17th International Conference on
Autonomic and Autonomous Systems
ICAS 2021

May 30, 2021 to June 03, 2021 - Valencia, Spain
and online due to COVID-19

Keynote:
20 Years of Autonomic Computing

a personal reflection

2001 – 2021

Roy Sterritt

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"Short" Bio

Roy Sterritt,
Ulster University, Northern Ireland.
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- Biography—Roy Sterritt is a member of Faculty in Computing and Engineering at Ulster University. He spent several years in industry with IBM, first at their UK headquarters in Portsmouth, and then at the IBM Hursley Labs in Winchester. Initially he was a Software Developer in their KBS department but then became a Product Development Manager with responsibility for tools to support risk assessment and project management in personal and mobile environments which were used widely in the UK and US. Roy's academic research career began in 1996 when he was appointed to the first of a series of joint University of Ulster and Nortel research projects investigating parallel, automated and intelligent approaches to the development and testing of fault management telecommunications systems.

- Roy's main focus of research is **Systems and Software Engineering of Autonomic (Self-Managing Computer-Based) Systems**, essentially a research area developed from a call from industry to deal with the complexity and total cost of ownership of our systems of systems (IBM 2001). To date he has 200+ publications in the field including research collaborations with NASA, IBM TJ Watson Center, BT, SAP, HP and Core Systems as well as many academic partners. The research with NASA also led to 16 US patents. **He was the founding chair of the IEEE Task Force and subsequently Technical Committee on Autonomous & Autonomic Systems** and elected chair of IEEE Technical Committee on Engineering of Computer-Based Systems. He has held many other IEEE roles such as; IEEE CS Publications board member, chair of the Conference Publications Operations Committee (CPOC); served on the IEEE CS Technical & Conferences Activities Board (T&C Excom and Opcom) and chaired the Conference Advisory Committee (CAC). He has been appointed to the many editorial boards including the NASA Journal on Innovations in Systems and Software Engineering, ACM Transactions on Autonomous and Adaptive Systems (TAAS), AIAA Journal of Aerospace Computing, Information, and Communication, Journal of Autonomic and Trusted Computing, and Multiagent and Grid Systems - An International Journal; and served on steering and/or program committees of the majority of the conferences in his field at some stage during the last 20 years.

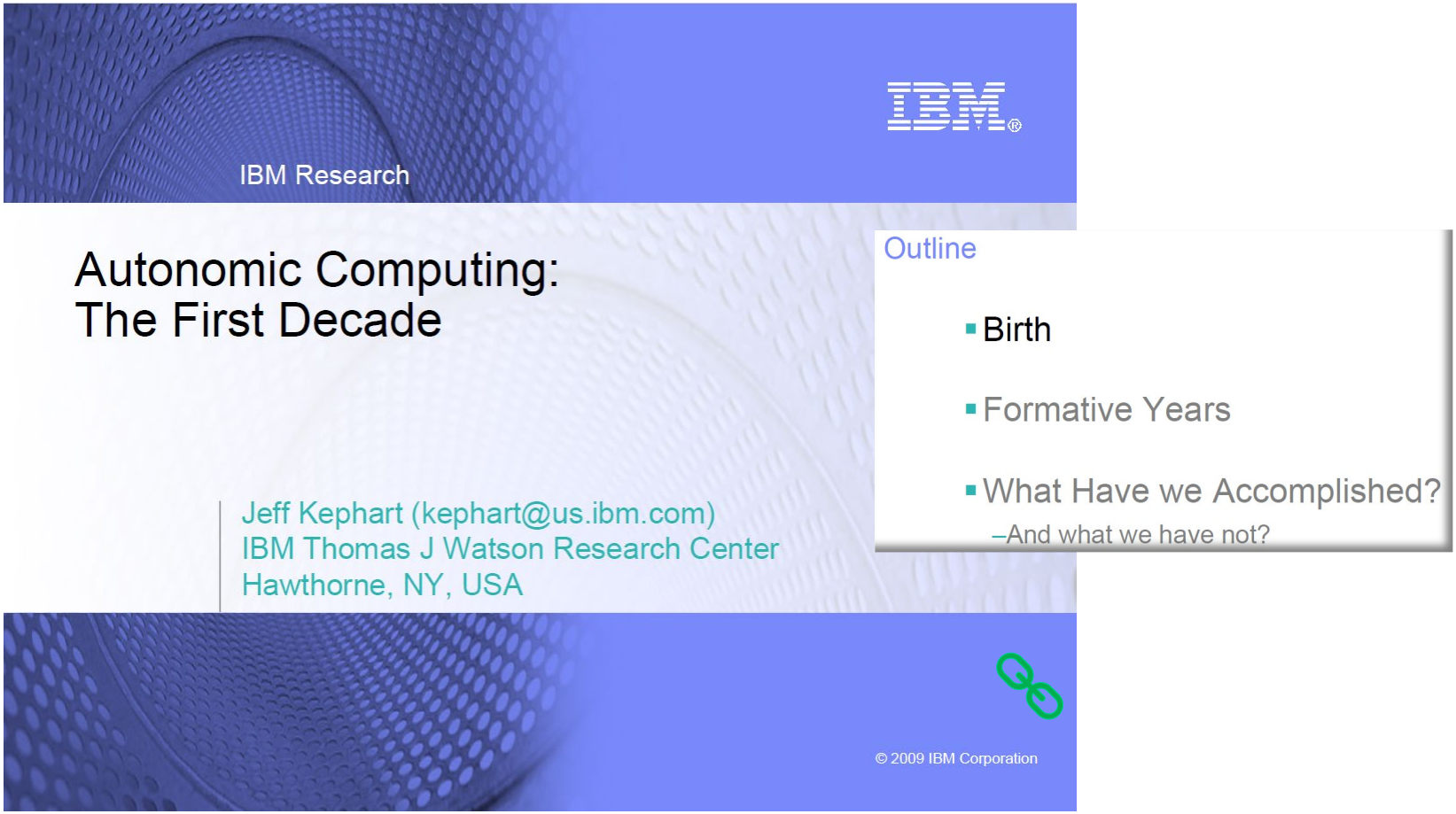
- This extensive research community activity and NASA collaboration during the *noughties* led to the common query from colleagues and management "are you ever at home?". As such Roy scaled back his international activity during the *tens* and took on institutional roles such as; Placement Coordinator-looking after 400+ students while seeking and on year-long industrial placement; Manager of CPPD (Continuous Personal and Professional Development) including developing outreach courses and summer schools in both Computer Science and Space Science. Yet with 16 patents with NASA, Roy also took the opportunity to explore spinning out the Autonomic Research as well as continuing that research, in particular through his PhD students.

Personal reflections on 20 Years of Autonomic Computing

Apologies for the personal reflections "" and "wordy" presentation that follow. With the changing nature of the conference format due to COVID, I've attempted to put what I would have said face to face against picture-oriented slides, into a stand-alone presentation as well as the rational being that by giving some background on my small part and situation in the Autonomic Computing story it may give some insight and lessons learnt.

*Please accept the intent is just to reflect and provide insight into history (*his-story*, *her-story, their-story, not always facts, personal reflections and the mind often revises, but not intending to be "alternative-facts"*) and in no way intended as whistle blowing nor accusations against anyone or any organization; my memories may not be fully accurate, nor my understanding correct at the time from the positions I held.

Jeff Kephart, IBM Research, did an excellent job covering the first decade in his ICAC 2011 Keynote.



Jeff Kephart, "Autonomic Computing: The First Decade" ICAC 2011 Keynote June 15, 2011

The next few slides recap some of the points Kephart made concerning the Birth of AC…

Jeff Kephart, "Autonomic Computing: The First Decade" ICAC 2011 Keynote June 15, 2011

Where it All Began: The Autonomic Computing Manifesto

- IBM Senior Research VP Paul Horn first set forth the idea of Autonomic Computing in keynote to National Academy of Engineers
- Harvard University, October 2001
- Autonomic Computing Manifesto released immediately thereafter

AUTONOMIC COMPUTING:

IBM's Perspective on the State of Information Technology

THE INFORMATION TECHNOLOGY INDUSTRY LOVES TO PROVE THE IMPOSSIBLE POSSIBLE.

We obliterate barriers and set records with astonishing regularity. But now we face a problem springing from the very core of our success — and too few of us are focused on solving it.

More than any other I/T problem, this one — if it remains unsolved — will actually prevent us from moving to the next era of computing. Interestingly enough, it has little to do with the usual barriers that preoccupy us.

It's not about keeping pace with Moore's Law, but rather dealing with the consequences of its decades-long reign. It's not directly related to how many bits we can squeeze into a square inch, or how thinly we can etch lines in silicon. In fact, a continued obsession with the smaller/faster/cheaper triumvirate is really a distraction.

It's not a barrier of "machine intelligence," either, that threatens our progress. It has less to do with building "thinking machines" that embody the popular conception of artificial intelligence (AI) than automating the day-to-day functioning of computing systems. It may sound odd coming from the creators of Deep Blue, but we don't really need a better chess-playing supercomputer — or sentient machines and androids programmed to love and laugh — to overcome the largest obstacle standing in our way.

The obstacle is complexity. Dealing with it is the single most important challenge facing the I/T industry.

It is our next Grand Challenge.

P. Horn, "Autonomic computing: IBM perspective on the state of information technology", IBM (2001) Autonomic computing concepts. White Paper, IBM IBM T.J. Watson Labs, NY, 15th October 2001. Presented at AGENDA 2001, Scotsdale, AR. (originally available http://www.research.ibm.com/autonomic/), 2001

How will this possibly help?

By embedding the complexity in the system infrastructure itself—both hardware and software — then automating its management. For this approach we find inspiration in the massively complex systems of the human body.

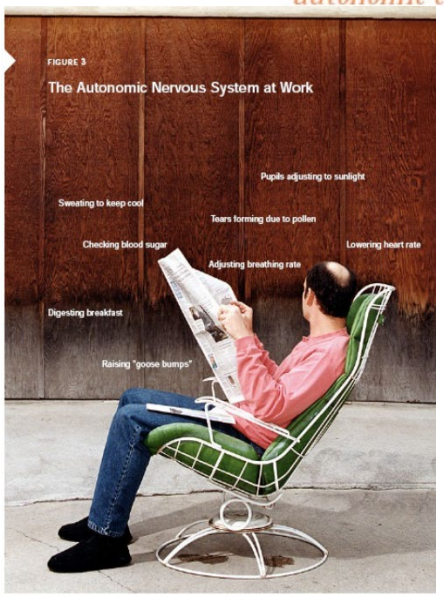
Think for a moment about one such system at work in our bodies, one so seamlessly embedded we barely notice it: *the autonomic nervous system.*

It tells your heart how fast to beat, checks your blood's sugar and oxygen levels, and controls your pupils so the right amount of light reaches your eyes as you read these words. It monitors your temperature and adjusts your blood flow and skin functions to keep it at 98.6°F. It controls the digestion of your food and your reaction to stress—it can even make your hair stand on end if you're sufficiently frightened. It carries out these functions across a wide range of external conditions, always maintaining a steady internal state called homeostasis while readying your body for the task at hand. SEE FIGURE 3

But most significantly, it does all this without any conscious recognition or effort on your part. This allows you to think about what you want to do, and not how you'll do it: you can make a mad dash for the train without having to calculate how much faster to breathe and pump your heart, or if you'll need that little dose of adrenaline to make it through the doors before they close.

It's as if the autonomic nervous system says to you, *Don't think about it — no need to. I've got it all covered.*

THAT'S PRECISELY HOW WE NEED TO BUILD COMPUTING SYSTEMS—AN APPROACH WE PROPOSE AS *autonomic computing.*



Eight Key Elements of an Autonomic Computing System

1 *To be* AUTONOMIC, a computing system needs to "know itself"—and comprise components that also possess a system identity.

2 *An* AUTONOMIC COMPUTING SYSTEM must configure and reconfigure itself under varying and unpredictable conditions.

3 *An* AUTONOMIC COMPUTING SYSTEM never settles for the status quo — it always looks for ways to optimize its workings.

4 *An* AUTONOMIC COMPUTING SYSTEM must perform something akin to healing — it must be able to recover from routine and extraordinary events that might cause some of its parts to malfunction.

5 *A* VIRTUAL WORLD is no less dangerous than the physical one, so an autonomic computing system must be an expert in self-protection.

6 *An* AUTONOMIC COMPUTING SYSTEM knows its environment and the context surrounding its activity, and acts accordingly.

7 *An* AUTONOMIC COMPUTING SYSTEM cannot exist in a hermetic environment.

8 *Perhaps* MOST CRITICAL for the user, an autonomic computing system will anticipate the optimized resources needed while keeping its complexity hidden.

This was soon boiled down to four …

Jeff Kephart, "Autonomic Computing: The First Decade" ICAC 2011 Keynote June 15, 2011

IBM wanted to help drive a new research agenda

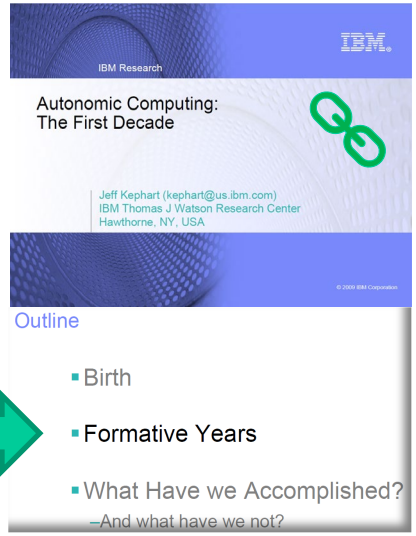
THIS IS
BIGGER THAN ANY *single*
I/T COMPANY.

It's a vision that requires the involvement of the top minds in the technology community. That's why we're forming an advisory board of leading academic and industry thinkers to help define our autonomic research agenda. We're also consulting with a large group of customers and I/T partners as part of our eLiza project to define a strategy for bringing autonomic innovations to products.

We call on our academic colleagues to drive exploratory work in autonomic computing. We propose that the research community recognize it as an important field of academic endeavor. We also call on our partners at government labs to collaborate with us on crucial projects in this area. We plan to fund a regular stream of academic grants to support research in this area, and we call on others in the I/T industry to do the same.

Paul Horn

Paul Horn, *Senior Vice President*
IBM RESEARCH



AC Advisory Board Recommendations for Recruiting Academia

1. Publish a well-placed, high-quality manifesto
2. Show that AC is radical, revolutionary, world-changing
   a. Publicize IBM's own high-quality research in AC
   b. Target top academics
      - Define problem in their specific terms
      - If they write good papers, rest of field will follow
3. Demonstrate *industry-wide* interest in AC (not just IBM hype)
4. Organize, sponsor, and participate in workshops, conferences
   a. International conferences and workshops
   b. Special IBM AC workshops

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IEEE Computer Cover Feature, January 2003

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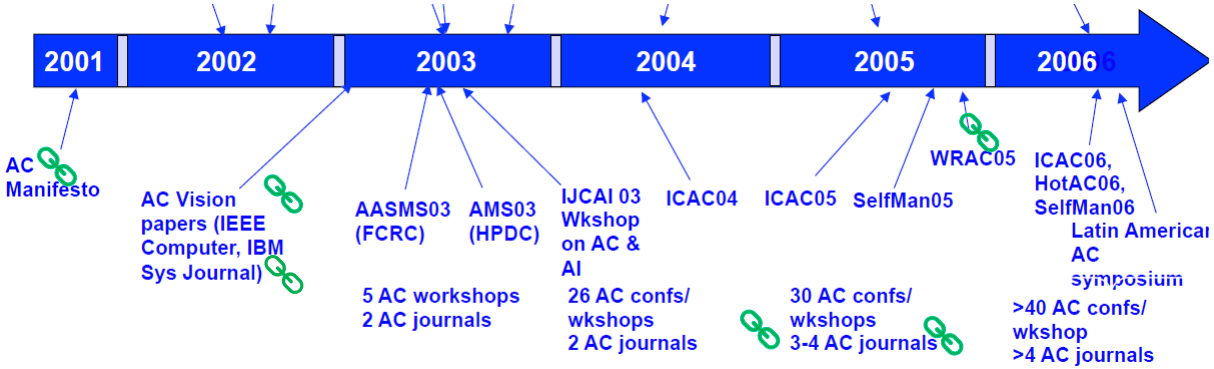
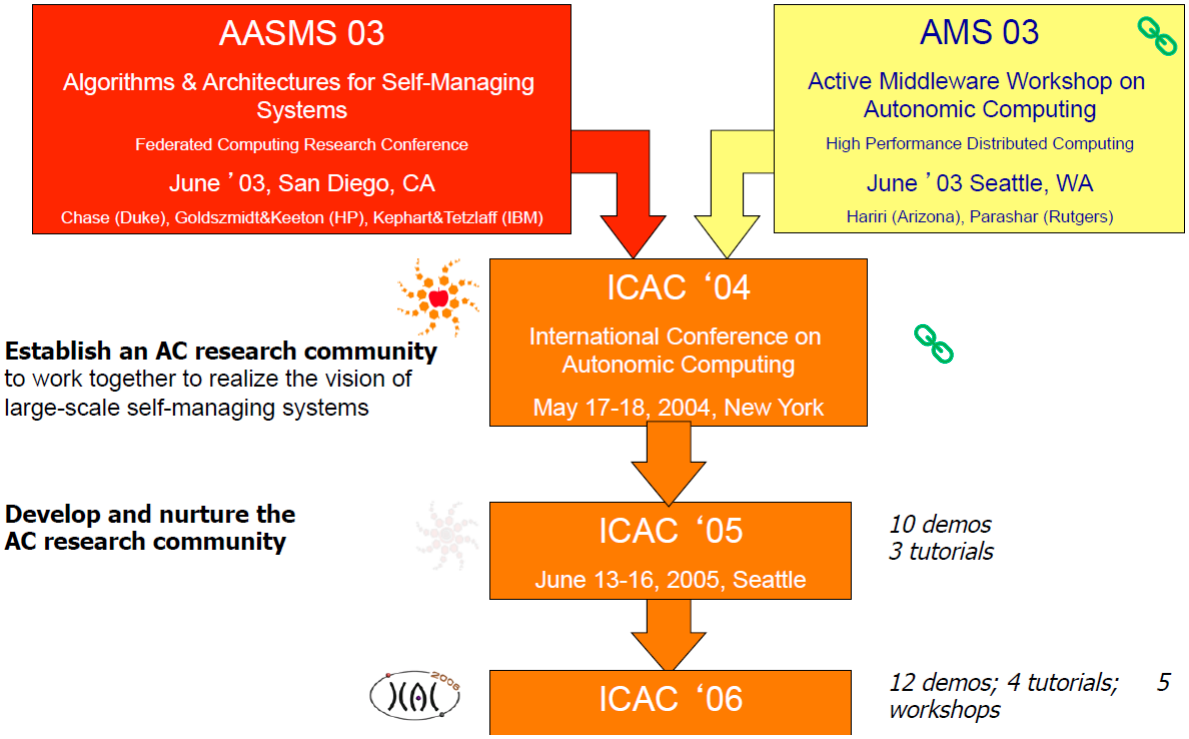
IBM Systems Journal
Vol. 42, No. 1, 2003
Autonomic Computing



Organize and sponsor workshops, conferences



Personal reflections – setting the scene…

Assuming one skipped over the bio at the start, I had worked for IBM as a graduate in their UK HQ in Portsmouth, then Hursley Labs at the end of what was a previous AI wave (early 1990s). So our KBS team removed the Reasoning shell and coded it straight in C (for licensing reasons) – and as trends change so did the name of the dept. and AI was gone for another decade! Anyhow that's another story. I returned to Ireland for family reasons and took up a series of research posts with Nortel and Ulster in parallel programming (Transputers), and Intelligent fault management (A.I. never disappeared from Academia). These projects that spanned 6 years convinced me that intelligent solutions that kept the human extensively in the loop were not working, and that we needed much more co-design (Systems & Software Engineers working together).

