ARTIST: A Network for ARTifical Immune SysTems

Part I: Previous Research and Track Record

Investigators and co-authors of this network proposal are involved a wide variety of research areas and bring a broad spectrum of experience to the proposed network. Backgrounds of researchers range from biologically inspired computing such as artificial immune systems, genetic algorithms and neural networks, to theoretical computer science. However, backgrounds are not restricted just to computer science, researchers from dependable systems engineering, electronics, modelling of complex systems and immunology bring a rich array of skills and experiences that are essential to the success of the proposed network. Below are listed all co-investigators and co-authors of the network proposal, clearly showing a breadth of experience and skills.

Dr Uwe Aickelin is a Lecturer in Operational Research at the University of Bradford. His research is conducted within the Intelligent Computer Systems Centre (ICSC) and includes: artificial immune systems, genetic and other evolutionary algorithms and combinatorial and in particular constrained optimisation. He has published in international journals and conferences and is a member of the Operational Research Society, the Inter-Disciplinary Scheduling Network and EvoNet (the Network of Excellence in Evolutionary Computing).

Dr Peter J Bentley is an Honorary Research Fellow at the University College, London and at the University of Kent. He has published over 60 papers including 3 books on the topic of evolutionary computation, including artificial immune systems, computational development, swarming systems and evolvable hardware. He is a regular keynote speaker at international conferences and is committee member of journals, conferences, chair of the Council of Editors of the International Society for Genetic and Evolutionary Computation, and chair of the ISGEC Standards Committee.

Dr. Howard Bowman is a senior lecturer in Computer Science at the University of Kent. He received his PhD from Lancaster University in 1991. His research is focussed on the theoretical underpinnings of diverse research areas, including, concurrent systems, verification technology, cognitive and neural systems. Of particular relevance is his interest in subsymbolic (biologically inspired) systems, where he has investigated a number of neural network learning algorithms and architectures. In the last five years he has held three research grants from the EPSRC, two from the European commission and two from British Telecom. In the last five years, he has published 11 journal papers, two book chapters and 29 conference papers. In the same time he has also edited two books and one journal special issue. He is a member of IFIP TC6 Working Group 6.1 and is a visiting scientist at the Medical Research Council's Cognition and Brain Sciences Unit in Cambridge.

Dr. Rogério de Lemos is a Lecturer in Computer Science at the University of Kent. He received his PhD in Computing Science from the University of Newcastle upon Tyne, where he worked as a Senior Research Associate at the Centre for Software Reliability (CSR). His main research interest has been in the area of software development for dependable systems, and more recently, he is investigating the application of artificial immune systems techniques into fault tolerance of embedded systems. He has over 40 scientific publications in international journals and conferences. He is a member of the IEEE.

Prof. Robin E Callard is a Professor of Immunology and Head of Infection and Immunity at the Institute of Child Health, University College London/Great Ormond Street Hospital. He is a joint Director with Professor Jaroslav Stark of the integrated four year MRes/PhD programme in Modelling Biological Complexity run by CoMPLEX at UCL and is on the CoMPLEX steering/management committee. His scientific research in experimental immunology is concerned with activation of dendritic cells by *Neisseria meningitides* and the interaction of the dendritic cells with the adaptive immune response, the genetic epidemiology and role of gene environment interactions in allergic dermatitis, and the function of cytokines in human antibody responses. He also has an active research programme on mathematical modelling of the immune system, which is focussed mainly on homeostatic control of T cell memory populations and the transcription factor and cytokine control of Th1 and Th2 cell differentiation. His research work is supported by grants from the BBSRC, MRC, and Wellcome Trust.

Dr. Netta Cohen is a Lecturer in the BioSystems Group at the School of Computing, Leeds. She received her PhD in Physics from the Technion in Israel for her work on dynamics in biological excitable cell networks. Her main expertise lies in biological time-series analysis, complex synchronisation, and deterministic and stochastic modelling of complex systems. In her research she combines tools from dynamical systems theory and knowledge of biological networks to study complex behaviour with a view to applications in bioinspired computing. Her recent interest in pathogen-immune interactions has led to a publication in Proc. Roy. Soc. Lond. B (vol.269, 809, 2002). Dr. Cohen's multi-disciplinary research involves active international collaborations with biologists, physicists, mathematicians and computer scientists. Her work is published in refereed journals and has been presented at international conferences.

