providing some training as an interim measure". METKIT was used in her organisation "to train a working group in the science of introducing and running a metrics programme" (Bacon [18]). Finally, the *workers* upon whom responsibility for collection of data and the impact of change is likely to fall. "Measurement in workplace is an emotive issue for all members of staff.....another common problem is fear - fear of having your customary working practices subjected to scrutiny and laid bare to criticism" (**AMI** Consortium [1]).

A year after the establishment of the **ami** User Group, there has been a slight shift of emphasis in the role of the **3 P's**, away from planned promotion towards provision. This has arisen largely through the increase in self sustaining promotion ("I heard of **ami.....** through a colleague/at a workshop/by word of mouth"), so that it has become far more difficult to differentiate between planned and 'chance' - or direct and indirect promotion. This is not to say that there is cause for complacency on the promotion front - far from it. Rather it reflects the fact that the **ami** approach is beginning to filter through and between the organisations at which it was originally targeted. Returning to Rogers' work, the 'interpersonal' channels of communication have taken on a greater significance in the diffusion process than the mass media

channels which were so important in the early stages of the project. Since the method is designed to be used at any level: at organisational level, at project level or at team level, promoters of **ami** now have reason to be cautiously optimistic. At the same time, however, it has become even more important to ensure that individuals and members of those organisations can be updated and supported. In Raghavan and Chand's model, **ami** probably falls into Rogers' "early majority" category. As Furnham suggests (Furnham [19]), the adopters in this group are a little sceptical and a little cautious; although good candidates for taking up innovation they still need some convincing, hence the importance of a regular newsletter which reflects their problems and their experiences; the provision of consultancy support; the availability of a tool which comes with a complete example serving as a tutorial for the method, and workshops.

Experience exchange, method improvement and update, and influence on standards are all activities which are likely to contribute with increasing significance in the future. It is the role of the whole team to ensure that users can influence and hear about and participate in such developments.

ami has been selected for evaluation as one of the technologies which will constitute the initial technology baseline of the new European Software Institute in Bilbao, Spain, and the project has links with the international SPICE[2] initiative. These are exciting new developments for **ami**. The **ami** User Group is a solid infrastructure, providing both a home for the **ami** method and mechanisms to support its diffusion. Around and ahead of it the environment is challenging and far less tangible however; a fluid and dynamic framework is fast developing to meet the growing needs of the software measurement community. The task of the **ami** User Group should be to continue to develop its own products and services and simultaneously to liaise with others having similar missions, so as to remain an integral part of that framework.

CONCLUSIONS

ami comprises a method for implementing measurement programmes based on goal-oriented measurement and process maturity assessment. In this paper, we have examined **ami** as a case study in software technology transfer. Having

compared the diffusion of the **ami** method with models of technology transfer, we have found some interesting and useful parallels, the most noticeable of which occur with the innovation roles proposed by Buxton and Malcolm in their generic model of technology transfer [11]. It has been more difficult to draw comparisons with phases in the process of innovation within an organisation (proposed in the same model) since this calls for a more detailed analysis of the take-up of **ami** over a range of individual organisations; a study which should be undertaken in the future. At the risk of over-generalising, however, the diffusion of **ami** does appear to have reached the third of these phases, "assessment and choice", industry-wide. The majority of those (particularly 'gatekeepers') who approach us, are it seems, having to review and assess an overwhelming number of "new offerings" in the area of software quality management. If we consider that, in the evolution of a new technology across industry, software measurement itself is going through the "evaluation of economic feasibility phase", then, according to Buxton and Malcolm, the next stage should be "adoption". In encapsulating core software measurement technology, we can expect that **ami** too, should mature and move on into the next phase in the process of innovation within an organisation: "decision to proceed" and beyond into "adoption for real use" or, as has always been our goal, the use of **ami** as a de facto standard for the introduction of measurement throughout the European software industry.

***ami** was developed by a consortium consisting of GEC-Marconi Software Systems (lead partner), Alcatel Austria Forschungzentrum GmbH, Bull AG, Corelis Technologie, GEC Alsthom, ITS, RWTÜV, South Bank University and O. Group. Information on the **ami** Handbook and the **ami** User Group may be obtained from Alison Rowe, **ami** Promotions Coordinator, CSSE, South Bank University, Borough Road, London SE1 0AA, UK, Tel: +44 71 815 7504, Fax: +44 71 928 1284.

VALUE[1] VALUE stands for Valorisation and Utilisation for Europe. This programme is concerned with the dissemination and utilisation of the results of Community scientific and technological research under programmes such as ESPRIT.

SPICE[2] SPICE stands for Software Process Improvement Capability dEtermination.

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