Anyhow as the Telcos struggled to change quick enough from traditional voice to data and the I.T. new entrants succeeded in their market I saw the risk and left the research positions and took a tenured academic role with Ulster. At the same time IBM launched their Autonomic Computing call to industry and academia – and it made total sense to me in terms of what I had been doing with Nortel. And as a new academic looking to distinguish himself from his mentoring Profs it was a case of the right time, right place,…

Since the Nortel research allowed me to hit the ground running, that led to a couple of early Autonomic publications (from a non-IBMer nor IBM sponsored researcher – important point for later) that hit those 2002 & 2003 stats in Kephart's 1st decade keynote. The first was presented at the NASA Software Engineering Workshop which sparked a decade+ collaboration bringing Autonomic Computing to NASA, in particular Goddard. Right time, right place, luck…

Personal reflections – leading to TF/TC chair

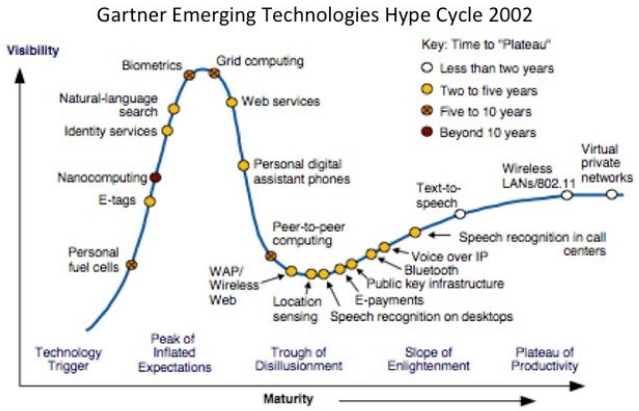
In those early days pre-AC, I had published the Nortel research at IEEE Engineering of Computer-Based Systems (ECBS), which happens to be a community of Systems & Software Engineers and I found it a 'happy research home' and got more involved … the community also had a Technical Committee (TC-ECBS) within IEEE Computer Society. For those unfamiliar with TCs (which I was at the time), IEEE (non-profit organisation) had approx. 40 Societies – the Computer Society and Communication Society both making up about ¼ each of all IEEE memberships and the cash cows that fund the majority of the deficit running smaller societies – yet had the same voting rights as each of the other approx. 40 societies (important point for later). Then within the Computer Society it was divided up into Technical Activities, Conferences (T&C merged later), Standards, Publications, Professional/Educ. Activities, Member & Geographic Activities.
So, the Technical Activities (later Technical & Conference Activities) operated with approx. 40 Technical Committees providing technical direction, oversight and sponsorship of the workshops, conferences, symposiums in their respective field. Larger TCs may also have a Transactions but that fell under the jurisdictions of the Publications board, and not all Trans had TCs!
Back on point, as I was growing my own Autonomic Computing research, I saw the benefit of holding an AC workshop at ECBS in terms of being an Autonomic evangelist '*every CBS needs autonomicity*' and also growing the ECBS conference with new hot topics – so EASe was established (see later).
With the growing collaboration with NASA GSFC, EASe became heavily influenced with NASA research which we brought to ECBS. What I hadn't realised, was a founder of ECBS and past chair of TC-ECBS was in the IEEE hierarchy – then the Chair of the Technical Activities Board – the ExCom & OpCom that represented and oversaw all 40+ TCs. Prof. Stephanie White had spotted this growing new activity cumulating in a talk where ECBS & EASe collocated with ICECCS (TC-CX) hosted by NASA GSFC in Maryland; "Why computer-based systems should be autonomic" and approached me (as a non-IBMer, since seemed to be important to avoid this IBM led initiative being perceived as IBM centric within the IEEE Computer Society) to establish a Task Force (a precursor to a potential Technical Committee). Again, right time, right place, luck…

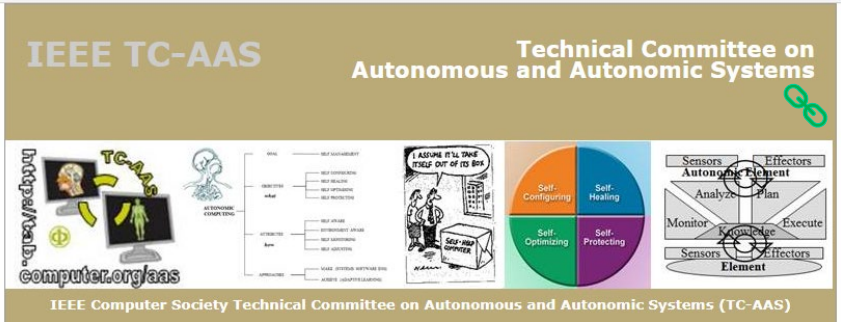
Personal reflections – TF/TC on Autonomous & Autonomic systems

My own personal rise in autonomic research was only reflecting what was going on in the computing in general. I don't believe AC made the Gartner Hype Cycle ("hype curve") – but it felt like it should have done. The power of IBM, its research division director putting it out there as a call to industry and academia to collaborate and turning many departments and staff to the cause, to cure the issue of ever increasing complexity did cause a significant buzz in the industry. Much of this happening in the US with offshoots around the world.

One of those offshoots was within the European Union a workshop on Future Internet Technologies (2003) that was to assist in defining the next EU funding round was highly influenced. So much so that the funding call became "Situated and Autonomic Communications" marking the high number of comms companies throughout the EU and obviously the AComp vision.

Now, consider IEEE is an international organisation (even if often perceived as USA centric), it represents it members throughout the industry who work for all sorts of employers, so cannot be seen to favour one… also internationally it wasn't all about Computing, as mentioned in the EU it was Comms, so discussions and advice when establishing the proposal for the "TF on Autonomic Computing" it became "Autonomous and Autonomic Systems", to widen its reach somewhat and not to be perceived as too IBM centric.
That also became an issue when selecting the steering committee which may have had implications later for the success of the TC…





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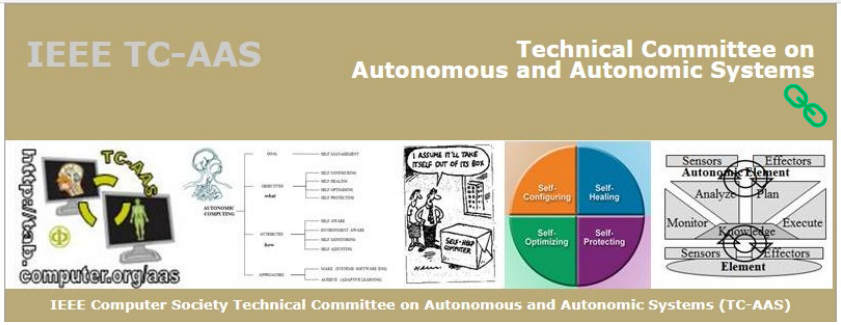
- TC Steering Committee
- Publications
- AAS Community
- 2005-07 TF-AAS
- IEEE CS T&C

TC AAS has sunset – links only for archival reasons

In **2005** IEEE established a Task Force (TF) on Autonomous & Autonomic Systems

AAS was promoted to a Technical Committee (TC) in **2007**, by an unanimous decision by IEEE CS Excom & Opcom (this was seen as a success as to become a TC the minimum is 2 years as a TF, and many TFs spend much longer in that status).

The TC was sunset in **2013** … a discussion on why may give some hints as to why the AC research field/community isn't bigger than it is and indeed deserves to be…



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Personal reflections – TF/TC on Autonomous & Autonomic systems

The steering committee was the most difficult task, and as we were starting small as a Task Force (non-funded stage, where TF doesn't see any of the sponsored conferences revenues until at the TC stage – which is at a minimum two years later) we kept it small – in hindsight perhaps too small.

There were so many 'big' names quickly established in the growing field from IBM, but as previously highlighted there was a concern not to be perceived as IBM centric, so we invited Profs. Hariri & Parashar academics with sponsored research with IBM and co-founders of ICAC.

IBM had reached out to the community at large, so going beyond IBM was key to AC success, both from IBM & the TF/TC perspective.

IEEE TC-AAS Past Chairs

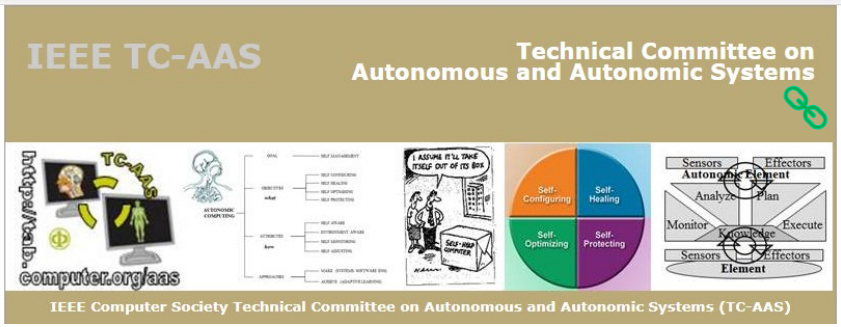
Founding Chair 2007-present: **Roy Sterritt**, University of Ulster, Northern Ireland

Task Force AAS (TF-AAS)
Founding Chair 2005-2007: **Roy Sterritt**, University of Ulster, Northern Ireland
TF-AAS Steering Committee:
Michael G. Hinchey, *TF Vice-Chair*, NASA
Jose Fernandez-Villacanas, European Union
Salim Hariri, Uni. of Arizona, AZ, USA
Sam Lightstone, IBM Canada
Manish Parashar, Rutgers Univ., NJ, USA

IEEE TC-AAS Steering Committee

TC-AAS Chair Roy Sterritt

Julie McCann, Imperial College, England (TC-AAS Vice-Chair)
Ozalp Babaoglu, University of Bologna, Italy
Larry Bergman, JPL, USA
Karin Brietman, PUC Rio, Brazil
Simon Dobson, St Andrews, Scotland
Giovanna Di Marzo Serugendo, University of Geneva, Switzerland
Robert Laddaga, Dynamic Object Language Labs, USA
Jean-Philippe Martin-Flatin, EPFL, Switzerland
Mike Hinchey, Lero, Ireland (Past TC-AAS Vice-Chair)



Personal reflections – TF/TC on Autonomous & Autonomic systems

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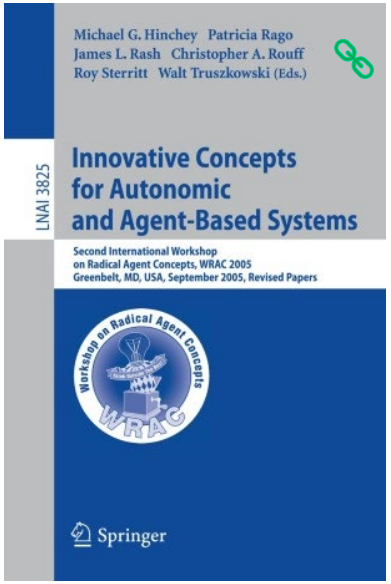
In 2005, we were running a (non-IEEE) workshop at NASA GSFC on Radical Agent Concepts (WRAC) and intentionally invited Jeff Kephart to be the keynote, with the intention of inviting him to the steering committee of TF-AAS.
Our paths had crossed previously in co-organising the IJCAI'03 workshop and had met at Profs Hariri & Parashar' AMS'03 workshop (half of what became ICAC in 2004).
In the meantime I was advised to not follow through with the invite as the TF would then become too IBM centric.



The embarrassing side is it was obvious Jeff was expecting the invite – why we'd brought him to a small workshop in Maryland. He was gracious when I explained the IBM centric concern...
If there was one thing I could change it is that moment – they say 2020 vision is hindsight!
With Jeff onboard, I've no doubt his growing influence in the AC community would have been enough to anchor ICAC with IEEE and prevent it going to ACM, which became one of the death nails for the TC.

The "community" (in a broad sense) did find it challenging getting together which didn't really happen till ICAC successor merged/collocated with SASO post 2019 editions – but that's jumping ahead too much.
Perhaps this was bound to happen with the field receiving so much hype in the first instance and its broad research agenda appealing and being relevant to so many…

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IEEE Workshop on Engineering of Autonomic and Autonomous Systems (EASE)

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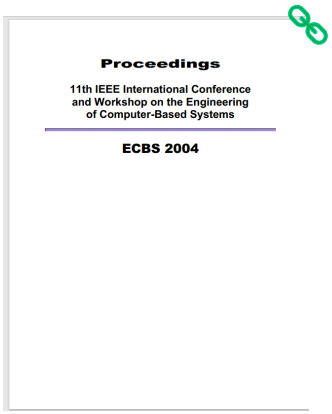
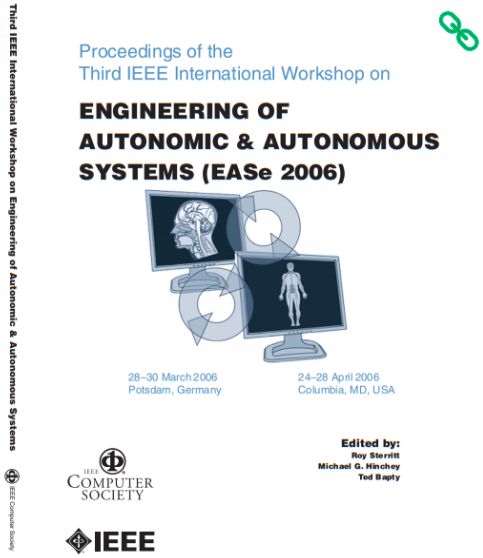
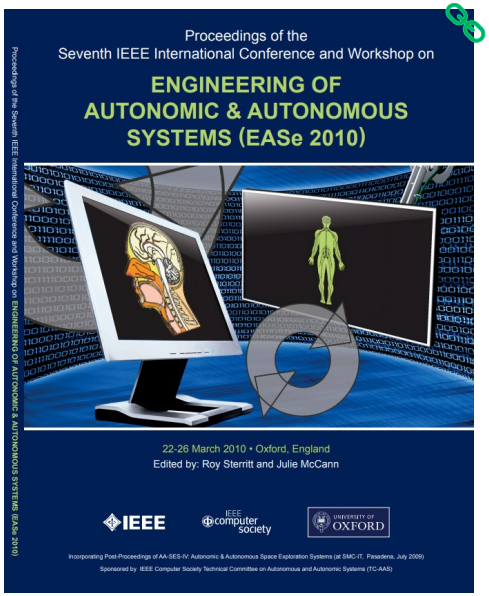
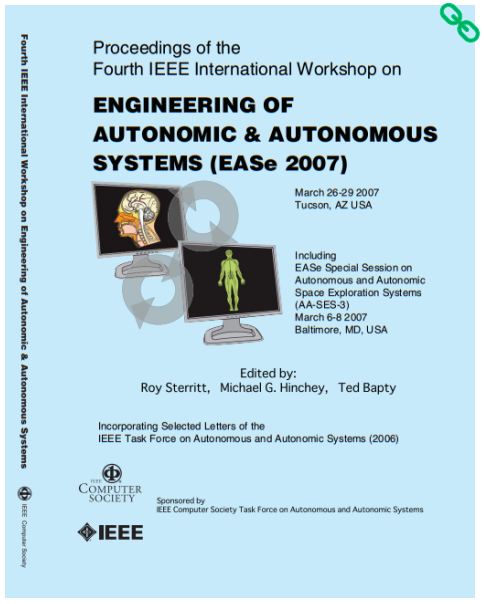


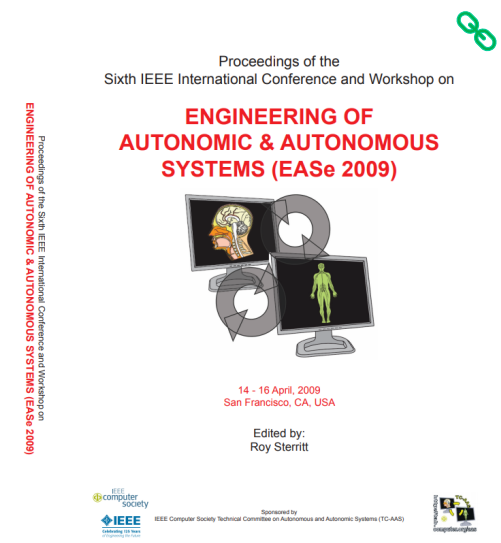
1st EASe (2004) in ECBS

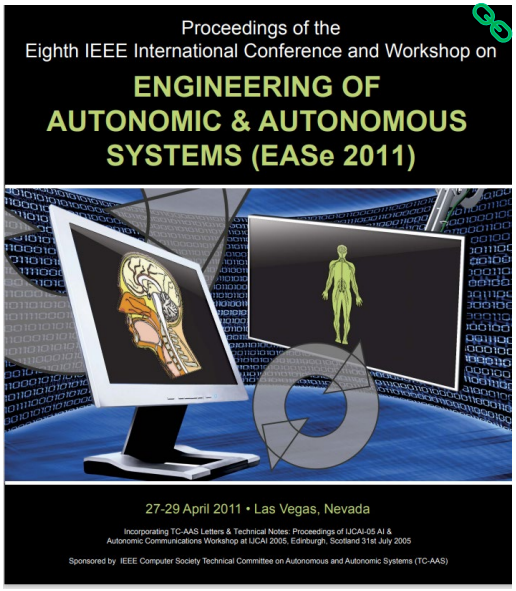


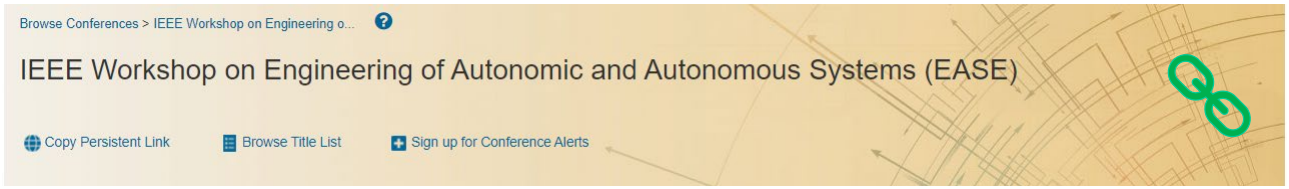


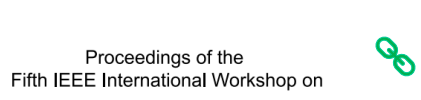
2nd EASe (2005) in ECBS







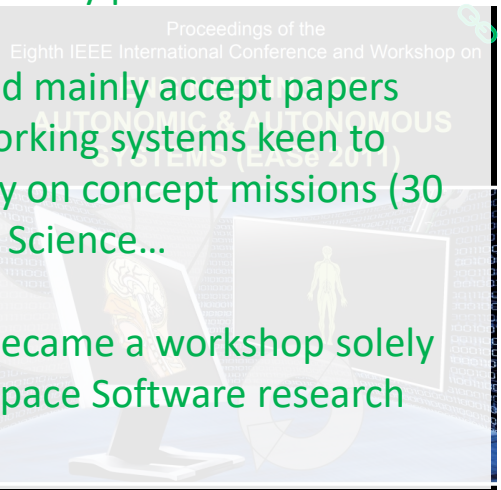




The 1st EASe workshop was held at the 11th ECBS (Engineering of Computer-Based Systems – a more modern term would be CPS!) in 2004 (after establishing it at ECBS 2003 following the ECBS paper "Autonomic Computing-a Means of Achieving Dependability?") as a strategy to bring in a new hot topic which was very relevant to the IEEE ECBS Technical Committee (System & Software Engineers).