Dr. Simon Garrett is a Lecturer in Computer Science at the University of Wales, Aberystwyth. He has been working in developing biologically and psychologically inspired machine learning algorithms for eight years, and has been involved in both theoretical and applied work. It is in this context that he has been working in artificial immune systems. He has applied his research to both robotic and bioinformatic data; recent work includes a review of evolutionary algorithms in robotics for the Journal of Adaptive Behaviour and a work on Bioinformatic System Identification inspired by the human approach to using data and background information.

Dr Emma Hart is a lecturer in Computer Science at Napier University. Her interests lie in the area of artificial immune systems, evolutionary computing and evolutionary learning. She has published in international conferences and journals, and is a regular reviewer for the major evolutionary computing conferences and journals, (GECCO, PPSN, IEEE Transactions on Evolutionary Computing, Evolutionary Computing). She is chair of the EvoNET working group for Scheduling and Timetabling, and the local chair for the 2nd International Conference on Artifical Immune Systems to be held in Edinburgh in 2003. Currently she is principal investigator on an EPSRC grant investigating HyperHeuristics and a project funded under the EU Future and Emerging Technologies initiative which is aims to develop a combined strategy and structure (systemic architecture) enabling artefacts to "grow up".

Dr. Jungwon Kim is a research associate at Kings College, London. She has been pursuing artificial immune system research as a part of her doctoral research that is particularly focussing on integrating various artificial immune algorithms for intrusion detection and fraud detection. She works as a doctoral research associate for the project "Computational Immunology for Fraud Detection (CIFD)", a joint project between the Department of Computer Science, King's College London, Royal Mail Group plc. and Anite Government Systems Ltd, funded by EPSRC and DTI. She acts as a member of the Committee of the 2002 and 2003 International Conference on AIS, the 2001 and 2002Conference of Evolutionary Computation and a member of ISGEC (International Society of Genetic and Evolutionary Computation).

Dr Julie McLeod is a Principal Lecturer in Immunology and Head of School of Biomedical Sciences at the University of West of England. Her research is conducted within the Centre for Research in Biomedicine (CRIB) and includes studies investigating regulators of T cell death, cancer immune privilege, biomarkers of the ageing immune system and the neuro-immune interface. She has published in international journals and conferences and is a member of the British Society for Immunology, a member of the Executive of the British Society for Research in Ageing and Chair of the R&D committee of the Bath Institute for Rheumatic Diseases. In addition, she is a steering group member of the EU Framework V concerted network 'ImAginE' which involves 33 European laboratories investigating biomarkers of T cell ageing. She is a reviewer for the BBSRC, Welcome Trust and the journals - Mechanisms of Ageing & Disease and Immunology.

Dr. Mark Neal is a lecturer in Computer Science at the University of Wales, Aberystwyth. In 1993 he was awarded a PhD on combining neural and conventional processing. His main research interests are in the fields of machine learning and intelligent agent design, especially as applied to robotics. His main involvement with artificial immune systems has been as principal investigator on the ISYS project, which developed an immune network algorithm for data analysis. He has published this and other work in international journals and conferences. Recent and ongoing work includes further development of immune network algorithms and software and their application to data analysis and robotics.

Dr. Peter Nichols is a lecturer in Molecular & Cellular Biology. He received a PhD in Biochemistry from the University of London, prior to spending four years as a Research Fellow at the National Institutes of Health, Bethesda MD, working on a number of antibody engineering projects. After two years in industry developing novel antibody-targeted delivery vehicles for gene therapy, he moved to the University of Kent. The main focus of his current research is the development of novel therapies for leukaemia, and the structure/function of cytokine receptors. He has over 20 publications in these areas, and is a member of the British Society for Immunology (BSI).

EurIng Dr. Richard E Overill, BSc, PhD (Leicester), CEng, FBCS, CMath, FIMA, is a Senior Lecturer, having joined the Kings College, London in 1987. He has published some 55 papers in computational science, high performance computing and information security, and has undertaken research into intrusion detection technologies, Risk Assessment methodologies and threat assessment strategies under the auspices of the International Centre for Security Analysis (ICSA) and the Information Assurance Advisory Council (IAAC). He is a member of IAAC and is PI for the Computational Immunology for Fraud Detection project within the DTI LINK MI research programme.