My personal plan for EASe was it would remain a supporting workshop at ECBS … but other things took over. Once a TF then TC for AAS was established metrics become important, and EASe was needed as a TC-AAS sponsored event. For its active (published proceedings) years it co-located with ECBS and often ICECCS. In those early years it was often also run with the IEEE/NASA SMC-IT (Space Mission Challenges for I.T.), which was held tri-annually then bi-annually, as this linked with some of my personal research Autonomic Computing for Space, a collaboration with NASA GSFC.
EASe also found a role as the 'concepts' conference on AC, as often ICAC would mainly accept papers with proven findings – and who would blame them with many IBMers with working systems keen to publish in those early days. This role suited the research with NASA, especially on concept missions (30 years hence), sometimes described at that stage as more Science Fiction than Science…

With the sunsetting of the TC-AAS (TC-ECBS & TC-CX were also sunset) EASe became a workshop solely at SMC-IT with the aim to keep Autonomic Computing on the agenda within Space Software research (for instance EASe@SMCIT-2021)



2nd EASe (2005) in ECBS

Obviously, there are other Autonomic Computing technical meetings beyond those sponsored by IEEE or ACM, (for instance I'd previously mentioned the NASA workshop WRAC which we'd published through Springer Lecture Notes in Computer Science series).
One of the longest running since 2005 till this day,
(which happens to have a familiar and nice name ;)) is:

ICAS: International Conference on Autonomic and Autonomous Systems

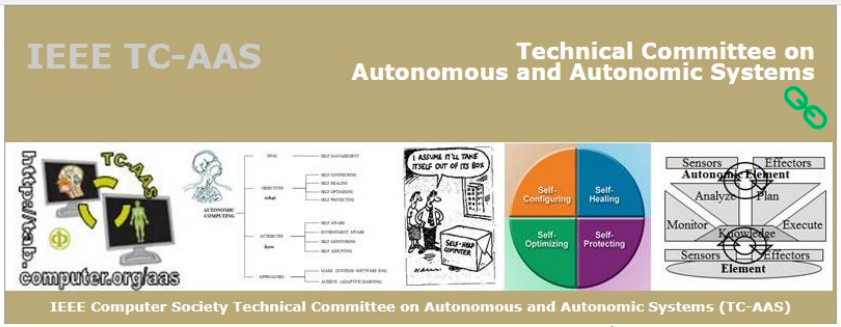
ICAS is currently on its 17th edition in 2021, an IARIA sponsored conference.

In the early days, as with other IARIA conferences, the proceedings were published through IEEE Computer Society's CPS (Conference Publication Services) – for instance 2005

For the Twenty-Tens, IARIA made the strategic decision to move their publications from behind a paywall to free access.
So, the ICAS proceedings from 2011 are freely accessible at ThinkMind. *A very positive contribution to the community.*

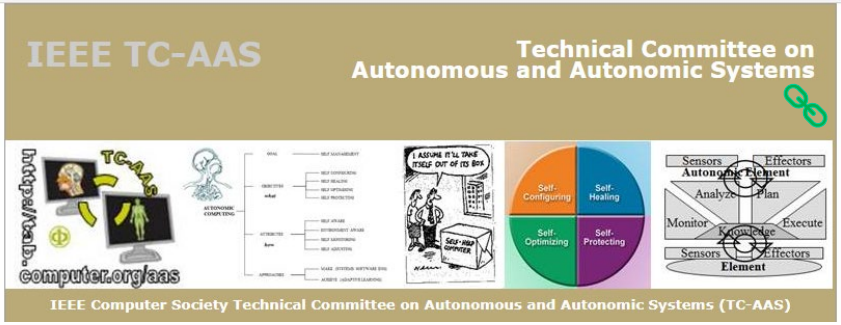
IARIA's **ADAPTIVE, International Conference on Adaptive and Self-Adaptive Systems and Applications** conference is also very relevant to the field, as well as its affiliated journal, the **International Journal on Advances in Intelligent Systems**.

Both also free to access.



The new TF/TC not only took on sponsoring EASe but the prestigious conference established by IBM researchers & IBM sponsored/collaborative researchers ICAC – The International Conference on Autonomic Computing (ICAC).
As well as co-sponsoring with TC-CX, the NASA/IEEE International Conference on Space Mission Challenges for Information Technology (SMC-IT).
It was also involved in sponsoring SelfMan (IEEE Int. Workshop on Self-Managed Networks, Systems & Services) 2006 which was ¼ of what led to the establishing & technical sponsorship of IEEE International Conferences on Self-Adaptive and Self-Organizing Systems (SASO) (2007-2012); also, establishing & technically sponsoring the IEEE International Symposium on Dependable, Autonomic and Secure Computing (DASC).

The TF was approved by both TAB ExCom & OpCom in 2005, then with all the activity that had been established, it was unanimously approved to become a TC in the minimum time specified at ExCom & OpCom in 2007.
Ironically though, the establishment of DASC caused internal T&C (Technical Activities Board (TAB) merged with Conferences Activity Board (CAB)) issues in 2008 as “Dependability” was seen as the remit of TC-FTC whom complained to the board. TC-FTC were so incensed they changed their 20 year name from FTC to TC on Dependability and Fault Tolerant Computing. Another death nail for TC-AAS.
I often viewed Autonomic Computing as horizontally going across many verticals – we needed expertise from Systems Eng., Software Eng., AI, FTC, Parallel & Distributed Systems and more fields … perhaps this is an indicator it isn’t a traditional field – this was expressed in TC-AAS’s defence to the T&C board.



The TF/TC also established a **newsletter** to help promote the research community's activities.
A part of that was also establishing **Letters**…

- Home
- About/Join TC-AAS
- Events & Activities
- Newsletters
- TC Steering Committee
- Publications
- AAS Community
- 2005-07 TF-AAS
- IEEE CS T&C

TF-AAS newsletter

IEEE COMPUTER SOCIETY

Issue 0 :: June 2005

Thursday 9th June 2005 – the proposal for a Task Force on Autonomous and Autonomic Systems went through the final stage of approval at the IEEE TAB committees in Long Beach and was approved.

As a community we now have formal representation within IEEE.

It is planned that the TF-AAS newsletter will act as a focal point for news concerning the (related) activities of the IEEE Computer Society Autonomous and Autonomic Systems task force. If you have any items for the next issue please contact r.sterritt@ulster.ac.uk.

ICAC 2005

The 2nd International Conference on Autonomic Computing (ICAC'05) got underway in Seattle 13th – 16th June with keynote speakers Rick Rashid (Microsoft), Ozalp Babaoglu (University of Bologna) and Alan Ganek (IBM).

Note DUBLIN, Ireland in your diary for ICAC 2006.

EASe 2005

The 2nd Workshop on Engineering of Autonomic Systems was held as part of the 1st Systems and Software Week in Greenbelt, Maryland April 2005. The week also included NASA's Software Engineering Workshop and the 12th Annual Engineering Computer-Based Systems.
www.infj.ulst.ac.uk/~ease/ease-2005/

Since last years workshop in Brno a special issue of IEEE Transactions Systems Man and Cybernetics–C on the Engineering of Autonomic Systems is in preparation.
www.infj.ulst.ac.uk/~ease/smc/

Activities @ EASe 2005

The social program included conference dinner at George Washington's home – Mt. Vernon, a walking tour of DC at night and a tour of NASA's Goddard Space Flight Center.

Your TF-AAS EXCOM Contacts

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Available soon: Join TF AAS

You are invited to join online the IEEE Computer Society Autonomous and Autonomic Systems Task Force.

Details will soon be available at the web site http://www.computer.org/tab/

Where you will be able to sign-up to TF-AAS and four other TC/TFs free
http://www.computer.org/TCsignup/index.htm

This prelude issue was released at ICAC'05 in Seattle to announce the new IEEE Task Force on Autonomous and Autonomic Systems. It contained some extracts from the June 2005 TC-ECBS newsletter.

UPCOMING ACTIVITIES

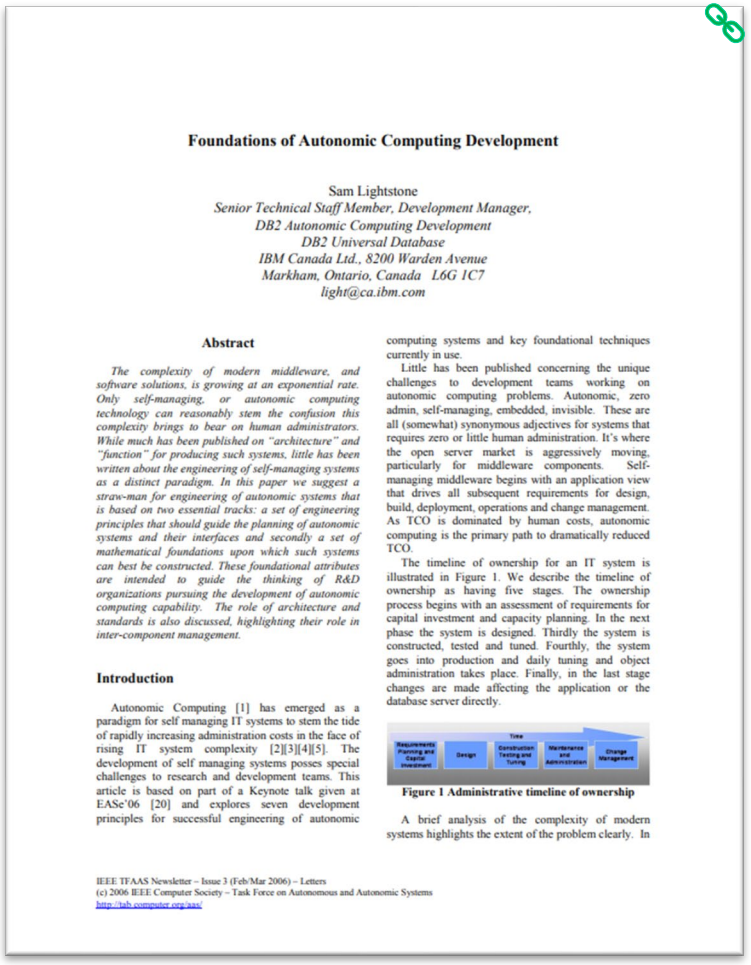
Call for Participation

- Reliability & Autonomic Management in Parallel and Distributed Systems (RAMPDS05), 11th Int. Conf. Parallel and Distributed Systems (ICPADS-2005), July 20-22, 2005 http://www.cs.iupui.edu/~ydai/RAMPDS05/RAMPDS05.htm
- IJCAI AI and Autonomic Communications Workshop (AI+AComms), Scotland, July 31, 2005, http://www.infj.ulst.ac.uk/~acomms/ijcai-05/
- 3rd Self-Adaptive and Autonomic Computing Systems (SAACS 2005) at 16th DEXA'2005, Copenhagen, Denmark, 22-26 August 2005 http://cms1.gre.ac.uk/conferences/saacs-2005/
- 2nd IFIP TC6 WG6.6 International Workshop on Autonomic Communication (WAC 2005), Athens, Greece, 3-5 October 2005

Call for Papers

- 2nd NASA/IEEE Workshop on Radical Agent Concepts 2005 (WRAC 05) (deadline 17 June 2005) http://aaaprod.gsfc.nasa.gov/WRAC/
- 1st IFIP WS Trusted and Autonomic Ubiquitous and Embedded Systems (TAUES-05) Nagasaki, Japan, 6 to 9th December 2005 http://www.cs.iupui.edu/~ydai/TAUES05/TAUES05.htm
- Adaptive and Resilient Computing Security workshop (ARCS-05), Santa Fe Institute, 2-3 November 2005 (Deadline 31 July 2005) www.arcs-workshop.org
- 3rd IEEE Workshop on the Engineering of Autonomic Systems (EASe 2006), Dual located event: 13th ECBS 2006, Potsdam (Berlin), Germany March 2006 and SEW-30, Columbia, MD, April 2006 www.ulster.ac.uk/ease
- IEEE Internet Computing – special issue on Autonomic Computing; Jan/Feb 2007 (Deadline 1 June 2006) cs-ieee.manuscriptcentral.com

IEEE Computer Society Autonomous and Autonomic Systems Task Force
Available soon : http://tab.computer.org/aas/



Foundations of Autonomic Computing Development

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DB2 Universal Database
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Abstract

The complexity of modern middleware, and software solutions, is growing at an exponential rate. Only self-managing, or autonomic computing technology can reasonably stem the confusion this complexity brings to bear on human administrators. While much has been published on "architecture" and "function" for producing such systems, little has been written about the engineering of self-managing systems as a distinct paradigm. In this paper we suggest a straw-man for engineering of autonomic systems that is based on two essential tracks: a set of engineering principles that should guide the planning of autonomic systems and their interfaces and secondly a set of mathematical foundations upon which such systems can best be constructed. These foundational attributes are intended to guide the thinking of R&D organizations pursuing the development of autonomic computing capability. The role of architecture and standards is also discussed, highlighting their role in inter-component management.

Introduction

Autonomic Computing [1] has emerged as a paradigm for self managing IT systems to stem the tide of rapidly increasing administration costs in the face of rising IT system complexity [2][3][4][5]. The development of self managing systems posses special challenges to research and development teams. This article is based on part of a Keynote talk given at EASe'06 [20] and explores seven development principles for successful engineering of autonomic computing systems and key foundational techniques currently in use.

Little has been published concerning the unique challenges to development teams working on autonomic computing problems. Autonomic, zero admin, self-managing, embedded, invisible. These are all (somewhat) synonymous adjectives for systems that requires zero or little human administration. It's where the open server market is aggressively moving, particularly for middleware components. Self-managing middleware begins with an application view that drives all subsequent requirements for design, build, deployment, operations and change management. As TCO is dominated by human costs, autonomic computing is the primary path to dramatically reduced TCO.

The timeline of ownership for an IT system is illustrated in Figure 1. We describe the timeline of ownership as having five stages. The ownership process begins with an assessment of requirements for capital investment and capacity planning. In the next phase the system is designed. Thirdly the system is constructed, tested and tuned. Fourthly, the system goes into production and daily tuning and object administration takes place. Finally, in the last stage changes are made affecting the application or the database server directly.

Figure 1 Administrative timeline of ownership

A brief analysis of the complexity of modern systems highlights the extent of the problem clearly. In

TF-AAS newsletter

Issue 1 :: Oct./Nov. 2005

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ICAC 2005

by **Manish Parashar**

AUTONOMIC COMPUTING

The International Conference on Autonomic Computing (ICAC) series of conferences address both theoretical and practical issues in the field of Autonomic Computing with the primary goal of bringing together researchers from different fields of research who are addressing aspects of self-management in computing systems, and developing and nurturing a community that can work together to realize the vision of large-scale self-managing systems. ICAC 2005, the second conference in this series, was held between June 13 and 16, 2005 in Seattle, Washington, and was a resounding success with an attendance of 125 participants.

The ICAC 2005 call for papers received an overwhelming response, attracting approximately 140 paper and poster submissions from universities and industry labs all over the world, and representing a broad array of topics pertaining to autonomic computing. The technical program consisted of 25 full papers and 39 posters selected from these submissions after careful review. Reflecting the international nature of the field, the program included papers from the U.S., Europe, and Asia. Reflecting the breadth of the field, the papers addressed a wide range of issues pertinent to creating future self-managing computing systems and applications, with topics ranging from learning techniques and their use in pervasive systems, to self-management in databases, networks, and storage systems, to systems monitoring and self-healing technologies, to middleware- and system-level support for better understanding and managing the complex software systems now routinely being deployed in commercial and research settings.

ICAC 2005 also featured two exciting keynotes; the first titled "Looking Forward to the Future" by Richard ("Rick") F. Rashid, Senior Vice President, Research, Microsoft Corporation; and the second titled "Grassroots Approach to Autonomic Computing" by Ozalp Babaoglu, Professor of Computer Science, University of Bologna. Alan Ganek, Vice President, Autonomic Computing, IBM, gave the keynote at the conference banquet titled "Autonomic Computing: Progress and Future Directions".

ICAC'05 Seattle 13th – 16th June 2005

Other important elements of the ICAC 2005 technical program were the tutorials preceding the conference and covering a range of subjects such as semantic services, autonomic computing toolkits and reinforcement learning; a special industry session exposing participants to some of the autonomic and adaptive technologies being developed in companies like IBM, Intel, and HP, an academic panel addressing the "Grand Challenges of Autonomic Computing," a poster session, and demonstrations form industry and academia.

ICAC 2005 was sponsored by the IEEE Computer Society (TCPP) and the National Science Foundation, and received support from BT, DoCoMo USA Labs, Hewlett-Packard, IBM Corporation, Intel, Microsoft Research and Raytheon.

Note in your diary, June 2006 for ICAC'06 taking place in DUBLIN, Ireland.
http://www.autonomic-conference.org

Also Self-Man 2006 is co-located with ICAC:
http://research.ihost.com/selfman2006/

Dates for the Diary

Some other dates to note in your diary are:

- Dec 2005 (cfp closed): Workshop on Trusted and Autonomic Ubiquitous and Embedded Systems; http://www.cs.iupui.edu/~ydai/TAUES05/TAUES05.htm
- Mar/Apr 2006 (cfp 15 Nov'05): IEEE EASe (Engineering of Autonomic Systems); http://www.ulster.ac.uk/ease
- Apr 2006 (cfp 31 Oct'05): IEEE Workshop on Trusted and Autonomic Computing Systems; http://cs.okstate.edu/~xiaolin/tacs06/
- Sep/Oct 2006 (cfp 15 Apr'06): IEEE Dependable Autonomic and Secure Computing (DASC'06) http://www.cs.iupui.edu/DASC06/

TF Chair's Column

Welcome to the debut issue of the TF-AAS newsletter which marks the formal representation for our self-managing systems research and development community within IEEE after the Technical Activities Board unanimously approved the Task Force in June 2005.

In the first couple of months since its inception several queries have been received asking why 'Autonomous and Autonomic Systems'? It was felt that the Task Force should reach wider than the growing self-managing initiatives to include the excellent research that has gone before within the autonomy and other communities.

In terms of computer-based systems design paradigms, autonomy implies 'self-governance' and 'self-direction' whereas autonomicity implies 'self-management'. That is, autonomy/self-governance is the automation of responsibility including some decision making for the success of *tasks/objectives* whereas autonomicity/self-management is the automation of responsibility including some decision making for the successful *operation* of the system.

From this perspective It may be argued at the systems level that the success of autonomy requires successful autonomicity and vice-versa, for instance ultimately to ensure success in terms of the system's tasks requires that the system is reliable.

Autonomic is derived from the noun 'autonomy', and we hope in the future months and years we will benefit from each other's research to achieve the overarching strategic long term vision of self-managing systems.

Roy Sterritt, chair TF-AAS

(Reprinted from Times Higher Education, UK)

TF-AAS newsletter

Issue 2: Dec. 2005/Jan. 2006

The TF-AAS newsletter is produced as a focal point for news concerning the (related) activities of the IEEE Computer Society Autonomous and Autonomic Systems Task Force. If you have any items for the next issue please contact
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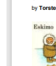
SAACS 2005

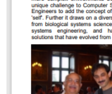
by **Torsten Eymann**



The workshop on "Self-Adaptive and Autonomic Computing Systems" (SAACS), which is held in conjunction with the DEXA conference each year, has in 2005 again attracted a close group of ca. 30 followers. As was the case with its predecessors in Prague and Zaragoza, the SAACS workshop in Copenhagen has shown familiar atmosphere and a lively discussion between academics and industrial researchers.

The topic of the SAACS workshop, as the name suggests, is not only Autonomic Computing. "Like Eskimos having 50 words or more for snow, the computing and technologies communities have a similar number of terms for self-managing computing systems. You say Pro-active! I say Dynamic! And so on and on. Lets call the whole thing SAACS!" is a quote by the organizers in their self-description. What is behind AC is of interest, not only the current (and maybe passing) term itself.

This is because AC not only hoping to solve the many problems that Industry is experiencing with unreliable or increasingly more complex environments but it brings a unique challenge to Computer Scientists and Engineers to add the concept of the system's 'self'. Further it draws on a diverse community from biological systems science to operating systems engineering, and has produced solutions that have evolved from earlier work, reworking of older computing science and genuinely revolutionary ideas.



SAACS'05 Social: Moh Ibrahim & Manish Parashar

To this end the workshop mixes industrialists and academics and not only provides an arena for the presentation of innovative work, but panel sessions and opportunities to debate and brainstorm in a uniquely meaningful yet informal setting.

Looking forward, the 2006 issue of the SAACS workshop will be held again over two days alongside DEXA, which runs from September 4-8, 2006. Submissions are open until March 15, 2006, and the proceedings will be published in an IEEE DEXA workshop proceedings volume. The colourful webpages of the workshop can be found at: http://cms1.gre.ac.uk/conferences/saacs06/

SOAS 2005

by **Huaglory Tianfield**

The 2005 International Conference on Self-Organization and Adaptation of Multi-agent and Grid Systems (SOAS 2005) was held at the University of Paisley, Glasgow, Scotland, United Kingdom between 11 - 13 December 2005.