Dr. Jon Timmis is a Lecturer in Computer Science at the University of Kent and is head of the Applied and Interdisciplinary Informatics Research Group. He received his PhD in Computer Science from the Univeristy of Wales, Aberystwyth, where he worked as a Research Associate investigating the use of immune system metaphors for machine learning. He is principle investigator for an EPSRC funded CASE award and fully funded industrial research project. He has served on several program committees for artificial immune systems at international conferences and has given a number of invited talks on artificial immune systems at UK and international universities. He has published over 25 papers on artificial immune system related research and is the co-author of the first book on artificial immune systems. He supervises seven PhD students all working in the area of artificial immune systems. He was the conference co-chair with Dr. Peter Bentley for the first international conference on artificial immune systems (ICARIS) and continues to be the co-chair for the 2nd ICARIS in 2003. He is a member of the IEEE and a member of ISGEC (International Society of Genetic and Evolutionary Computation). He is an advisor to the NSF on bioinspired computing.

Prof. Andy Tyrrell, BSc, PhD (Aston), CEng, FIEE, Senior MIEEE is a Professor at the University of York. Professor Tyrrell joined the Electronics Department at York University in April 1990. He was programme chair for the IEE/Euromicro Workshop on Dependable Computing Systems in Sweden in August 1998. He will be general programme chair for the 5th International Conference on Evolvable Systems in Norway, March 2003. He is on the editorial board of IEE Computing and Digital Techniques and IEEE Transactions on Evolutionary Computation. His main research interests are in bio-inspired designs, fault tolerant design, and the design of embryonic computing systems. He has published over 140 papers in these areas, and attracted funds in excess of £1.6M.

Industrial Supporters

This network is addressing the needs of the academic community and the industrial community. There are a number of letters of support from the following organisations: BAE SYSTEMS, Sun Microsystems, Royal Mail Group plc. and

immune systems as a worthy avenue of further exploration, which may lead to clear commercial benefit in the longer term.

Executive Summary

The field of Artificial Immune Systems (AIS) is a new and exciting area of research, whose implications to the design and implementations of systems in the future are manifold. This is not limited to the obvious virus detection in computer systems, but could extend from fault-tolerant hardware design to machine learning. However, to allow this new area to develop and for the UK to continue to led the world in such activities, a more structured approach is needed to co-ordinate and support researchers in this area. By examining the mechanisms of the natural immune system, it has been possible to extract a number of high-level metaphors for use in computation. Immune algorithms have been developed for machine learning, optimisation, robotic control and network security and many other areas. There is an emerging body of researchers in the UK who are making an impact at the international level within this field. This network proposal is designed to help bolster these researchers in the UK, stimulate and extend the community of AIS practitioners within the UK and provide the necessary infrastructure and financial support for them to pursue further interactions between themselves in order to drive forward this area of research.

The success of the network will be measurable by a number of outcomes, including establishment of an electronic support infrastructure to share and disseminate research resource and public domain software, the establishment of a number of workshops and research meetings which will be used to identify key research issues, support the secondment of network members to other institutions to allow for fruitful research collaborations to be built, the support of an established conference ICARIS (International Conference on Artificial Immune Systems) as an international flagship event for AIS, successful secondments of individuals between academia and industry, a number of submitted multi-site research proposal and the identification of concrete research collaborations between members and non-members of the network.

Part II. Description of the Proposed Network

Artificial Immune Systems (AIS) is a new and emerging field of biologically inspired computing. AIS utilises metaphors from the immune system, based on both theoretical immunology and observed immune components and functions, in various commercial and research-based contexts.

The UK AIS community are advancing the area of artificial immune systems; both in theoretical and practical work and are already competitive with the USA in this area. The USA has traditional been strong in the area of AIS, but recent conference and journal publications suggest that the UK is fast approaching them in both quality and quantity of research.