Multi-agent systems comprising of a collection of fully or semi- autonomous entities/components, whose global behaviors come from emergent interactions among these entities/components. Such multi-agent systems have been studied widely, not only in computer science, software engineering and artificial intelligence, but even more widely in economics, management science, sociology, systems science, etc. In fact, multi-agent systems permeate social, economic, and technical domains.

While Grid computing is the new generation of distributed and networked information and computing systems which have the capacity to enable users and applications in an emergent manner to transcend the organizational boundaries and to gain access to the local computing resources administrated by different organizations. A Grid computing system is by nature a large-scale, complex, and open multi-agent system. Grid computing integrates distributed computing resource management, semantic web technology, service oriented architecture and service management, distributed workflow management, monitoring and control of distributed problem solving, etc.

While self-organization and adaptation have been studied intensively in control theory, systems theory, adaptive complex systems, robotics, etc., they are relatively new concepts for computing systems. In recent years it has widely been recognized that large-scale complex computing systems are increasingly demanding self-organization and adaptation, as advocated by the autonomic/adaptive computing initiatives in, e.g., IBM, HP, etc. [cont. page 2].

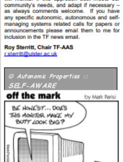
[cont. page 2]

TF Chair's Column

Belated Happy New Year! And what a busy year we have ahead; this year will mark the first conferences and workshops sponsored and co-sponsored by the TFAAS. There are also many wider community events taking place internationally [see *Calendar of Community Activity* within the newsletter, or watch the TF website:
http://www.infj.ulst.ac.uk/~autonomic/IEEE_TF-AAS/index.html

Speaking of activities, in terms of a subscription-based email posting service for relevant cfp etc, initially we avoided the temptation to go down that route for our community TF self-* related conferences, since the calls are already cross-posted so widely on the other forums (SEWorld, DBWorld, ACF etc.). Yet in the 6 months since our formal beginning there have been many queries on this matter. Our view would appear to be an academic's view of the world since we tend to subscribe to all these lists. Yet our industrial colleagues appear to be less over-subscribed and would appreciate a specialised timely activities email. As such we plan to start emailing specific calls for papers closely related to the TF to our members. At this stage this will not be a full posting service, we will attempt to minimize the traffic and combine calls in a single email posted to the TF members, initially on a weekly or so basis. We will monitor if this approach best meets our community's needs, and adapt if necessary – as always comments welcome. If you have any specific autonomic, autonomous and self-managing systems related calls for papers or announcements please email them to me for inclusion in the TF news email.

Roy Sterritt, Chair TF-AAS
r.sterritt@ulster.ac.uk



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TF-AAS newsletter

Issue 3: Feb./Mar. 2006

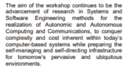
The TF-AAS newsletter is produced as a focal point for news concerning the (related) activities of the IEEE Computer Society Autonomous and Autonomic Systems Task Force. If you have any items for the next issue please contact
r.sterritt@ulster.ac.uk

EASe 2006 @ Potsdam, Germany

The first of the dual meetings of the 3rd IEEE International Workshop on the Engineering of Autonomic and Autonomous Systems (EASe) took place in conjunction with the ECBS (Engineering of Computer-Based Systems) in Potsdam, Germany in March. Following EASe 2004 in Europe (Brno, Czech Republic) and EASe 2005 in USA (Greenbelt, Maryland), EASe 2006 is dual located in both the EU and USA.

This meeting marks the inaugural sponsorship of an event by our IEEE Computer Society Task Force (TFAAS). Also, this year the workshop has corporate sponsorship from IBM.

The aim of the workshop continues to be the advancement of research in Systems and Software Engineering methods for the realization of Autonomic and Autonomous Computing and Communications, to conquer complexity and cost inherent within today's computer-based systems while preparing the self-managing and self-directing infrastructure for tomorrow's pervasive and ubiquitous environments.



Potsdam, Germany

Sam Lightstone, leader of IBM Canada's DB2 Autonomic Technologies efforts, gave the keynote talk (available in the letter's section below).

EASe website is at
http://www.ulster.ac.uk/ease

Proceedings available on IEEE website at http://doi.ieeecomputersociety.org/10.1109/EASE.2006.18 (doi:10.1109/EASE.2006.18).

LETTERS

Foundations of Autonomic Computing Development

by **Sam Lightstone**

Abstract: *The complexity of modern middleware, and software solutions, is growing at an exponential rate. Only self-managing, or autonomic computing technology can reasonably stem the confusion this complexity brings to bear on human administrators. While much has been published on "architecture" and "function" for producing such systems, little has been written about the engineering of self-managing systems as a distinct paradigm. In this paper we suggest a straw-man for engineering of autonomic systems that is based on two essential tracks: a set of engineering principles that should guide the planning of autonomic systems and their interfaces and secondly a set of mathematical foundations upon which such systems can best be constructed. These foundational attributes are intended to guide the thinking of R&D organizations pursuing the development of autonomic computing capability. The role of architecture and standards is also discussed, highlighting their role in inter-component management.*

Sam expands the themes from his EASe'06 keynote in this article exploring foundational techniques along with seven development principles for successful engineering of autonomic computing systems:
#1 Build what users need, not what's cool
#2 Always give the user "an out". Features providing system automation must have an off switch.
#3 Features must be on by default in order for the majority of users to exploit them.
#4 Never force the user to make a choice that your scientists and engineers could not.
#5 The plague of benchmarking: Autonomic computing technology must work in real world scenarios.
#6 Never automatically undo or contradict the explicit choices of the administrator/application(s).
#7 Minimize policy and keep it human.

Read the full article at: http://tab.computer.org/aas/newsletter/2006-2/2006-2-tf-aas-letters.pdf

TF Chair's Column

Welcome to the February-March 2006 issue of our TF newsletter and we've had a productive start to IEEE Computer Society's 60th year.

Announced in this issue is the launch of the Autonomic Community Web Portal. Many thanks goes to Manish for championing this, also to Pat Rago for her excellent effort assisting in pulling together the content and last but not least, Vincent Matossian, for the great development effort.

In this issue we are launching what will hopefully grow over the next couple of years, articles and papers as a *letters section* which will be available online and links provided from the newsletter. Sam Lightsone gets us off to an excellent start with a paper based on topics he explored in his keynote talk at EASe-2006 in Potsdam.

As our special interest in self-managing computing, communications and systems bring together software, computing hardware and communications – and people (that aren't totally out of the loop yet ☺), please also keep in mind that if you are organizing any conference or workshop activities in the area in the years ahead there are options available for IEEE TFAAS to sponsor or co-sponsor your event, please feel free to contact us to discuss.

Roy Sterritt, Chair TF-AAS
r.sterritt@ulster.ac.uk

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TF-AAS newsletter

Issue 4: Apr./May 2006

The TF-AAS newsletter is produced as a focal point for news concerning the (related) activities of the IEEE Computer Society Autonomous and Autonomic Systems Task Force. If you have any items for the next issue please contact
r.sterritt@ulster.ac.uk

EASe 2006 @ Columbia, USA

The second of the dual meetings of the 3rd IEEE International Workshop on the Engineering of Autonomic and Autonomous Systems (EASe) took place as a part of the 2nd SASW (System and Software Week) which incorporated the 30th NASA/IEEE Software Engineering Workshop (SEW-30) in Columbia, USA in April.

This meeting marked the inaugural sponsorship of an event by our IEEE Computer Society Task Force (TFAAS). Also, this year the workshop has corporate sponsorship from IBM.

Columbia, Maryland, USA

Dave Atkinson, program manager of the NASA JPL Exploration Systems Engineering Office gave the keynote, raising autonomic and autonomous software system challenges for the Constellation Program. (available in the letter's section below).

EASe website is at
http://www.ulster.ac.uk/ease

Proceedings available on IEEE website at http://doi.ieeecomputersociety.org/10.1109/EASE.2006.18 (doi:10.1109/EASE.2006.18).

Other Connected links:

http://sel.gsfc.nasa.gov/

http://www.systemsandsoftwareweek.org/

LETTERS

Constellation Program Return to the Moon: Software Systems Challenges – Autonomy and Autonomicity a Solution?

by **Dave Atkinson**

Abstract: *This letter introduces NASA's Constellation Program, which is developing new space systems for renewed human exploration of the moon, and eventually, Mars. A selection of challenges for software systems will be introduced that arise from the special circumstances of Constellation Systems. These challenges illustrate a variety of the types of problems that must be addressed related to software quality, automation, autonomy and autonomicity. The challenges are further compounded since Constellation missions represent a mixing of the human space-flight processes with those of NASA's robotic exploration missions. These factors and others give rise to many unique and/or significantly more complex engineering than has been previously faced in the development of space systems. In this context, software reliability and safety become critical qualities for what will arguably be the most complex software systems artifact ever created.*

Read the full article at: http://tab.computer.org/aas/newsletter/2006-3/2006-3-tf-aas-letters.pdf

TF Chair's Column

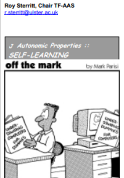
Welcome to the April-May 2006 issue of our TF newsletter.

The TF-AAS will be 1 year old in June, and I will be reporting back on progress to the IEEE TAB. As it happens, the TAB meetings clash with our prestigious ICAC conference, and I was so excited that ICAC was coming to my home, Ireland! So it is with deep regret that I cannot make ICAC'06 - I hope you all have a great time and enjoy the Guinness and the craic!

It's a pleasure to take the opportunity on your behalf to thank Simon, Fabrice and their team for doing such an excellent job organizing ICAC'06. Mazin and Omer have efficiently produced an outstanding program for us and are due our gratitude and thanks for their hard work. Hopefully see you all in Florida in 2007 (if not before!).

In this issue we continue with our *letters section* on the theme of expanded *AAS* keynote presentations. Dave Atkinson continues the excellent start with a paper based on topics he explored in his keynote talk at EASe-2006 in Columbia.

Roy Sterritt, Chair TF-AAS
r.sterritt@ulster.ac.uk



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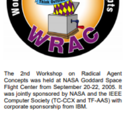
TF-AAS newsletter

WRAC 2005



The 2nd Workshop on Radical Agent Concepts was held at NASA Goddard Space Flight Center from September 20-22, 2005. It was jointly sponsored by NASA and the IEEE Computer Society (TC-CCX and TF-AAS) with corporate sponsorship from IBM.

The workshop series provides opportunity to present new and evocative ideas on agent-based systems, covering emerging and incipient concepts and initial reports on research that could revolutionize agent-based systems, often strongly inspired by theoretical or empirical studies of human behavior, social intelligence, psychology, arts, biology, computer science and philosophy. The organizers aim for an inter-disciplinary program with original (out-of-the-box) thinking from industrialists and academics with an interest in radical (innovative) concepts.

WRAC at NASA Goddard Space Flight Center

This year's WRAC had encouraged submissions from the Autonomic Systems community where agents will play a pivotal role as well as seeking influence from the self-managing systems for creating radical self-managing agent based systems. Jeff Kephart, from IBM TJ Watson Center, gave the workshop keynote on "The Role of Agents in Autonomic Computing".

The post workshop proceedings from WRAC will be published late this year/early next year by Springer in their LNCS series.

URL: http://aaaprod.gsfc.nasa.gov/wrac

In Brief: Other Community Activity

This section briefly lists some of the additional activity within the community (both within IEEE and beyond) over the last few months.

June 2005

ASMEA 2005

The 1st International Workshop on Adaptive and Self-Managing Enterprise Applications was held in Porto, Portugal on the 14 June 2005.
http://www.elet.polimi.it/conferences/asmea05

A&A-SES-1

A&A-SES-1 – a Special Session on Autonomic & Autonomous Space Exploration Systems was held as part of Software Engineering Research and Practice (SERP'05), June 27-30, 2005, Las Vegas.
http://www.infj.ulst.ac.uk/~autonomic/AA-SES/

July 2005

AEI Special Issue Journal

A Special Issue on *Autonomic Computing*, of Elsevier's Advanced Engineering Informatics edited by H. Tianfield and R. Unland was released in July. Issue details are volume 19, no. 3, Pages 179-252 (July 2005), ISSN 1474-0346
http://www.sciencedirect.com/science/journal/14740346

RAMPDS 2005

A Workshop on Reliability and Autonomic Management in Parallel and Distributed Systems (RAMPDS-05) was held in Fukuoka, Japan at ICPADS-2005.
http://www.cs.iupui.edu/~ydai/RAMPDS05/RAMPDS05.htm

August 2005

IJCAI'05 AI+AComms 2005:

A Workshop on AI and Autonomic Communications was held as part of IJCAI'05 in Edinburgh, Scotland on 31 July 2005, focusing on how to achieve the Knowledge Plane within next generation self-managing communications.
http://www.infj.ulst.ac.uk/~acomms/ijcai-05/

SAACS 2005

The 3rd International Workshop on Self-Adaptive and Autonomic Computing Systems connected with DEXA, was held in Copenhagen, Denmark, 22 - 26 August 2005.
http://cms1.gre.ac.uk/conferences/saacs-2005/

October

WAC 2006

The 2nd IFIP TC6 International Workshop on Autonomic Communication (WAC 2005) took place Oct. 3-5, 2005, in Vouliagmeni, Athens, Greece.
http://cgi.di.uoa.gr/%7Eistavrak/WAC_2005/

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Details can be found at the web site
http://www.computer.org/tab/

Where you can sign-up to TF-AAS and three others free
http://www.computer.org/TCsignup/index.htm

If you have already signed up, manage your Technical Activity through TECA:
http://www.computer.org/services/teca

Your TF-AAS EXCOM Contacts

Roy Sterritt TF Chair
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Michael G. Hinchey, TF Vice-Chair
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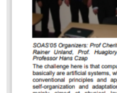
TF-AAS newsletter

SOAS'05 [cont. from page 1]



SOAS'05 Organizers: Prof Cherif Branki, Prof. Rainer Unland, Prof. Huaglory Tianfield & Professor Hans Czap

The challenge here is that computing systems basically are artificial systems, which prevents conventional principles and approaches for self-organization and adaptation, which are mainly aimed at physical laws governed systems, from being applied to computing systems. To tackle the complexities of physical laws governed systems such as openness, uncertainty, discrete event randomness, etc., there have been established frameworks of principles and approaches for understanding and engineering self-organization and adaptation. However, for artificial systems such as large-scale complex computing systems, the understanding of the openness, uncertainty, discrete event dynamics, etc. is still very limited and the framework for self-organization and adaptation has yet to be established.

To respond to these challenges, SOAS was established to provide a focal forum to exchange and disseminate the state-of-art developments from different disciplines. The SOAS'05 Conference aimed to provide a timely forum to present the latest theoretical and practical results on self-organization and adaptation that have been arising in recent years especially in the areas of Multi-Agent Systems, Grid Computing and Autonomic/Adaptive Computing, and also served as an opportunity to focus on the challenges and to shape the future.

The SOAS'05 Conference was attended by about 60 delegates from near 20 countries around the world. The Conference accepted 19 regular, 20 short and 8 Work-in-Progress papers from its near 60 submissions. The Conference had four very distinguished keynote presentations from Dr Omer F. Rana on "Agent-based Computational Grids: Research Issues and Challenges", Prof Philippe De Wilde on "Micro-economic multi-agent systems that trade populations", Prof Franco Zambonelli on "Engineering Self-Organization and Emergence: Issues and Directions" and Roy Sterritt on "Autonomous and Autonomic Systems: Paradigms for Future Space Exploration". Selected papers of the SOAS'05 Conference have been published by IOS Press as "Self-Organization and Autonomic Informatics (I)", Edited by H. Czap, R. Unland, C. Branki and H. Tianfield, Volume 135 in the series of Frontiers in Artificial Intelligence and Applications, December 2005, approx. 396 pp., ISBN: 1-58603-577-0.

SOAS'06 will be in Erfurt, Germany, 18 - 21 September 2006. For details see http://www.soas2006.org/

Calendar of Community Activity

This section briefly lists some of the additional activity within the community (both within IEEE and beyond) over the forthcoming months.

March 2006

- Mar 27-30, 3rd IEEE EASe (Engineering of Autonomic Systems); Potsdam, Germany (co-located with IEEE 13th ECBS) http://www.ulster.ac.uk/ease

April 2006

- Apr 18-20: IEEE WS on Trusted and Autonomic Computing Systems (TACS); Vienna, Austria http://cs.okstate.edu/~xiaolin/tacs06/
- Apr 24-28: 3rd IEEE EASe (Engineering of Autonomic Systems); Columbia, MD, USA (co-located with NASA/IEEE SEW 30) http://www.ulster.ac.uk/ease

May 2006

- May 4-5: 3nd Int. WS Managing Ubiquitous Communications and Services (MUCS'06), Cork, Ireland http://www.aws.cit.ie/mucs2006/
- May 21-22: ICSE 2006 WS Software Engineering for Adaptive and Self-Managing Systems, Shanghai, China http://www.cse.msu.edu/SEAMS/

June 2006

- June 1st: Special Issue Journal on "Autonomic and Trusted Computing Systems and Applications" (JoATC) http://cs.okstate.edu/~xiaolin/joatc/CFP06.htm
- June 12-16: 3rd IEEE Int. Conf. Autonomic Computing, Dublin, Ireland. http://www.autonomic-conference.org
- June 12-16: (cfp 14th Feb) 2nd Self-Man 2006 @ ICAC'06 http://research.ihost.com/selfman2006/
- June 12-16: (cfp 17th Mar) 2nd Int. WS Smart Grid Technologies (SGT06), @ ICAC'06. http://www.iw.uni-karlsruhe.de/sgt06/
- other ICAC'06 workshops: www.caip.rutgers.edu/icac2006/wrk_tut.htm

July 2006

- July 17-21: A&A-SES-2 – Mini workshop Autonomic & Autonomous Space Exploration Systems as part of 2nd Int. Conf. Space Mission Challenges For Information Technology (SMC-IT 2006), Pasadena, California, USA. http://www.infj.ulst.ac.uk/~autonomic/AA-SES/ http://smc-it.jpl.nasa.gov/
- July 19-21: *(cfp 5 Mar'06)* Int. Conf. Autonomic and Autonomous Systems (ICAS), Silicon Valley, USA. Incorporating: SYSAT 2006: Advances in system automation; AUTSY 2006: Theory and practice of autonomous systems; AWARE 2006: Design and deployment of context-awareness networks, services and applications; AUTONOMIC 2006: Autonomic computing: design and management of self-behavioural networks and services; MCMAC 2006: Monitoring, control, and management of autonomous self-aware and context-aware systems; CASES 2006: Automation in specialized mobile environments; ALCOC 2006: Algorithms and theory for control and computation; MODEL 2006: Modeling, virtualization, any-on-demand, MDA, SOA http://www.iaria.org/conferences/ICSA06.html

September 2006

- Sept 3-6: *(cfp 10 Mar '06)*, 3rd Int. Conf. Autonomic and Trusted Computing (ATC'06), Wuhan and Three Gorges, China http://grid.hust.edu.cn/atc06/
- Sept 4-8, *(cfp 15 Mar '06)* 4th Int. DEXA WS Self-Adaptive and Autonomic Computing Systems (SAACS06), Krakow, Poland. http://cms1.gre.ac.uk/conferences/saacs06/
- Sept 18-21, *(cfp 30 Apr'06)* Int. Conf. Self-Organization and Autonomic Systems in Computing & Communications (SOAS'2006) Erfurt, Germany. http://www.soas2006.org/
- Sept 29th -Oct 1st 2006 *(cfp 15 Apr'06)*: IEEE Dependable Autonomic and Secure Computing (DASC'06), Indianapolis, USA http://www.cs.iupui.edu/DASC06/

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http://www.computer.org/TCsignup/index.htm
If you have already signed up, manage your Technical Activity through TECA:
http://www.computer.org/services/teca

TF-AAS newsletter

TFAAS Website & New Emails

http://tab.computer.org/

In the last newsletter, it was announced that we would start a weekly news email listing the relevant community calls for papers closely related to the TFAAS. This is now ongoing. For a listing of events see the TFAAS website @ tab.computer.org/aas/ . If you have any specific autonomic, autonomous and self-managing systems related calls for papers or announcements please email them to us for inclusion in the TF news email.