Artificial immune systems are proving to be a very generic and applicable form of biologically inspired computing. A great deal of work has gone into developing algorithms that extrapolate basic immune processes such as clonal selection, negative selection and immune networks [1]. To date AIS have been applied to areas such as machine learning [2], network intrusion detection [3], reliable systems [4] [5] and scheduling [6] and many other areas [1]. A natural application of AIS is to network security or virus detection (given the role and perception of the immune system). Notable examples of these are the use by IBM of AIS for virus detection [7], United States Air force for the use of AIS virus detection [8]. However, the area of AIS is by no means restricted to this area. Indeed, AIS has proven itself to be a very powerful tool in a wide variety of areas, as previously mentioned.

In order to foster the momentum within the UK, a network is proposed that will allow for current researchers, those from other computational intelligence paradigms and biologists to collaborate more formally, share information and provide a financial support mechanism to establish the UK as a major player in the area of AIS. This network will aim not only to encourage current researchers, but also draw in new researchers to help develop the field. In order for the field of AIS to be effective, a better dialogue needs to be created between computer scientists and immunologists. This will allow for the AIS work to be rooted in immunology and lead to more effective computational solutions. Additionally this network will capitalise on the increasing interest from commercial partners. Recently, a number of commercial partners have been showing interest in this area of research, which is illustrated by the supporting letters for this network. AIS technology is currently being used to develop software and associated management processes for the detection of anomalous and potentially fraudulent patterns of behaviour in retail sector financial transactions, using Royal Mail Group plc's Post Office Counters transaction databases. NCR FSG are currently investigating an AIS to embedded fault tolerance in electromechanical devices. The objective of the research is to increase availability of machines rather than their reliability. The University of York is currently involved in a project with BAE Sowerby. The project involves the design and implementation of an AIS to protect certain critical functions in a real-time robotic application. It is expected that this network will assist in promoting effective transfer of technology from academia into industry. In an attempt to raise the profile of AIS within the UK, a number of potential network members organised the first international conference on Artificial Immune Systems held in September 2002 (http://www.aber.ac.uk/icaris-2002) and are organising the second conference in September 2003 to be held at Napier University (http://www.aber.ac.uk/~icawww/IC3/icaris2003.htm). It is expected that the network will go to support this venture and that the ICARIS conference will become a flagship event for the network and will go to promote the field of AIS to the wider community. ICARIS 2002 attracted some 26 papers, from 13 countries. It was attended by 45 researchers from around the world and was financially supported by EOARD

(European office for Aerospace Research and Development). This illustrates the interest in this area and potential for growth. A special issue of Genetic Programming and Evolvable Machines was also created as a result of ICARIS 2002 and is currently in the process of being edited by two of the proposal authors (Timmis and Bentley).

II.2 Background & Scientific Relevance

There has been a growing interest in the use of the biological immune system as a source of inspiration to the development of computational systems [1]. The natural immune system protects our bodies from infection and this is achieved by a complex interaction of white blood cells called B Cells and T Cells. Upon encountering an antigen (an infecting item), B Cells are stimulated by interacting with the antigen and with the help of T Cells undergo rapid cloning mutation. This is an attempt by the immune system to kill off the invading antigen and prepare the immune system for another infection from that antigen (or similar antigen). The immune system maintains a memory of the infection so that if ever exposed to the same antigen a quicker response can be elicited against the infection.

There are many facets of the immune system that can be considered useful for the computational domain, including pattern recognition, feature extraction, learning, noise tolerance, memory and inherent distributed parallel processing. For these and other reasons, the immune system has received a significant amount of interest as a metaphor within computing. This emerging field of research is known as Artificial Immune Systems (AIS).

Essentially, AIS is concerned with the use of immune system components and processes as inspiration to construct computational systems. AIS is very much an emerging area of biologically inspired computation. This insight into the natural immune system has led to an increasing body of work in a wide variety of domains. Much of this work emerged from early work in theoretical immunology [9] [10] and [11] where mathematical models of immune system process were developed in an attempt to better understand the function of the immune system. This acted as a mini-catalyst for computer scientists, with some of the early AIS work being on fault diagnosis [12], computer security [13] and virus detection [7]. Researchers realised that, although the computer security metaphor was a natural first choice for AIS, there are many other potential application areas that could be explored such as machine learning [14] scheduling [6], immunised fault tolerance [15] [4] and optimisation [16]. In addition, AIS has been offering better understanding of the immune system [17], [18], whose mechanisms are hugely complex and poorly understood even by immunologists. The field of AIS is being shown to be a powerful computing paradigm as well as a prominent apparatus for improving understanding of complex biological systems. Likewise, the proposal of this network is very timely. There is a great deal of work to be undertaken at four levels:

- **Theoretical foundation for AIS as a new computational intelligence paradigm**. Much work on AIS has concentrated on simple extraction of metaphors and direct application. Work has begun on the creation of a framework for developing AIS, but it still lacks significant formal and theoretical underpinning. One aspect of this work will be to develop a more theoretical understanding of AIS techniques and pursue a detailed comparison of the strengths and weaknesses of current AIS technology as compared to more traditional techniques, such as neural networks, evolutionary computing, etc. It is anticipated this will be addressed through interactions within the network and through the inclusion of researchers from other computational intelligence research areas. It is proposed to hold a competition event for AIS and other paradigms to benchmark performance of the algorithms.
- **Extraction of accurate metaphors from the immune system**. It has been shown that the cornerstone of other biologically inspired computing's success lies on pinpointing the analogies of complex biological systems, which would be beneficial for computational problems. By working more closely with immunologists, it is hoped that the immune metaphors employed within AIS will be more accurate, but not necessarily at the cost of complexity. The network will foster relationships between the two fields of research to enable this transfer of information.
- **Immune System Modelling**: The extraordinarily complex nature of immune systems has led immunologists to seek for new research tools that are capable of handling the remarkably complexity displayed by the immune system. Conventional research tools, based on wet experiments, often handle small numbers of variables at one time, and thus, often fail to allow for a fuller investigation of the immune system. Close links between immunologists and computer scientists, fostered through the network, will promote computer scientists to model computer immune systems, that will directly benefits immunologists to explore the high complexity within the immune system. The recent discovery of the new vaccination strategy through computer immune system simulation [17] is such a example that provides unexpected benefits to immunologists via the computer immune system modelling. It is also possible for interactions between members of EPSRC funded MIPNet who are concerned with the modelling of biological systems to further explore this area.
- **Application of AIS**. Identifying where AIS are more useful (or applicable) is vital and it is hoped that commercial partners will be able to provide some practical focus for the work, with the academics providing suitable AIS technology.

II.3. Programme and Methodology

I.3.1 Objectives

The proposed network aims to create a community of researchers and practitioners, drawn from biology, computer science and engineering, to *identify*, *articulate* and *develop* the scientific basis of artificial immune system research. The major objectives of the network shown below, together with a concrete measurable for each, by which the success of the network can be measured.

Objective	**Measurable**
Strengthen the UK's position in artificial immune systems.	Increase in the number of UK based authors publishing in high quality journals and conferences.
Be a forum for exchanging ideas and transferring technology to commerce.	Secondments of individuals between industry and academia and attendance at workshops by industrial partners.
Be a forum for exchanging ideas between computer scientists/engineers and immunologists.	Secondments of individuals between sites and a measurable number of joint authored papers between sites and disciplines. Support of the ICARIS conference.
Establishment of niche areas for AIS technology and facilitating the comparison of the technique with other areas of computational intelligence.	The establishment of a competition to benchmark the performance of AIS techniques against other computational intelligence technologies, and attendance of non-AIS researchers at workshops, organising special tracks and tutorials at international conferences.
Stimulate and extend collaboration with colleagues at a national and international level.	A number of joint grant proposals between network members submitted to suitable funding bodies and industrial partners.
Extend the community of AIS researchers within the UK;	Increase in the number of members of the network
Act as a centre of expertise for training young researchers in the development of artificial immune systems;	Increase in the number of students undertaking PhDs in the area of AIS. Organise special tutorials by network members for students at international workshops.
Collate and publish expertise in a way that will improve the competitiveness of both developers and users of artificial immune systems;	The production of an edited book at the completion of the network term, with contributions from network members.
Identify areas of application where AIS have special relevance or advantage.	Outcome of a workshop, which will be a list of areas relevant. This will be published to members and non-members.
Establish a virtual centre that will provide a variety of communication mechanisms (both electronic and physical) in order to: Complement existing strengths and support rapid exchange of ideas; Promote awareness of state-of-the-art technology and solutions; Improve the understanding of commercial requirements; Act as a 'dating agency' to match expertise to real world problems; and Facilitate the setting up of more specific investigations.	Creation of a website, mailing list, newsletter and running of workshops and research meetings with the following results: Successful use of on-line resources by members. New collaborations and joint papers. New proposals for research in AIS. Increased take-up of ideas by industry. Increased take-up of ideas by researchers at various different areas.