AC Community Web Portal

http://www.autonomiccomputing.org/

The Autonomic Computing web portal is now available for your review and comments. It's goal is to be a place for all things related to autonomic computing (non-marketing) for both academics and industry. Please feel free to critique and suggest additions/modifications/deletions.

Please send all comments to:
Vincent Matossian
<vincentm@caipclassic.rutgers.edu>,
cc: Manish Parashar
<parashar@caip.rutgers.edu>

Calendar of Community Activity

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May 2006

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- June 12-16: 2nd Int. WS Smart Grid Technologies (SGT06), @ ICAC'06. http://www.iw.uni-karlsruhe.de/sgt06/
- other ICAC'06 workshops: www.caip.rutgers.edu/icac2006/wrk_tut.htm
- June 15: ICC 2006 Workshop on Autonomic Communications at ICC'06 in Istanbul, Turkey http://www.icc2006.org/index/conference-program-w.html
- June 26: ACC 2006, 2nd IEEE WoWMoM Workshop on Autonomic Communications and Computing, Niagara-Falls, Buffalo-NY. http://www.autonomic-communication.org/acc/

July 2006

- July 17-21: *(cfp 1st May)* A&A-SES-2 – Mini workshop Autonomic & Autonomous Space Exploration Systems as part of 2nd Int. Conf. Space Mission Challenges For Information Technology (SMC-IT 2006), Pasadena, California, USA. http://www.infj.ulst.ac.uk/~autonomic/AA-SES/ http://smc-it.jpl.nasa.gov/
- July 18-19: *(cfp 21st Apr)* LAACS 2006: First Latin American Autonomic Computing Symposium, Dom Bosco Catholic University in Campo Grande, MS, Brazil http://www.fee.unicamp.br/laacs2006
- July 19-21: Int. Conf. Autonomic and Autonomous Systems (ICAS), Silicon Valley, USA. Incorporating: SYSAT 2006: Advances in system automation; AUTSY 2006: Theory and practice of autonomous systems; AWARE 2006: Design and deployment of context-awareness networks, services and applications; AUTONOMIC 2006: Autonomic computing: design and management of self-behavioural networks and services; MCMAC 2006: Monitoring, control, and management of autonomous self-aware and context-aware systems; CASES 2006: Automation in specialized mobile environments; ALCOC 2006: Algorithms and theory for control and computation; MODEL 2006: Modeling, virtualization, any-on-demand, MDA, SOA http://www.iaria.org/conferences/ICSA06.html

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- Sept 18-21, *(cfp 30 Apr'06)* ATAC 2006: First International Workshop on Agent Technology and Autonomic Computing, Erfurt, Germany. http://www.netobjectdays.org
- Sept 25-29, Autonomic Networking 2006 incorp: SMARTNET - INTELLCOMM - IWAN - WAC, Paris – France. www.autonomic-net.org
- Sept 29th -Oct 1st 2006 *(cfp ext: 30 Apr'06)*: IEEE Dependable Autonomic and Secure Computing (DASC'06), Indianapolis, USA http://www.cs.iupui.edu/DASC06/

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http://www.computer.org/TCsignup/index.htm
If you have already signed up, manage your Technical Activity through TECA:
http://www.computer.org/services/teca

TF-AAS newsletter

TACS 2006

The IEEE International Workshop on Trusted and Autonomic Computing Systems (TACS-06) took place in April (19th) at the Vienna University of Technology, Vienna, Austria. This workshop brings to the community a focus on Trusted systems through self-management and the need for the synergistic research efforts ranging from computer science and engineering, to the natural sciences to the social sciences.. The workshop had presenters from Canada, China, Germany, Italy, Switzerland, UK and USA.

TACS'06 website is at
http://cs.okstate.edu/~xiaolin/tacs06/

ICSE SEAMS 2006

In May (21st-22nd), in Shanghai, China at the prestigious IEEE International Conference on Software Engineering (ICSE), the workshop on Software Engineering for Adaptive and Self-Managing Systems (SEAMS) took place. Specifically, participants from academia, industrial organizations, and government agencies presented projects and discussed many open issues relating to the software engineering of systems that have the ability to self-manage by adapting itself at run time to handle such things as changing user needs, system intrusions or faults, a changing operational environment, and resource variability. Such a system must configure and reconfigure itself, augment its functionality, continually optimize itself, protect itself, and recover itself, while keeping its complexity hidden from the user. The workshop brought together the different communities of software engineering to discuss the state of research and practice when dealing with self-adaptive, self-managing systems, self-healing, self-optimizing, self-configuring, and autonomic software. The workshop included sessions on formal methods and assurance, model-driven development, architecture, and domain-specific aspects of self-adaptive systems. Each session included a topical presentation that overviewed the state of the art in that particular area in the context of self-adaptive systems, followed by brief paper presentations and discussions. There was a keynote by John Strassner from Motorola Research Labs, and two invited talks about: the NASA ANTS Project, and the EU IST MADAM Project.

SEAMS'06 website is at
http://www.cse.msu.edu/SEAMS/

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December 2006

Dec 20-23, *(cfp 15th July)* 14th Int. Conf. on Advanced Computing & Communications (ADCOM 2006). Surathkal, Mangalore, India The theme for ADCOM 2006 is Autonomic Computing
http://www.adcom2006.nitk.ac.in

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If you have already signed up, manage your Technical Activity through TECA:
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TF-AAS newsletter
SelfMan 2006
TF-AAS newsletter
TC-AAS newsletter
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TC-AAS newsletter
IEEE EASe 2012
TC-AAS newsletter

The newsletter became somewhat formulistic and repetitive (CFPs etc) but one of the best parts in the early years was we'd paid for some "off the mark" cartoons that we'd found that had a tongue-in-cheek loose connection with self* properties. We'd promised to commission some in the future when a suitable occasion occurred … (screenshots from the bottom right hand corner in the newsletters)

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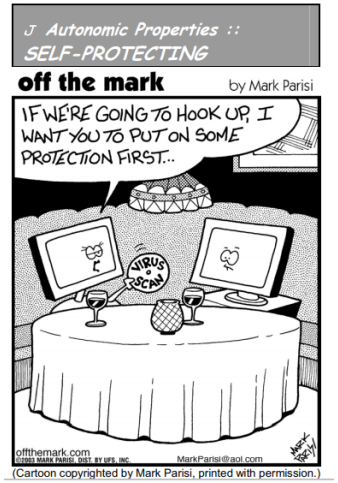

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10,000 + off the mark cartoons by Mark Parisi

Establishing AAS Letters…

IEEE AAS Letters

AAS Letters Keynote Series

[@ Published in EASe 2007 proceedings]

Issue 3 - Feb/Mar 06: **Foundations of Autonomic Computing Development** by *Sam Lightstone* (IBM Canada) [@ computer.org] [@ ieeexplore]

Issue 4 - Apr/May 06: **Constellation Program Return to the Moon:Software Systems Challenges – Autonomy and Autonomicity a Solution?** by *Dave Atkinson* (NASA JPL) [@ computer.org] [@ ieeexplore]

Issue 5 - Jun/Jul 06: **Using Autonomic Principles to Manage Converged Services in Next Generation Networks** by *John Strassner* (Motorola Research) [@ computer.org] [@ ieeexplore]

Issue 6 - Aug/Sep 06: **99% (Biological) Inspiration …** by *Mike Hinchey & Roy Sterritt* (NASA GSFC & University of Ulster) [@ computer.org] [@ ieeexplore]

Issue 7 - Oct/Nov 06: **Achieving an acceptable design model for autonomic systems** by *Simon Dobson* (UCD) [@ computer.org] [@ ieeexplore]

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IEEE computer society

Foundations of Autonomic Computing Development

Sam Lightstone
Senior Technical Staff Member, Development Manager,
DB2 Autonomic Computing Development
DB2 Universal Database
IBM Canada Ltd., 8200 Warden Avenue
Markham, Ontario, Canada L6G 1C7
light@ca.ibm.com

Abstract

The complexity of modern middleware, and software solutions, is growing at an exponential rate. Only self-managing, or autonomic computing technology can reasonably stem the confusion this complexity brings to bear on human administrators. While much has been published on "architecture" and "function" for producing such systems, little has been written about the engineering of self-managing systems as a distinct paradigm. In this paper we suggest a straw-man for engineering of autonomic systems that is based on two essential tracks: a set of engineering principles that should guide the planning of autonomic systems and their interfaces and secondly a set of mathematical foundations upon which such systems can best be constructed. These foundational attributes are intended to guide the thinking of R&D organizations pursuing the development of autonomic computing capability. The role of architecture and standards is also discussed, highlighting their role in inter-component management.

Introduction

Autonomic Computing [1] has emerged as a paradigm for self managing IT systems to stem the tide of rapidly increasing administration costs in the face of rising IT system complexity [2][3][4][5]. The development of self-managing systems poses special challenges to research and development teams. This article is based on part of a Keynote talk given at EASe'06 [20] and explores seven development principles for successful engineering of autonomic computing systems and key foundational techniques currently in use.

Little has been published concerning the unique challenges to development teams working on autonomic computing problems. Autonomic, zero admin, self-managing, embedded, invisible. These are all (somewhat) synonymous adjectives for systems that requires zero or little human administration. It's where the open server market is aggressively moving, particularly for middleware components. Self-managing middleware begins with an application view that drives all subsequent requirements for design, build, deployment, operations and change management. As TCO is dominated by human costs, autonomic computing is the primary path to dramatically reduced TCO.

The timeline of ownership for an IT system is illustrated in Figure 1. We describe the timeline of ownership as having five stages. The ownership process begins with an assessment of requirements for capital investment and capacity planning. In the next phase the system is designed. Thirdly the system is constructed, tested and tuned. Fourthly, the system goes into production and daily tuning and object administration takes place. Finally, in the last stage changes are made affecting the application or the database server directly.

Figure 1 Administrative timeline of ownership

A brief analysis of the complexity of modern systems highlights the extent of the problem clearly. In

Constellation Program Return to the Moon: Software Systems Challenges – Autonomy and Autonomicity a Solution?

Dr. David J. Atkinson
Program Manager, JPL Exploration Systems Engineering
Jet Propulsion Laboratory, California Institute of Technology
4800 Oak Grove Dr., Pasadena, California USA 911089
David.J.Atkinson@jpl.nasa.gov

Abstract

This letter, based on a keynote talk at EASe-2006 introduced NASA's Constellation Program, which is developing new space systems for renewed human exploration of the moon, and eventually, Mars. A selection of challenges for software systems were introduced that arise from the special circumstances of Constellation Systems. These challenges illustrate a variety of the types of problems that must be addressed related to software quality, automation, autonomicity and autonomy. For example, Constellation program-level systems engineering and integration activities are tasked with ensuring interoperability, reuse, compatibility, and evolutionary upgrade of all systems. To further compound the challenges, Constellation missions represent a mixing of the human space-flight processes with those of NASA's robotic exploration missions. These factors and others give rise to many unique and/or significantly more complex engineering than has been previously faced in the development of space systems. In this context, software reliability and safety become critical qualities for what will arguably be the most complex software systems artifact ever created.

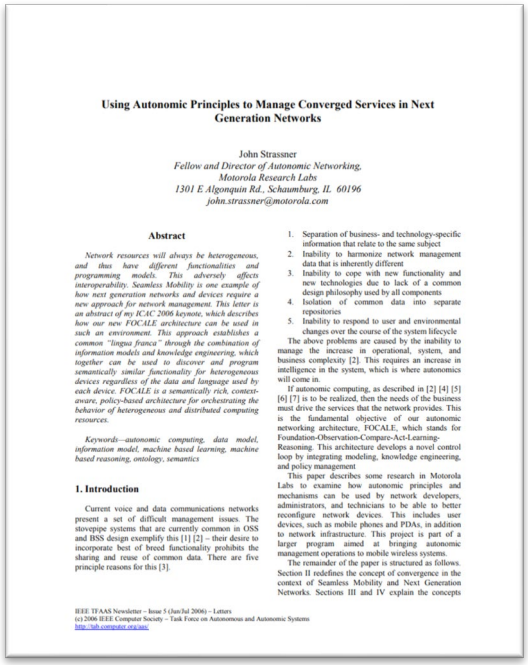
1. Introduction

The realities of today's missions; reducing costs while staying safe, and the vision for tomorrow's missions; extreme, novel, flexible and self-sustaining, dictate the need for automation, autonomy (self-direction/self-governance) and autonomicity (self-management),

The Constellation Program, managed by NASA's Exploration Systems and Mission Directorate, is charged with developing, integrating, and operating the space systems that will enable further human exploration of the moon, and eventually, Mars. Among the most critical of these systems is the Crew Exploration Vehicle (CEV), slated to replace the aging Space "Shuttle" fleet as the primary space transportation system to near-Earth space soon after 2010 and to lunar space around 2018. Other in-space systems include the Lunar Surface Access Module (LSAM), launchers, in-space propulsion, lunar surface habitat, and lunar surface systems including instrumentation and robots of various types. Supporting these integrated systems on the ground will be mission operation systems and ground data systems. Information technology, computing, software engineering and automation are technology areas that have each rapidly advanced since the last time NASA developed major space systems. There are significant challenges for software systems introduced by the unique requirements, scale, and complexity of this enterprise. Among the most challenging for software systems are those arising from automated, autonomous or autonomic systems.

2. Exploration Systems, Automation, Autonomicity and Autonomy

Although the on-going NASA procurements of some of the Constellation systems preclude a detailed discussion of system and mission requirements, it is possible to examine some of the more well know and previously disclosed scenarios involving automation, autonomicity and autonomy. Unlike many previous NASA systems, there are a great many capabilities and functions in the Constellation systems that must be automated (human-independent) or semi-automated



Using Autonomic Principles to Manage Converged Services in Next Generation Networks

John Strassner
Fellow and Director of Autonomic Networking,
Motorola Research Labs
1301 E Algonquin Rd., Schaumburg, IL 60196
john.strassner@motorola.com

Abstract

Network resources will always be heterogeneous, and thus have different functionalities and programming models. This adversely affects interoperability. Seamless Mobility is one example of how next generation networks and devices require a new approach for network management. This letter is an abstract of my ICAC 2006 keynote, which describes how our new FOCALE architecture can be used in such an environment. This approach establishes a common "lingua franca" through the combination of information models and knowledge engineering, which together can be used to discover and program semantically similar functionality for heterogeneous devices regardless of the data and language used by each device. FOCALE is a semantically rich, context-aware, policy-based architecture for orchestrating the behavior of heterogeneous and distributed computing resources.

Keywords—autonomic computing, data model, information model, machine based learning, machine based reasoning, ontology, semantics

1. Introduction

Current voice and data communications networks present a set of difficult management issues. The stovepipe systems that are currently common in OSS and BSS design exemplify this [1] [2] – their desire to incorporate best of breed functionality prohibits the sharing and reuse of common data. There are five principle reasons for this [3].

1. Separation of business- and technology-specific information that relate to the same subject
2. Inability to harmonize network management data that is inherently different
3. Inability to cope with new functionality and new technologies due to lack of a common design philosophy used by all components
4. Isolation of common data into separate repositories
5. Inability to respond to user and environmental changes over the course of the system lifecycle

The above problems are caused by the inability to manage the increase in operational, system, and business complexity [2]. This requires an increase in intelligence in the system, which is where autonomics will come in.

If autonomic computing, as described in [2] [4] [5] [6] [7] is to be realized, then the needs of the business must drive the services that the network provides. This is the fundamental objective of our autonomic networking architecture; FOCALE, which stands for Foundation-Observation-Compare-Act-Learning-Reasoning. This architecture develops a novel control loop by integrating modeling, knowledge engineering, and policy management.

This paper describes some research in Motorola Labs to examine how autonomic principles and mechanisms can be used by network developers, administrators, and technicians to be able to better reconfigure network devices. This includes user devices, such as mobile phones and PDAs, in addition to network infrastructure. This project is part of a larger program aimed at bringing autonomic management operations to mobile wireless systems.

The remainder of the paper is structured as follows. Section II redefines the concept of convergence in the context of Seamless Mobility and Next Generation Networks. Sections III and IV explain the concepts

99% (Biological) Inspiration …

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Abstract

Greater understanding of biology in modern times has enabled significant breakthroughs in improving healthcare, quality of life, and eliminating many diseases and congenital illnesses. Simultaneously there is a move towards emulating nature and copying many of the wonders uncovered in biology, resulting in "biologically inspired" systems. Significant results have been reported in a wide range of areas, with systems inspired by nature enabling exploration, communication, and advances that were never dreamed possible just a few years ago. We warn, that as in many other fields of endeavor, we should be inspired by nature and biology, not engage in mimicry. We describe some results of biological inspiration that augur promise in terms of improving the safety and security of systems, and in developing self-managing systems, that we hope will ultimately lead to self-governing systems.

1. Introduction

Thomas Alva Edison described invention as 1% inspiration and 99% perspiration. This quotation is attributed to him with multiple variations, some describing invention, others describing genius.[1].

We cannot possibly hope to match the inventiveness and genius of nature. We can be *inspired* by nature and influenced by it, but to attempt to mimic nature is likely to have very limited success, as early pioneers of flight discovered.

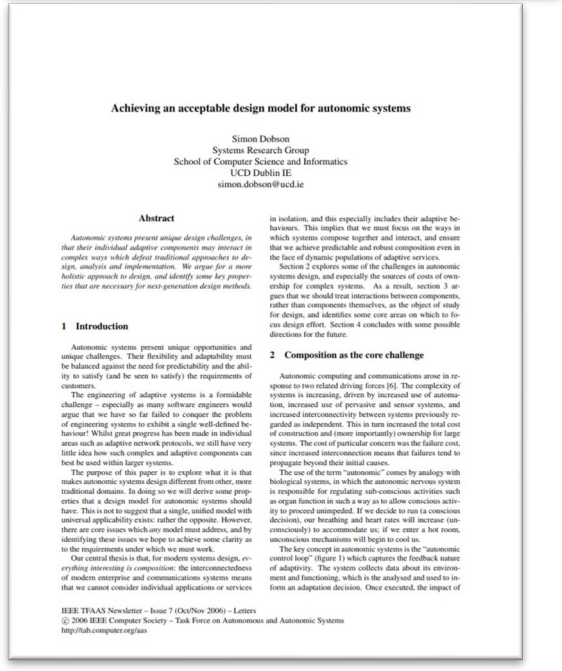
Icarus attempted to escape the Labyrinth in which he was imprisoned with his father, Daedalus, by building wings from feathers and wax. Despite Deadalus's warning not to fly so low as to get the feathers wet, nor so near the sun as to melt the wax, Icarus flew too high, the wax did indeed melt, and he fell to his death.

In 1809, a Viennese watchmaker named Degen claimed to have flown with similar apparatus. In reality, he only hopped a short distance, and was supported by a balloon. Early attempts at mechanical flight involved the use of aircraft with wings that flapped like a bird's. But clearly, trying to copy birds was not going to work:

> Since the days of Bishop Wilkins the scheme of flying by artificial wings has been much ridiculed; and indeed the idea of attaching wings to the arms of a man is ridiculous enough, as the pectoral muscles of a bird occupy more than two-thirds of its whole muscular strength, whereas in man the muscles, that could operate upon wings thus attached, would probably not exceed one-tenth of his whole mass. There is no proof that, weight for weight, a man is comparatively weaker than a bird ... [14].

It was only when inventors such as Otto Lilienthal, building on the work of Cayley, moved away from directly mimicking nature, and adopted fixed wings, originally as gliders and later as monoplanes, and eventually as aircraft with wings and a tail, as Cayley had identified was needed for flight [5], that success was achieved [14]. Even then, early aircraft had very limited success (the Wright brothers' historic first powered flight at Kitty Hawk, North Carolina, in 1903 only lasted 12 seconds and 120 feet [10]), and required the addition of gas-powered engine for thrust and the Wright brothers' identification of an effective means of

[1] The earliest recorded quotation is from a press conference, quoted by James D. Newton in *Uncommon Friends* (1929): "None of my inventions came by accident. I see a worthwhile need to be met and I make trial after trial until it comes. What it boils down to is one per cent inspiration and ninety-nine per cent perspiration."



Achieving an acceptable design model for autonomic systems

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Abstract

Autonomic systems present unique design challenges, in that their individual adaptive components may interact in complex ways which defeat traditional approaches to design, analysis and implementation. We argue for a more holistic approach to design, and identify some key properties that are necessary for next-generation design methods.

1 Introduction

Autonomic systems present unique opportunities and unique challenges. Their flexibility and adaptability must be balanced against the need for predictability and the ability to satisfy (and be seen to satisfy) the requirements of customers.

The engineering of adaptive systems is a formidable challenge – especially as many software engineers would argue that we have so far failed to conquer the problem of engineering systems to exhibit a single well-defined behaviour! Whilst great progress has been made in individual areas such as adaptive network protocols, we still have very little idea how such complex and adaptive components can best be used within larger systems.

The purpose of this paper is to explore what it is that makes autonomic systems design different from other, more traditional domains. In doing so we will derive some properties that a design model for autonomic systems should have. This is not to suggest that a single, unified model with universal applicability exists: rather the opposite. However, there are core issues which *any* model must address, and by identifying these issues we hope to achieve some clarity as to the requirements under which we must work.

Our central thesis is that, for modern systems design, *everything interesting is composition*: the interconnectedness of modern enterprise and communications systems means that we cannot consider individual applications or services in isolation, and this especially includes their adaptive behaviours. This implies that we must focus on the ways in which systems compose together and interact, and ensure that we achieve predictable and robust composition even in the face of dynamic populations of adaptive services.

Section 2 explores some of the challenges in autonomic systems design, and especially the sources of costs of ownership for complex systems. As a result, section 3 argues that we should treat interactions between components, rather than components themselves, as the object of study for design, and identifies some core areas on which to focus design effort. Section 4 concludes with some possible directions for the future.

2 Composition as the core challenge

Autonomic computing and communications arose in response to two related driving forces [6]. The complexity of systems is increasing, driven by increased use of automation, increased use of pervasive and sensor systems, and increased interconnectivity between systems previously regarded as independent. This in turn increased the total cost of construction and (more importantly) ownership for large systems. The cost of particular concern was the failure cost, since increased interconnection means that failures tend to propagate beyond their initial causes.

The use of the term "autonomic" comes by analogy with biological systems, in which the autonomic nervous system is responsible for regulating sub-conscious activities such as organ function in such a way as to allow conscious activity to proceed unimpeded. If we decide to run (a conscious decision), our breathing and heart rates will increase (unconsciously) to accommodate us; if we enter a hot room, unconscious mechanisms will begin to cool us.

The key concept in autonomic systems is the "autonomic control loop" (figure 1) which captures the feedback nature of adaptivity. The system collects data about its environment and functioning, which is the analysed and used to inform an adaptation decision. Once executed, the impact of

IEEE AAS Letters

AAS Letters Keynote Series
[@ Published in EASe 2007 proceedings]

Issue 3 - Feb/Mar 06: Foundations of Autonomic Computing Development by *Sam Lightstone* (IBM Canada) [@ computer.org] [@ ieeexplore]

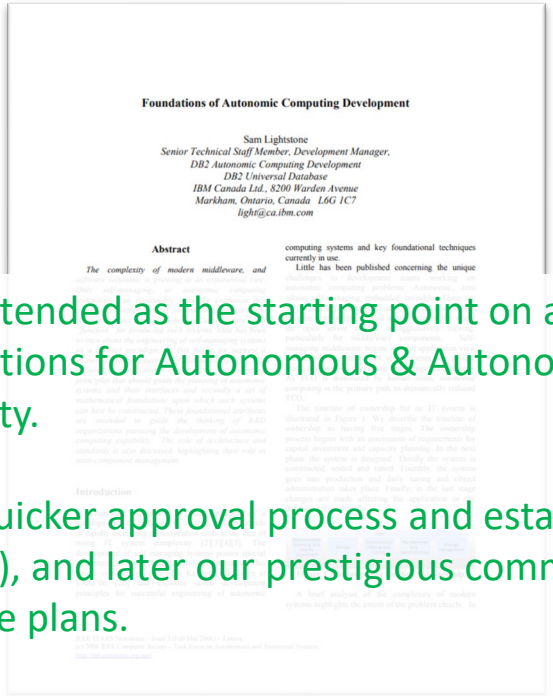
Issue 4 - Apr/May 06: Constellation Program Return to the Moon:Software Systems Challenges – Autonomy and Autonomicity a Solution? by *Dave Atkinson* (NASA JPL) [@ computer.org] [@ ieeexplore]

Issue 5 - Jun/Jul 06: Using Autonomic Principles to Manage Converged Services in Next Generation Networks by *John Strassner* (Motorola Research) [@

The TF/TC AAS Letters was intended as the starting point on a traditional approval roadmap seeking to establish an IEEE Transactions for Autonomous & Autonomic Systems... The first Letters were based on Keynotes to the community.

Unfortunately with ACM having a quicker approval process and establishing TAAS (Transactions on Autonomous and Adaptive Systems), and later our prestigious community conference (ICAC) moving to ACM, knocked the wind out of those plans.

Does it make a difference that there aren't IEEE Trans on Autonomic Systems?
Well ACM TAAS served as a home initially and had some of our key players from the AC community as EIC (for instance Manish Parashar) and many on its Editorial Board (inc. myself), but in recent years the AC aspect has essentially vanished in TAAS. Manish is currently EIC for IEEE Trans on Parallel Systems.
So have key initial researchers in AC returned to their core "subject" area?!
Having no Trans diminish AC as a subject field?
A Trans may encourage young researchers into the field?
Gives acknowledgement to the existence of a field, makes it easier to seek ad hoc research funding (as opposed to it being seen as a trend that has now past)?
…


Foundations of Autonomic Computing Development

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DB2 Autonomic Computing Development
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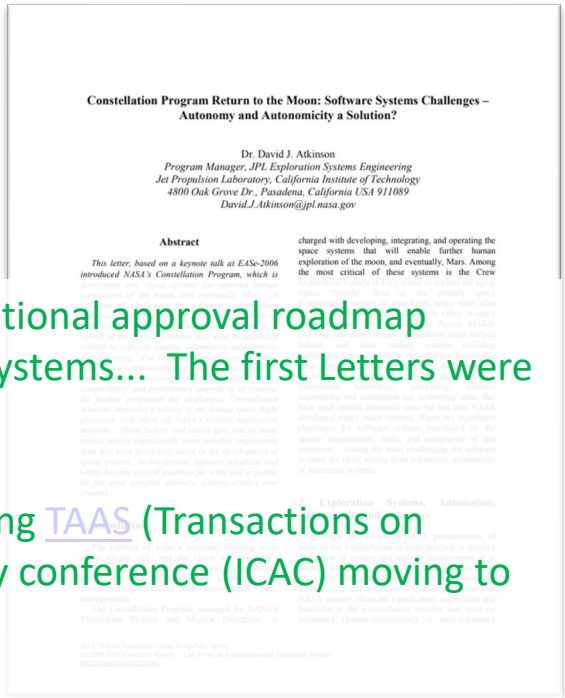
Abstract

The complexity of modern middleware, and

computing systems and key foundational techniques currently in use.

Little has been published concerning the unique


Constellation Program Return to the Moon: Software Systems Challenges – Autonomy and Autonomicity a Solution?

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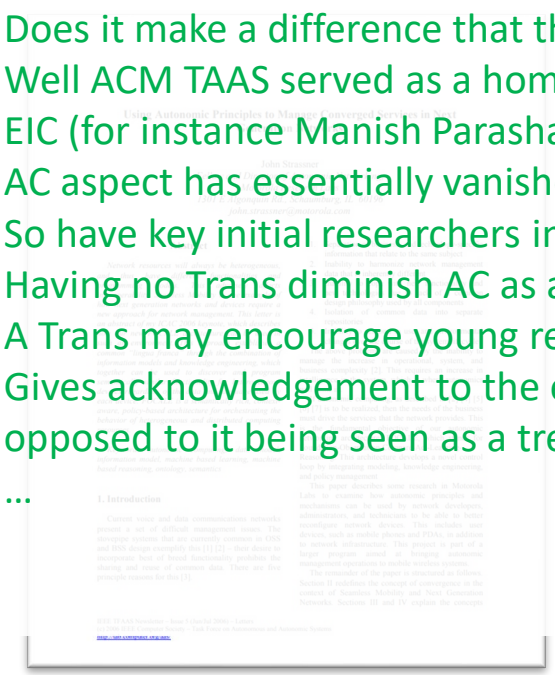
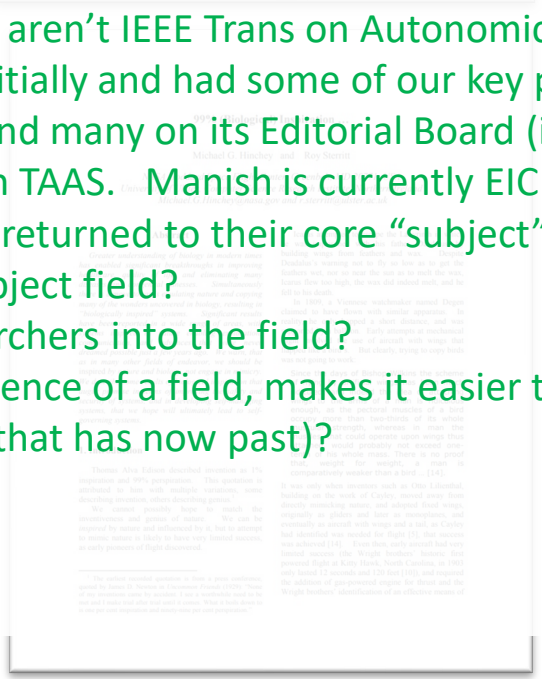
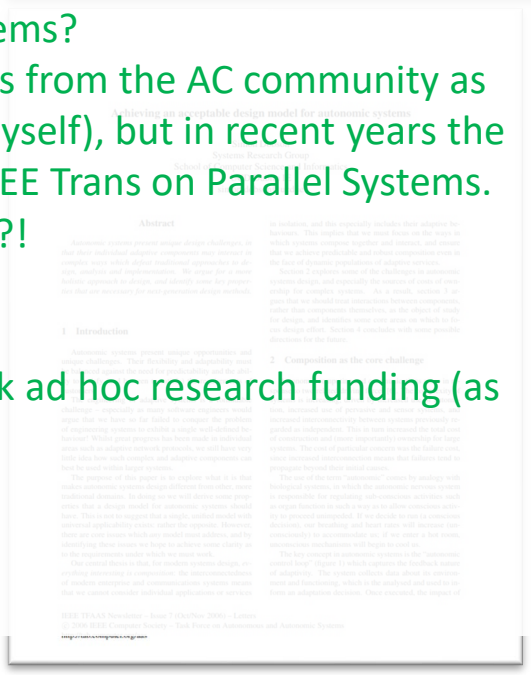
Abstract

This letter, based on a keynote talk at EASe-2006 introduced NASA's Constellation Program, which is

charged with developing, integrating, and operating the space systems that will enable farther human exploration of the moon, and eventually, Mars. Among the most critical of these systems is the Crew







We also began “standards” activities back in 2007 as the ACF (Autonomic Communications Forum), with the intent, when ready, of driving these standards through the TC into the IEEE Standards Board… the 2009 crash put pay to this activity…

The ACF was established to moved the Autonomic Research towards Standards for the industry.

ACF has effectively ceased to exist In 2009-10 when Motorola dissolved, due to economic conditions, its Autonomic Networking Research Lab firing its staff and the Autonomic Networking Director John Strassner who was also chair of the ACF.

The research continued, notably through the FAME project in the South of Ireland.

FAME FEDERATED, AUTONOMIC MANAGEMENT OF END-TO-END COMMUNICATIONS SERVICES

The slides are being retained here for information on the type of areas ACF felt was key to address in Autonomic Communications.

Introduction to the Autonomic Communications Forum (ACF)

MACE 2007
San Jose, CA
30 October, 2007
http://ragne

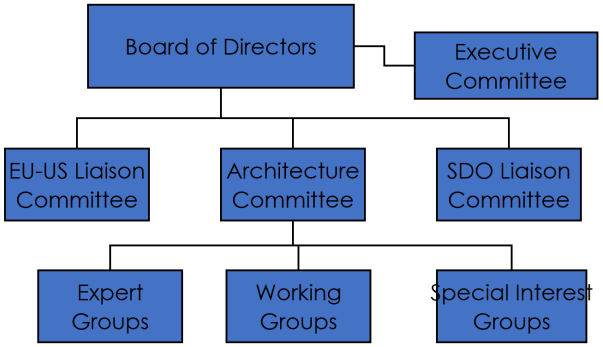
ACF Founding Members

- Industry:
  - Fujitsu, Hewlett-Packard, Hitachi, IBM, Intel, Motorola, Telefonica, Whitestein Technologies
- Academia:
  - Postech, Rutgers University, Trinity College of Dublin, Universitat Politecnica De Catalunya, Universite d’Evry, University College of Dublin, University of Ulster, University of Waterloo, Waterford Institute of Technology
- Other:
  - Fraunhofer-FOKUS

ACF Purposes

- Unify current thinking in autonomics by creating a new set of ACF sanctioned Autonomic Standards, focusing firstly on the *management* of systems, and secondly on computing and communications using autonomic mechanisms.
- Building on above, define an autonomic reference framework as well as a set of baseline compliance statements to guarantee interoperability.
- Create an organisational structure that will empower academia and industry to work together in developing and maintaining the above goal.

ACF Structure



ACF Board Officers

- Executive Committee and Board Officers:
  - Chairman: John Strassner, Motorola
  - Academic Vice-Chair: Willie Donnelly, WIT
  - Industry Vice-Chair: Kevin Twardus, IBM
  - R&D Vice-Chair: Spyros Denazis, Hitachi
  - Secretary: Joel Fleck, HP
  - Treasurer: Mazin Yousef, Intel
- Committee Chairs:
  - Architecture Committee Co-Chairs
    - Joel Fleck, HP and Dave Lewis, TCD
  - EU-US Liaison Co-Chairs
    - Manish Parashar, Rutgers and Mikhail Smirnov, FOKUS
  - SDO Liaison Co-Chairs
    - Monique Callisti, Whitestein and Roy Sterritt, Ulster

Personal reflections – TF/TC on Autonomous & Autonomic systems

As a conference organiser back then myself, I totally got the frustration with IEEE.
When organising a conference, you were an unpaid volunteer (not necessarily trained in the ways of event organisation and its pitfalls) and if the local organiser or programme chair, it would be substantial additional work on top of your paid role and duties for the year – with at least three months of that year intensive work to run a successful conference.
IEEE CS didn't make it easy, the approval process at that time, 20% risk margin on top of all income & expenditure including sponsorships received and expected a 10% surplus on the conference. Often a conference would be paying for IEEE CS publishing services (CPS) which was professional service with easy integration into the digital library but expensive … especially when authors were formatting their submissions themselves.
So from a volunteers perspective, when organising a "technical meeting" one felt one was paying IEEE for the privilege several times over; the 20% & 10% on the TMRF budget often were the margins that would bring a conference budget into a deficit, CPS costs were also within that budget – monies to IEEE. The monies made from the publications (from the conference) being on the digital library aka subscriptions was never taken into account on the Conference's budget (often a particular bugbear amongst the conference organisers), and so on.
So I personally understood when ICAC steering committee opted to try out ACM instead of IEEE after five years with IEEE (2004-2008) but it harmed the larger community and the TC over time.
SASO did stay with IEEE, but the question to move to ACM did arise bi-annually if not annually at the steering committee meetings at the annual conference and I found myself defending (what sometimes felt like the indefensible) IEEE CS each time. Once the TC was established (recall TF's didn't receive funding) and had a years incomes behind it, it was able to support SASO with some of its costs from TC budget.

Personal reflections – TF/TC on Autonomous & Autonomic systems

On the other hand, with that initial success with TF-AAS I found myself being volunteered into 'senior volunteer' roles within IEEE CS so could also understand it from the 'other side' – the situation and reasons for IEEE policies from the high costs of insurance, risk mitigation and just running a large organisation. Those roles ranged from ExCom treasurer of TAB, and then serving on the IEEE CS Technical & Conferences Activities Board (T&C Excom) for several years while chairing the Conference Advisory Committee (CAC) and in parallel for 2009 on the IEEE CS Publications board while chairing the Conference Publications Operations Committee (CPOC). I attempted to "fix" some of the issues the conference organisers had by bringing CPOC from the Publications board to within the T&C board and merge it with CAC, with the intention to enable monies made from the digital library on conferences being attributed to those conferences' budgets … but the wider western economic bank crash in 2009 put that on the back burner.

Recall IEEE CS was 1 of 40+ societies, IEEE "center" was setting such high returns for CS that CS was near bankrupt. CS had to sell off its DC building asset to survive while it negotiated better terms with IEEE*. This set T&C ExCom on a reduce and focus agenda for the next several years, so ironically from that role I was part of the team that established the sunsetting process for TCs (which in 2013 sunset the three TCs I was involved with TC-AAS, TC-ECBS & TC-CX). Recall T&C had around 40 TCs, just like IEEE and its societies, some very successful money generators, others let's say, at the other end of the spectrum. So simply as a matter of survival IEEE CS couldn't continue to support all and needed to focus. It was a painful process especially when some volunteers had put in decades for their TCs.

Back on point, when this process was enacted, TC-AAS wasn't one of those highflyers' revenue wise. Although IBM and others had been sponsoring conferences especially early on, this activity was not going through the TF/TC, so was never on its books*. ICAC had recently left for ACM and I was probably pushing things too far with seeking to align publications digital library revenue back to the TCs.

* This isn't intended as whistle blowing, it may not be fully accurate just memories from a long time ago of my understanding from the positions I was in…

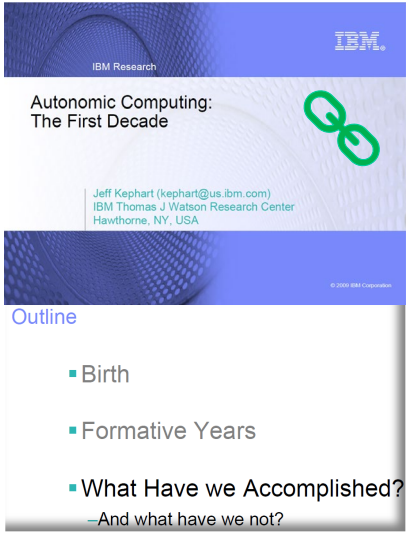
Personal reflections – TF/TC on Autonomous & Autonomic systems

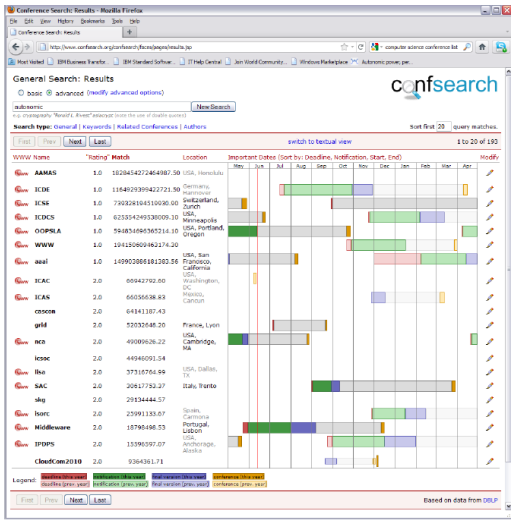
So, TC-AAS that had been the rising star of TAB/T&C in a few short years from its establishment and 12 years into the Autonomic Computing initiative was sunset, a process that hadn't even been on the books when AAS was born. Again time, place, but now lack of luck… There had been talk of me going forward for T&C chair (and thus a vice-chair of the Computer Society), but I'd had enough – even though being involved in ExCom that established the metrics and I knew the writing was on the wall for some time I still took it hard having TC-AAS, TC-ECBS & TC-CX sunset (btw I had attempted several times to merge them years earlier but got pushback from the loyal members who identified with those individual TCs – not everyone wants a big house and understandably sees the value in their specialism). And after a wild ride for over a decade I 'stayed home' more and undertook internal positions at my University back in Ireland.