II.3.2 Network Outcomes

In order to realise the above objectives, the following outcomes are to be achieved by the network.

- **Publicity**. A website will provide access to state-of-the-art techniques, a repository of, and links to, articles, bibliographic references, public domain software created by network members and data sets (such as machine

network's activities and details regarding the competition for benchmarking AIS techniques with other technologies. A mailing list will allow easy contact between members of the network, and will be used as a forum for exchanging ideas, stimulating and extending collaboration. Network members will organise special sessions and tutorials at international conferences and financial contributions will be made to support PhD students travelling to conferences. This will go to help publicise the network to the international community. Additionally, the network will support the ICARIS conference, which will be an annual international event to collate and publish the latest advancements on AIS.

- **Workshops.** Workshops will be used to identify and formulate key research issues in the subject area, and to extend and strengthen the new community and to establish communication and cross fertilisation of expertise in the currently separate fields of computer science, engineering, and biology. Workshops will be focussed with concrete outcomes such as research proposals between attendees. It is proposed to hold three workshops focussed on (1) AIS and its context within the computational intelligence community. It is envisaged to invite speakers from various computational intelligence paradigms, with the focus being on identify similarities and differences between paradigms and begin the establishment of research on theoretical analysis of the AIS approach; (2) A problem focused workshop, hosted by an industrial collaborator. BAE SYSTEMS have agreed to host this event. This would be open to industry and academics alike from a wide variety of backgrounds, with the aim to identify relevant application areas for AIS and (3) Discussing how computer scientists and immunologist can work together in a manner that benefits both communities. This will be coupled with the establishment of a research agenda for AIS and future directions for research. It is expected that from each workshop at least one multi-site proposal will be submitted as a result of interactions at that workshop.
- **Research meetings.** These will be used to discuss topical issues on artificial immune systems and related topics with presentations and contributions from network members and non-members alike. These will also be used in conjunction with workshops, and allow for more specific discussions raised from the workshops and the production of an action plan or technology road map to address those issues. Six research meetings are expected to run over the course of the network.
- **Research Visits.** These will be used to allow researchers to visit establishments for the purpose of discussing issues related to the networks agenda, with a view to future collaborative work.
- **Publications**. Joint publications will be used as a means to report collaborative research between the members and non-members of the network. Detailed annual reports will be produced for documenting the research achievements of the network members. At the end of the project, the best contributions will be compiled in the form of an edited book.
- **Research advancement**. A list of research questions will be maintained for providing the necessary focus for advancing the field of research. This list will be periodically evaluated and updated according with the advancements in the field. For exploring particular problems and areas of interest the network will support visits between sites. The network will also promote the growth of its membership, and contribute to the formation of consortia to bid for further research funding. An outcome will be an established infrastructure that will allow for the continuation of the consortia as a working group.

II. 4. Network Management

The general management role will be one of fostering collaboration and technical innovation with regular formal research meetings between the network members and a number of open workshops.

The network will be managed by an Executive Board (EB) that will be chaired by the Principle Investigator (PI). The EB will, initially at least, comprise the core partners of the network, but this will change as the network will seek actively to grow its membership and will undergo an annual review in terms of membership and performance. The review will be carried out by the EB and other nominated members of the network, to ensure a fair review. The role of the EB will be to identify opportunities to extend the network's membership and to secure its future funding, to determine how the various requests for funding will be distributed, to organise activities (workshops and research meetings), to oversee the work of the PI, and to produce the deliverables of this project, which include the periodic and final reports. A process of application for securing funding for secondments, research visits and international conference attendance will be established. Should such an application be made, the applicant will be required to complete a one page case for support outlining why they should be funded and provide a breakdown of all costs involved. This will be reviewed by the EB and a majority decision taken as to where support the application. Applications can be made at 3-month intervals lifetime of the project to allow for a number of cases to be heard at the same time. When the EB is unable to meet to discuss applications, provision will be made to undertake the review by email and telephone conference. The EB will meet every six months at sites of UK based collaborators. The PI will be responsible for organising and chairing the meetings of the EB, for managing electronic facilities, and for delegating specific tasks to EB members. The PI will also be the budget holder and will sign for travel requests and expenses once approved by the EB. The PI will be assisted by an administrator and a systems administrator (both part-time). The network partners will be asked to provide brief status reports regularly.

II. 5. Justification of Resources

The proposed network is a three-year project for which funding will be required in order to cover the costs of workshops, travel, administrative support and the development and maintenance of the computing resources. The funds applied for will cover the following:

- **Workshops and research meetings.** Travel, subsistence, and accommodation costs for supporting researchers to interact and learn from their peers and more experienced members of the research community. These will be open to members and non-members alike.
- **Research Visits.** Travel and subsistence will be provided for members of the network, including research students, to promote general interactions for research.
- **Secondments.** Travel and subsistence will be provided for members of the network, including research students, for prolonged periods of time to allow for greater interaction between network members. These are envisaged as 1 month periods (or longer) to undertake specific research projects, which are the outcome of the initial research visits.
- **International visitors.** Travel and accommodation costs for distinguished international researchers.
- **Project coordination.** The required administrative resource for organising visits, workshops and research meetings.
- **Computing facilities.** A part-time system administrator to set-up and maintain the computing facilities. A suitable domain name will be registered.
- **Conference attendance.** The attendance of researchers at national and international conferences, this fund is primarily aimed at assisting research student attendance, but it open for application to any active researcher.

6. Relevance to Beneficiaries

The beneficiaries of this network are numerous. Because of the dramatic increase in AIS research over the last 5 or 6 years, both in academia and in industry, the network will provide a timely and essential resource. Indeed, it is anticipated that the network will help integrate and define this important new field, for as yet there are no other networks, societies or bodies dedicated solely to AIS research. The activities of the network will actively promote and encourage further academic research and increased exploitation of the research by industry. Improved commercial-academic and computing-biology communication will provide more opportunity for researchers and developers to exchange problems, techniques and ideas, to collaborate on specific projects and to receive feedback from research ideas. Industrial partners will gain improved access to academic expertise and will benefit from technology transfer. (This will be in agreement with the IP policy of the relevant organisations.)

7. Dissemination and Potential Exploitation

Dissemination will be through workshops, meetings, papers and books. Three workshops and six research meetings will be held during the project. The first workshop will be held within the first six months of the project with the objective of creating an initial community and produce an initial *Landscape* document. The second workshop will be organised into the eighteenth month of the project with the objective to review the progress and the *Landscape* document, refine the objectives and disseminate the results and problems. The last workshop will be held during the last six months of the project with the objective of bringing together the results of the project and promote their dissemination. This dissemination will include a *Research Agenda* document reporting the main results from the project and the papers written by the project members. Finally, an *edited book* will be produced with contributions from network members.

The research meetings will be held at the same time as EB meetings to discuss topical issues on artificial immune systems and issues relating to workshop outcomes. These will be open to members and non-members alike and will be used (in conjunction with the workshops) to extended the community of AIS researchers and promote interaction with other researchers in related paradigms. The outcome of these meetings is a report that shall be disseminated among all attendees and network members via the newsletter.

It is expected that members of the network shall attend national and international conferences, presenting the results from the project. The most suitable conferences are Genetic and Evolutionary Computation (GECCO), Congress on Evolutionary Computation (CEC), Parallel Problem Solving from Nature (PPSN), Systems, Man and Cybernetics (SMC) and the International Conference on Evolvable Systems (ICES), NASA Workshop on Evolvable Hardware. Such publications will help to advertise the network.

Exploitation of AIS is already taking place by industrial partners such as Royal Mail Group (fraud detection), NCR FSG (fault tolerance), and British Aerospace (electronic circuit design), with further support by USAF EOARD and the International Society for Genetic and Evolutionary Computation for the ICARIS conference. One of the key goals of this network is to increase such collaboration and exploitation by industry. Just as fuzzy logic and neural networks have now become integrated into numerous technologies worldwide, the eventual aim of AIS research is to enable the appropriate exploitation of artificial immune systems. Experience suggests that technologies such as fraud detection, network security, virus detection, fault tolerant electronic devices, robotics, data analysis, and scheduling will benefit greatly from the utilisation of AIS algorithms.

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