I personally still believe TC-AAS could have contributed much more as a focal point for the Autonomic Computing initiative, the big mistake at the beginning was worrying about perceived too much IBM involvement, and as I've already stated Jeff Kephart may have been the anchor that kept ICAC within the TC and a different future may have happened – but we'll never know.

From 2013 onwards I was on the outside so don't know the inside story; ICAC appeared to split in two back in 2012/2013 with a new Cloud & AC conference running as a separate entity, initially with ACM for 1 year then CAC came under IEEE in 2014, and ICAC returned to IEEE in 2015. The two merged again in 2018 as ICCAC. Then by 2020 ICCAC & SASO merged to form the International Conference on Autonomic Computing and Self-Organizing Systems – (ACSOS). The community got there, perhaps if the TC had worked out differently it could have got there sooner.

Moving beyond "community" in the last 20 years and back to Kephart's 1st Decade and "What have we accomplished?" with reflections & comparisons into the 2nd Decade …



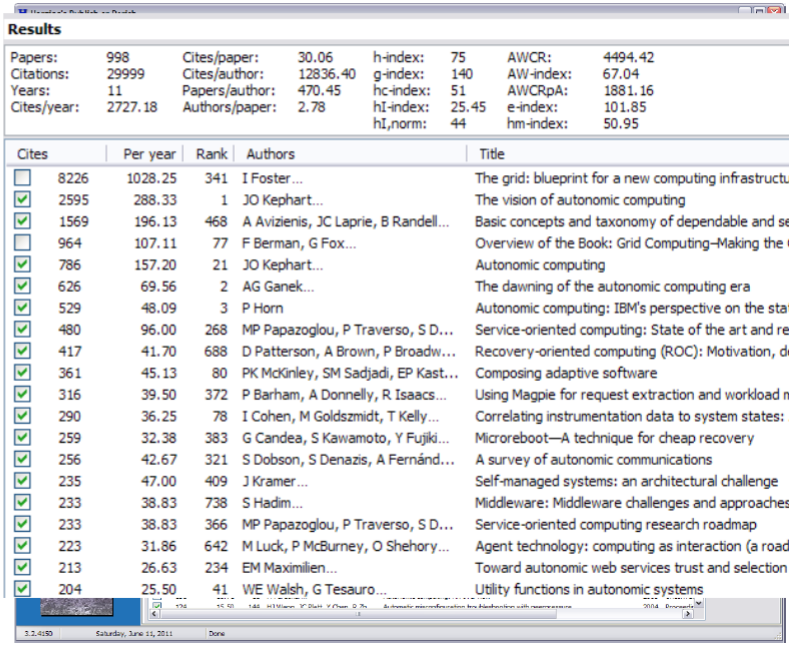


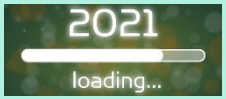
Have we kept the momentum (five years later)?

- Over 8000 papers on autonomic computing
  - Approximately 160 ICAC papers (2% of literature)
- Over 200 patents issued on autonomic computing
  - >100 more under evaluation
- Nearly 200 conferences or workshops solicit papers on autonomic computing
- Government funding
  - FP6: Situated autonomic communications
    - ANA, BioNETS, CASCADAS, HAGGLE, ACCA
  - FP7: Self-awareness in autonomic systems

Let's take a closer look at how AC is doing as a field

- Run Harzing's Publish or Perish with queries "Autonomic Computing" and "International Conference on Autonomic Computing"
  - Uses Google Scholar; finds top 1000 papers in terms of citation counts
- Put structured data in spreadsheet
- Cleanse the data
- Identify interesting trends



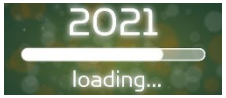


Using the same methodology as Kephart in 2011, Harzing's *Publish or Perish* tool w/queries on "Autonomic Computing" now in 2021 to see if any interesting patterns…

Jeff Kephart, "Autonomic Computing: The First Decade" ICAC 2011 Keynote June 15, 2011

Autonomic Computing Papers (2002)

417	D Patterson, A Brown, P E	Recovery-oriented computing (ROC): Motivation, definition, techr	2002 UC Berkeley Tech Report
168	JP Bigus, DA Schlosnagle	ABLE: A toolkit for building multiagent autonomic systems	2002 IBM Systems …
123	N Zhong, J Liu…	In search of the wisdom web	2002 COMPUTER-LOS ALAMITOS-
84	R Sterritt	Towards autonomic computing: effective event management	2002 … Workshop, 2002. Proceedings. 27
63	A LaMarca, W Brunette, D	Plantcare: An investigation in practical ubiquitous systems	2002 UbiComp 2002: …
55	M Satyanarayanan	A catalyst for mobile and ubiquitous computing	2002 Pervasive Computing
52	D Paulson	Computer system, heal thyself	2002 Computer
44	GM Lohman…	SMART: Making DB2 (more) autonomic	2002 … of the 28th international conferenc
43	IBMA Computing	IBM's Perspective on the State of Information Technology	2002 White Paper, information available at
42	SS Lightstone, G Lohman	Toward autonomic computing with DB2 universal database	2002 ACM SIGMOD Record
39	S Elnaffar, P Martin…	Automatically classifying database workloads	2002 Proceedings of the eleventh …
27	E Mainsah	Autonomic computing: the next era of computing	2002 Electronics & Communication Engine
24	RK Sahoo, M Bae, R Vilall	Providing persistent and consistent resources through event log a	2002 Workshop on Self- …
21	CH Crawford…	eModel: addressing the need for a flexible modeling framework ir	2002 Modeling, Analysis and Simulation of
20	DA Patterson	Recovery oriented computing: A new research agenda for a new	2002 Keynote address, HPCA
15	WW Gibbs	Autonomic computing	2002 Scientific American
14	E Schwartz	IBM Offers a Peek at Self-Healing PCS: Autonomic computing in	2002 Date Alleged: Nov
14	MN Huhns…	Robust software	2002 Internet Computing, IEEE
12	D Pescovitz	Helping computers help themselves	2002 Spectrum, IEEE
10	LD Paulson	IBM begins autonomic-computing project	2002 Computer
9	Y Tohma	Fault tolerance in autonomic computing environment	2002
8	A Wolfe	News analysis: IBM sets its sights on autonomic computing	2002 IEEE Spectrum
6	DJ Clancy	NASA challenges in autonomic computing	2002 Almaden Institute
4	JY Chung…	„Beyond e-Marketplace & Next Generation e-Business: Grid, Aut	2002 4th International Conference on Elect
4	YS Tan, B Topol, V Vellan	Implementing service Grids with the service domain toolkit	2002 IBM Corporation
3	E Grishikashvili, N Badr, D	Autonomic computing: A service-oriented framework to support t	2002 Proceeding of 3rd …
3	AZ Spector	Challenges and opportunities in autonomic computing	2002 Proceedings of the 16th international
2	J Kephart	Technology challenges of autonomic computing	2002 OOPSLA
2	R Sterritt	Towards autonomic computing: effective event management Sof	2002 Proceedings. 27th Annual NASA God



In 2011 (above) 29 AC papers from 2002 were in the top 1000 cited; a decade later only 13 remain…

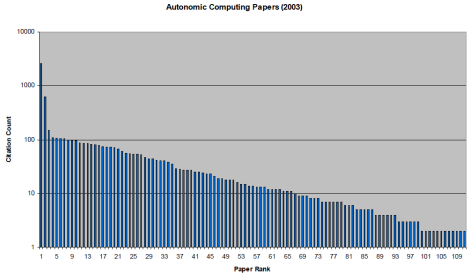
	Cites	Authors	Title	Year	GSRank
2	126	R Sterritt	Towards autonomic computing: effective event management	2002	35
3	82	SS Lightstone, G Lohman, D Zilio	Toward autonomic computing with DB2 universal database	2002	41
4	80	GM Lohman, SS Lightstone	Smart: Making db2 (more) autonomic	2002	180
5	76	LD Paulson	Computer system, heal thyself	2002	925
6	49	E Mainsah	Automatic computing: the next era of computing	2002	115
7	29	CH Crawford, A Dan	emodel: Addressing the need for a flexible modeling framework in autonomic computing	2002	154
8	24	WW Gibbs	Autonomic computing	2002	59
9	12	Y Tohma	Fault tolerance in autonomic computing environment	2002	217
10	11	LD Paulson	IBM begins autonomic-computing project	2002	192
11	9	A Wolfe	IBM sets its sights on “autonomic computing”-[News]	2002	254
12	6	G Lanfermann	Nomadic migration: a service environment for autonomic computing on the Grid	2002	502
13	4	AZ Spector	Challenges and opportunities in autonomic computing	2002	394
14	1	SS Adams, N Alvarado, S Burbeck, C Latta	Bootstrapping Semantics in an Autonomic Computing System	2002	977

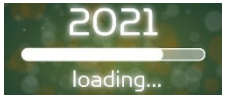
and at least 4 of them were “news” articles announcing Autonomic Computing initiative. Note though the search is no longer catching Patterson et.al.s’ ROC, or Bigus et.al.s’ ABLE toolkit which should be top in the rankings even from 2011’s figures.

Autonomic Computing Papers (2003)

2595	JO Kephart…	The vision of autonomic computing	Computer
626	AG Ganek…	The dawning of the autonomic computing era	IBM Systems Journal
147	H Kreger	Fulfilling the Web services promise	Communications of the ACM
108	R Sterritt…	Autonomic Computing-a means of achieving dependability?	Engineering of Computer-Based …
106	J Appavoo, K Hui, CAN S	Enabling autonomic behavior in systems software with hot swapping	IBM systems …
104	G Kaiser, J Parekh, P Gr	Kinesthetics extreme: An external infrastructure for monitoring distributed legacy systems	… Autonomic Computing …
104	R Sterritt…	Towards an autonomic computing environment	Database and Expert Systems …
99	AB Brown…	Undo for operators: Building an undoable e-mail store	Proceedings of the annual conferenc
96	M Agarwal, V Bhat, H Liu	Automate: Enabling autonomic applications on the grid	… Computing …
96	H Cervantes…	Automating service dependency management in a service-oriented component model	Proceedings of CBSE
86	DM Chess, CC Palmer…	Security in an autonomic computing environment	IBM Systems Journal
84	DF Bantz, C Bisdikian, D	Autonomic personal computing	IBM Systems …
84	Y Diao, JL Hellerstein, S	Managing web server performance with autotune agents	IBM Systems Journal
82	R Want, T Pering…	Comparing autonomic and proactive computing	IBM Systems Journal
80	F Heylighen…	The meaning of self-organization in computing	Information Systems
78	X Dong, S Hariri, L Xue, H	Autonomia: an autonomic computing environment	… Proceedings of the …
75	A Leff, JT Rayfield…	Service-level agreements and commercial grids	IEEE Internet Computing
73	V Markl, GM Lohman…	LEO: An autonomic query optimizer for DB2	IBM Systems Journal
73	D Capera	The AMAS theory for complex problem solving based on self-organizing cooperative agents	
70	C Sapuntzakis…	Virtual appliances in the collective: A road to hassle-free computing	Proceedings of the 9th conference o
67	P Buhler, JM Vidal…	Adaptive workflow= web services+ agents	… of the International Conference on
61	A Dan, H Ludwig, G Paci	Web service differentiation with service level agreements	White Paper, IBM Corporation
57	RJT Morris…	The evolution of storage systems	IBM Systems Journal
55	EM Maximilien…	Agent-based architecture for autonomic web service selection	Workshop on Web Services and Age
53	J Jann, LM Browning…	Dynamic reconfiguration: Basic building blocks for autonomic computing on IBM pSeries	IBM Systems Journal
53	M Milenkovic, SH Robins	Toward internet distributed computing	Computer
52	C Boutilier, R Das, JO Ke	Cooperative negotiation in autonomic systems using incremental utility elicitation	… on Uncertainty in …
47	R Sterritt	Pulse monitoring: extending the health-check for the autonomic GRID	… Informatics, 2003. INDIN 2003. P
44	M Agarwal…	Enabling autonomic compositions in grid environments	
44	JA Redstone, MM Swift…	Using computers to diagnose computer problems	… of the 9th Workshop on Hot …
42	F Berman, G Fox…	Grid computing	
40	JM Deegan…	High reliability memory subsystem using data error correcting code symbol sliced comma	US Patent App. 10/723,055
40	T De Wolf…	Towards Autonomic Computing: agent-based modelling, dynamical systems analysis, an	Industrial Informatics, 2003. INDIN …
38	S Elnaffar, W Powley, D I	Today's DBMSs: How autonomic are they	Database and Expert …
36	S Hariri, L Xue, H Chen, M	Autonomia: an autonomic computing environment	IEEE International …
29	DM Russell, PP Maglio, R	Dealing with ghosts: Managing the user experience of autonomic computing	IBM Systems Journal
28	G Lanfranchi, PD Peruta,	Toward a new landscape of systems management in an autonomic computing environmer	IBM Systems …

Autonomic Computing Papers (2003)





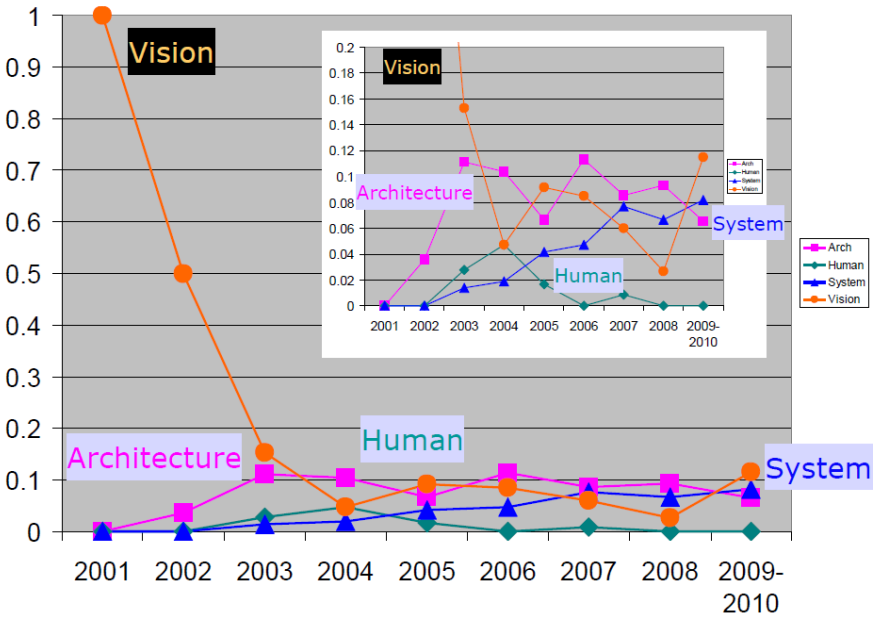
In 2011 (above left & right) 110 AC papers from 2003 were in the top 1000 cited; a decade later only 56 remain… feels about right – twice the time half the figures …

15	8103	JO Kephart, DM Chess	The vision of autonomic computing	2003	2
16	1907	F Berman, G Fox, T Hey	Overview of the book: grid computing–making the global infrastructure a reality	2003	963
17	1221	AG Ganek, TA Corbi	The dawning of the autonomic computing era	2003	4
18	209	X Dong, S Hariri, L Xue, H Chen…	Autonomia: an autonomic computing environment	2003	13
19	185	R Sterritt, D Bustard	Towards an autonomic computing environment	2003	10
20	172	R Sterritt, D Bustard	Autonomic Computing-a means of achieving dependability?	2003	27
21	169	R Want, T Pering, D Tennenhouse	Comparing autonomic and proactive computing	2003	38
22	167	G Kaiser, J Parekh, P Gross…	Kinesthetics extreme: An external infrastructure for monitoring distributed legacy systems	2003	624
23	166	DM Chess, CC Palmer, SR White	Security in an autonomic computing environment	2003	20
24	164	J Appavoo, K Hui, CAN Soules…	Enabling autonomic behavior in systems software with hot swapping	2003	250
25	159	F Heylighen, C Gershenson	The meaning of self-organization in computing	2003	193
26	147	DF Bantz, C Bisdikian, D Challener…	Autonomic personal computing	2003	25
27	147	M Agarwal, V Bhat, H Liu, V Matossian…	Automate: Enabling autonomic applications on the grid	2003	181
28	98	T De Wolf, T Holvoet	Towards autonomic computing: agent-based modelling, dynamical systems analysis, and decentralised control	2003	56
29	94	EM Maximilien, MP Singh	Agent-based architecture for autonomic web service selection	2003	457
30	93	J Jann, LM Browning, RS Burugula	Dynamic reconfiguration: Basic building blocks for autonomic computing on IBM pSeries servers	2003	83
31	72	R Sterritt	Pulse monitoring: extending the health-check for the autonomic grid	2003	255
32	69	S Elnaffar, W Powley, D Benoit…	Today's DBMSs: how autonomic are they	2003	346
33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
34	56	DM Russell, PP Maglio, R Dordick…	Dealing with ghosts: Managing the user experience of autonomic computing	2003	64
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
36	47	J Koehler, C Giblin, D Gantenbein…	On autonomic computing architectures	2003	51
37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
38	41	H Hanfield	Multi-agent based autonomic architecture for network management	2003	252
39	36	S Lightstone, B Schiefer, D Zilio…	Autonomic computing for relational databases: the ten-year vision	2003	131
40	35	B Khargharia, S Hariri, M Parashar, L Ntaimo…	vGrid: A Framework For Building Autonomic Applications.	2003	888
41	32	R Sterritt, D Bustard, A McCrea	Autonomic computing correlation for fault management system evolution	2003	129
42	26	S Anderson, M Hartswood, R Procter…	Making autonomic computing systems accountable: the problem of human computer interaction	2003	196

Yet the definitive AC paper to cite, Kephart & Chess "The vision of autonomic computing" from 2003, is the top cited paper in the field by a long shot. In 2011 it had 2596 citations – a decade on, in 2021 now 8103! A healthy indicator of three-times the growth in the field in the 2nd decade? Yet the next highest cited paper is from 2012 with 2369 maybe indicating growth not as positive as Kephart's citations?

AC Paper Trends 2001-2010: Vision, Architecture, etc.

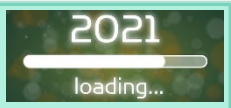
- Vision and architecture papers have settled to ~10%
  - **Appropriate**
- Human interaction study, never prevalent, became extinct in 2006
  - **BAD!**
- Study of system properties as a whole is rising steadily.
  - **GOOD!**



Vision

- Autonomic Computing
  - *Horn, Ganek, Kephart&Chess; Parashar&Hariri; Sterritt*
- Recovery-oriented computing
  - Don't try to ensure 99.9999% up time for each component
  - Accept that faults are always going to happen; cope with them at system level
  - Micro-rebooting – minimize downtime by designing systems to be quickly rebootable at multiple levels
  - If it's fast enough, occasional mistaken reboots are ok
  - *Patterson, Fox et al., UC Berkeley*
- Organic and bio-inspired computing
  - Use insights from biological systems to understand and exploit collective behavior
  - *KIT, BADS workshop; SASO; Richard Anthony*

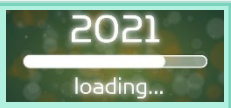
No work on applying autonomic nervous system principles to autonomic computing !?!



The number of papers published from 2004 onwards grows exponentially that Kephart moves to wordle charts to track trends…

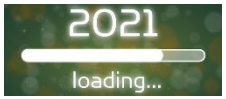
Early years were vision papers and a lot of self-Optimisation with the other elements of the Self-CHOP not so well covered (Configuration, healing and protection) as well as CHOP all working together to provide an Autonomic System.

	Cites	Authors	Title	Year	GSRank
2	8103	JO Kephart, DM Chess	The vision of autonomic computing	2003	2
4	1907	F Berman, G Fox, T Hey	Overview of the book: grid computing–making the global infrastructure a reality	2003	963
5	1221	AG Ganek, TA Corbi	The dawning of the autonomic computing era	2003	4
6	1152	MC Huebscher, JA McCann	A survey of autonomic computing—degrees, models, and applications	2008	6
7	889	S Dobson, S Denazis, A Fernández, D Gaïti...	A survey of autonomic communications	2006	878
8	575	MN Bennani, DA Menasce	Resource allocation for autonomic data centers using analytic performance models	2005	382
9	573	WE Walsh, G Tesauro, JO Kephart...	Utility functions in autonomic systems	2004	128
11	454	M Parashar, S Hariri	Autonomic computing: An overview	2004	3
12	453	JO Kephart	Research challenges of autonomic computing	2005	8
13	449	EM Maximilien, MP Singh	Toward autonomic web services trust and selection	2004	940
14	428	SR White, JE Hanson, I Whalley...	An architectural approach to autonomic computing	2004	7
16	426	JO Kephart, WE Walsh	An artificial intelligence perspective on autonomic computing policies	2004	14
17	416	G Tesauro, NK Jong, R Das...	A hybrid reinforcement learning approach to autonomic resource allocation	2006	450
18	384	Y Wang	The theoretical framework of cognitive informatics	2007	837
19	374	R Murch	Autonomic computing	2004	239
20	353	HN Van, FD Tran, JM Menaud	Autonomic virtual resource management for service hosting platforms	2009	854
21	345	G Tesauro, DM Chess, WE Walsh, R Das...	A multi-agent systems approach to autonomic computing	2004	22
22	317	QH Mahmoud	Cognitive networks	2007	598
23	279	B Jennings, S Van Der Meer...	Towards autonomic management of communications networks	2007	815
24	252	JO Kephart, R Das	Achieving self-management via utility functions	2007	640
25	245	SW Cheng, D Garlan, B Schmerl	Architecture-based self-adaptation in the presence of multiple objectives	2006	807
26	234	H Schmeck	Organic computing-a new vision for distributed embedded systems	2005	243
27	233	A Computing	An architectural blueprint for autonomic computing	2006	1
28	229	R Sterritt	Autonomic computing	2005	5
29	218	H Liu, M Parashar, S Hariri	A component-based programming model for autonomic applications	2004	253
30	215	H Hoffmann, J Eastep, MD Santambrogio...	Application heartbeats: a generic interface for specifying program performance and goals in autonomous computing environments	2010	237
31	214	R Sterritt, M Parashar, H Tianfield...	A concise introduction to autonomic computing	2005	21
32	209	X Dong, S Hariri, L Xue, H Chen...	Autonomia: an autonomic computing environment	2003	13
33	206	J Strassner, N Agoulmine, E Lehtihet	Focale: A novel autonomic networking architecture	2006	202
34	203	S Dobson, R Sterritt, P Nixon, M Hinchey	Fulfilling the vision of autonomic computing	2010	19
35	201	C Cetina, P Giner, J Fons, V Pelechano	Autonomic computing through reuse of variability models at runtime: The case of smart homes	2009	47
36	197	M Salehie, L Tahvildari	Autonomic computing: emerging trends and open problems	2005	17
37	192	H Psaier, S Dustdar	A survey on self-healing systems: approaches and systems	2011	893
39	190	JO Kephart, H Chan, R Das, DW Levine...	Coordinating multiple autonomic managers to achieve specified power-performance tradeoffs	2007	405
40	188	S Hariri, B Khargharia, H Chen, J Yang, Y Zhang...	The autonomic computing paradigm	2006	9
42	185	R Sterritt, D Bustard	Towards an autonomic computing environment	2003	10
43	185	G Tesauro	Reinforcement learning in autonomic computing: A manifesto and case studies	2007	29
45	180	L Zhang, D Ardagna	SLA based profit optimization in autonomic computing systems	2004	39
46	172	R Sterritt, D Bustard	Autonomic Computing-a means of achieving dependability?	2003	27
50	169	R Want, T Pering, D Tennenhouse	Comparing autonomic and proactive computing	2003	38
51	169	CS Yeo, S Venugopal, X Chu, R Buyya	Autonomic metered pricing for a utility computing service	2010	764
52	167	G Kaiser, J Parekh, P Gross...	Kinesthetics extreme: An external infrastructure for monitoring distributed legacy systems	2003	624
53	166	DM Chess, CC Palmer, SR White	Security in an autonomic computing environment	2003	20
54	164	J Appavoo, K Hui, CAN Soules...	Enabling autonomic behavior in systems software with hot swapping	2003	250
55	161	JA McCann, MC Huebscher	Evaluation issues in autonomic computing	2004	11
56	161	L Stojanovic, J Schneider, A Maedche...	The role of ontologies in autonomic computing systems	2004	30
57	160	B Jacob, R Lanyon-Hogg, DK Nadgir, AF Yassin	A practical guide to the IBM autonomic computing toolkit	2004	705
58	160	DA Menasce, MN Bennani	Autonomic virtualized environments	2006	183
59	159	F Heylighen, C Gershenson	The meaning of self-organization in computing	2003	193
60	156	Y Diao, JL Hellerstein, S Parekh...	Self-managing systems: A control theory foundation	2005	634
61	154	J Chen, G Soundararajan...	Autonomic provisioning of backend databases in dynamic content web servers	2006	716
64	149	A Patel, Q Qassim, C Wills	A survey of intrusion detection and prevention systems	2010	753
65	147	DF Bantz, C Bisdikian, D Challener...	Autonomic personal computing	2003	25
66	147	M Agarwal, V Bhat, H Liu, V Matossian...	Automate: Enabling autonomic applications on the grid	2003	181
67	146	D Agrawal, KW Lee, J Lobo	Policy-based management of networked computing systems	2005	308
68	145	DM Chess, A Segal, I Whalley...	Unity: Experiences with a prototype autonomic computing system	2004	24
69	143	H Liu, M Parashar	Accord: a programming framework for autonomic applications	2006	743
70	139	G Tesauro	Online resource allocation using decompositional reinforcement learning	2005	774
71	137	Y Diao, JL Hellerstein, S Parekh...	A control theory foundation for self-managing computing systems	2005	330
72	137	B Khargharia, S Hariri, MS Yousif	Autonomic power and performance management for computing systems	2008	475
74	136	A Lapouchnian, Y Yu, S Liaskos...	Requirements-driven design of autonomic application software	2006	267
75	136	MG Hinchey, R Sterritt	Self-managing software	2006	416
76	132	J Lee, M Ghaffari, S Elmeligy	Self-maintenance and engineering immune systems: Towards smarter machines and manufacturing systems	2011	817
77	130	P Bodik, G Friedman, L Biewald...	Combining visualization and statistical analysis to improve operator confidence and efficiency for failure detection and localization	2005	956
78	130	J Almeida, V Almeida, D Ardagna...	Resource management in the autonomic service-oriented architecture	2006	157
79	130	MR Nami, K Bertels	A survey of autonomic computing systems	2007	15
81	126	R Sterritt	Towards autonomic computing: effective event management	2002	35



Left: First decade of AC papers ordered by 2021 citation figures (cites).

Note 699 of the top 1000 cited AC papers are from the first decade…

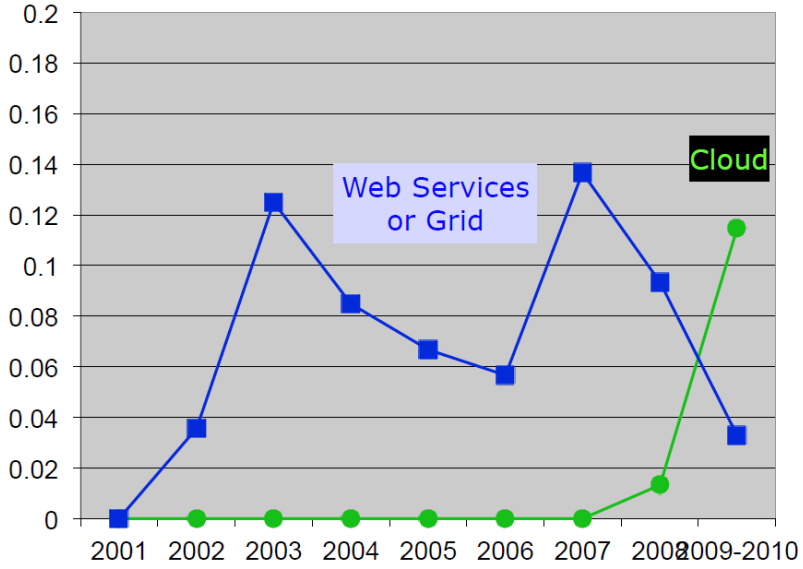


Looking only at papers published in the 2nd decade 2012-2021 …

1	Cites	Authors	Title	Year	GSRank
3	2369	D Zissis, D Lekkas	Addressing cloud computing security issues	2012	911
10	569	NR Herbst, S Kounev, R Reussner	Elasticity in cloud computing: What it is, and what it is not	2013	222
15	427	A Patel, M Taghavi, K Bakhtiyari, JC Júnior	An intrusion detection and prevention system in cloud computing: A systematic review	2013	427
38	191	SW Cheng, D Garlan	Stitch: A language for architecture-based self-adaptation	2012	722
41	186	P Lalanda, JA McCann, A Diaconescu	Autonomic computing: principles, design and implementation	2013	12
44	182	M Parashar, S Hariri	Autonomic computing: concepts, infrastructure, and applications	2018	18
47	170	CZ Xu, J Rao, X Bu	URL: A unified reinforcement learning approach for autonomic cloud management	2012	890
48	170	S Singh, I Chana	QoS-aware autonomic resource management in cloud computing: a systematic review	2015	667
49	170	S Pothumani, J Hameed Hussain	A novel economic framework for cloud and grid computing	2017	375
62	152	RD Nicola, M Loreti, R Pugliese, F Tiezzi	A formal approach to autonomic systems programming: the SCEL language	2014	473
63	150	D Novak, M Mihelj, M Munih	A survey of methods for data fusion and system adaptation using autonomic nervous system responses in physiological computing	2012	916
73	137	A Gandhi, P Dube, A Karve, A Kochut…	Adaptive, model-driven autoscaling for cloud applications	2014	912
80	130	R Buyya, RN Calheiros, X Li	Autonomic cloud computing: Open challenges and architectural elements	2012	380
96	103	M Ghobaei-Arani, S Jabbehdari…	An autonomic resource provisioning approach for service-based cloud applications: A hybrid approach	2018	311
99	101	MB Alaya, Y Banouar, T Monteil, C Chassot…	OM2M: Extensible ETSI-compliant M2M service platform with self-configuration capability	2014	700
102	99	M Maggio, H Hoffmann, AV Papadopoulos…	Comparison of decision-making strategies for self-optimization in autonomic computing systems	2012	45
113	91	A Kertész, G Kecskemeti, I Brandic	An interoperable and self-adaptive approach for SLA-based service virtualization in heterogeneous Cloud environments	2014	932
118	88	Y Al-Dhuraibi, F Paraiso, N Djarallah…	Autonomic vertical elasticity of docker containers with elasticdocker	2017	223
129	79	E Casalicchio, DA Menascé, A Aldhalaan	Autonomic resource provisioning in cloud systems with availability goals	2013	312
135	75	P Jamshidi, AM Sharifloo, C Pahl…	Self-learning cloud controllers: Fuzzy q-learning for knowledge evolution	2015	935
136	75	S Kounev, P Lewis, KL Bellman, N Bencomo…	The notion of self-aware computing	2017	323
139	72	M Samaniego, R Deters	Internet of smart things-iost: Using blockchain and clips to make things autonomous	2017	899
151	67	MI Alam, M Pandey, SS Rautaray	A comprehensive survey on cloud computing	2015	471
155	65	J Diaz-Montes, M AbdelBaky, M Zou…	Cometcloud: Enabling software-defined federations for end-to-end application workflows	2015	713
156	65	M Mohamed, M Amziani, D Belaïd, S Tata…	An autonomic approach to manage elasticity of business processes in the cloud	2015	979
161	61	SS Gill, I Chana, M Singh, R Buyya	CHOPPER: an intelligent QoS-aware autonomic resource management approach for cloud computing	2018	857
169	55	MP Hosseini, TX Tran, D Pompili…	Deep learning with edge computing for localization of epileptogenicity using multimodal rs-fMRI and EEG big data	2017	474
171	54	Q Chen, S Abdelwahed, A Erradi	A model-based approach to self-protection in computing system	2013	364
177	52	DM Shila, W Shen, Y Cheng, X Tian…	AMCloud: Toward a secure autonomic mobile ad hoc cloud computing system	2016	675
188	49	T Baker, Y Ngoko, R Tolosana-Calasanz…	Energy efficient cloud computing environment via autonomic meta-director framework	2013	804
198	47	C Savaglio, G Fortino, M Zhou	Towards interoperable, cognitive and autonomic IoT systems: An agent-based approach	2016	385
200	46	P Mayer, A Klarl, R Hennicker, M Puviani…	The autonomic cloud: a vision of voluntary, peer-2-peer cloud computing	2013	166
201	46	S Farokhi, P Jamshidi, I Brandic…	Self-adaptation challenges for cloud-based applications: A control theoretic perspective	2015	954

The 2nd highest cited paper in the field was published in 2012 “Addressing cloud computing security issues” (2369 cites). The first three papers are all about the Autonomic Cloud, then Cheng & Garlan Stitch language, two AC text books (2012 & 2011 (note the tool is incorrectly indicating 2018 for Parashar & Hairi’s book – should be 2011)). Then lots more Autonomic Cloud papers … This reflects the major success AC has had in the last decade – providing self-management for the Cloud.

AC Paper Trends 2001 – 2010: Relationships: WebServices/Grid



Relationships: WebServices/Grid

- Agent communication standards likely to derive from services
- Foresee convergence of autonomic computing, web services, grid interfaces

Web-Scale Workflow
Editor: M. Brian Blake • mb7@georgetown.edu

Agents and Service-Oriented Computing for Autonomic Computing

A Research Agenda

Frances M.T. Brazier • *Vrije Universiteit Amsterdam*
Jeffrey O. Kephart • *IBM T.J. Watson Research Center*
H. Van Dyke Parunak • *Tech Team Government Solutions*
Michael N. Huhns • *University of South Carolina*

Autonomic computing is the solution proposed to cope with the complexity of today's computing environments. Self-management, an important element of autonomic computing, is also characteristic of single and multiagent systems, as well as systems based on service-oriented architectures. Combining these technologies can be profitable for all — in particular, for the development of autonomic computing systems.

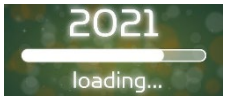
In recent years, computing environments' complexity has begun to grow beyond the limits of what human system administrators can manage. This increasing complexity has three sources. First, individual components of computing systems, such as workload managers and database management systems, are becoming more difficult to configure, manage, and maintain as each release includes ever more system, which regulates heart and respiratory rates, digestion, and other bodily functions, freeing the conscious brain to focus on higher-level goals. Similarly, autonomic computing systems are expected to free system administrators to focus on higher-level goals. Autonomic computing systems can perform the following functions without human intervention:

Brazier, Kephart, Parunak, and Huhns, Internet Computing, June 2009

Article resulted from brainstorming session at Agents for Autonomic Computing workshop, ICAC 2008

This was predicted by Kephart in his 2011 keynote…
"Foresee convergence of autonomic computing, web services, grid interfaces"

So much so has AC as a field converged into Cloud computing where it made a major impact during its second decade?



2021
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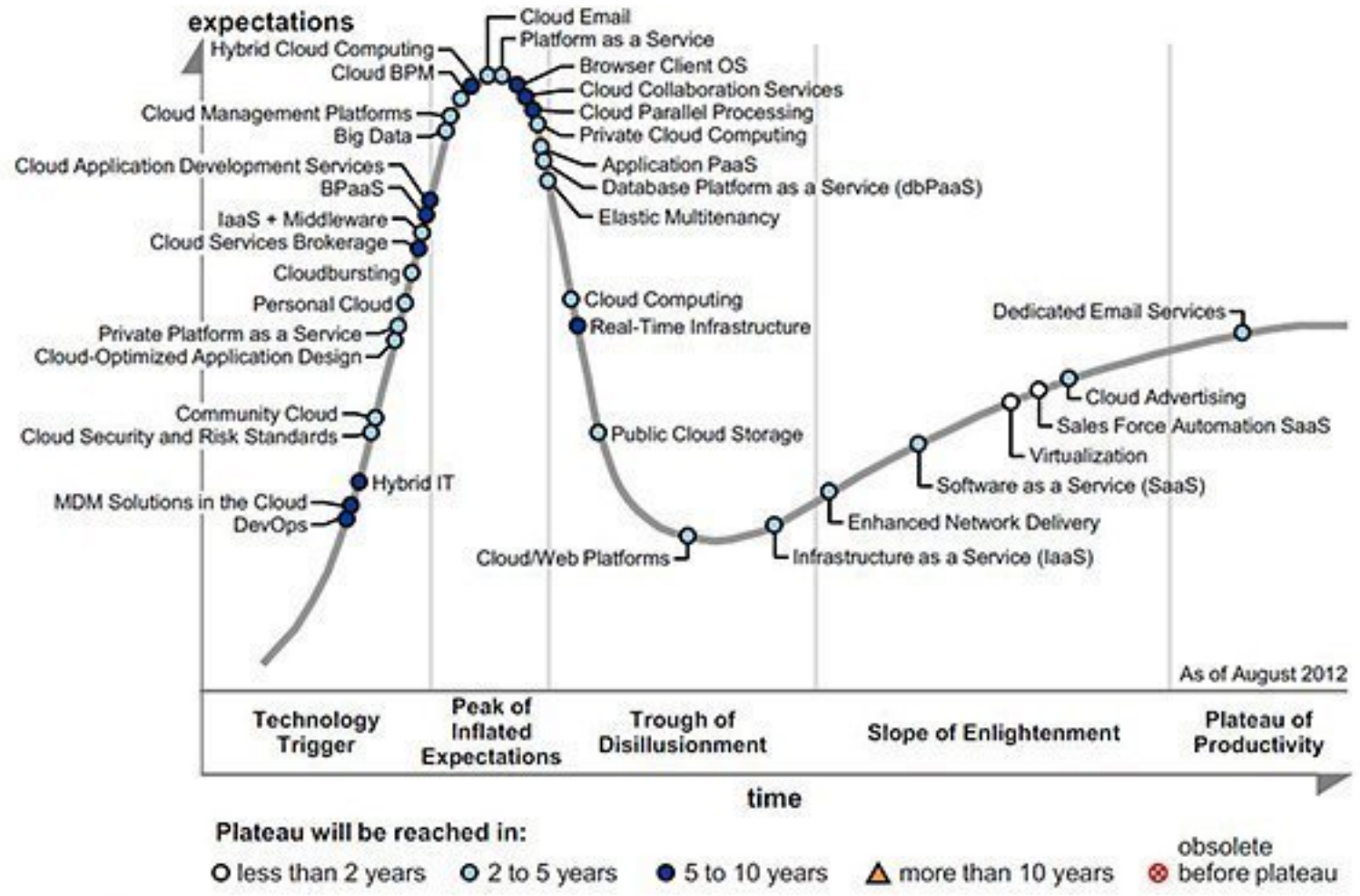
When you consider the 2012 hype curve for Cloud Computing, you can see why Autonomic Computing has such an impact…

Figure 1. Hype Cycle for Cloud Computing, 2012



Source: Gartner (August 2012)

2021
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And 2020 refocus on Cloud Security … more contributions to be made.

Hype Cycle for Cloud Security, 2020

gartner.com/SmarterWithGartner

Gartner

Gartner Top Strategic Technology Trends for 2021

People centricity	Location independence	Resilient delivery
Internet of Behaviors	Distributed cloud	Intelligent composable business
Total experience strategy	Anywhere operations	AI engineering
Privacy-enhancing computing	Cybersecurity mesh	Hyperautomation

Combinatorial innovation

gartner.com/SmarterWithGartner

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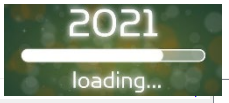

Listings for 2001-2021 ... by cites

Publication years: 2002-2021
Citation years: 19 (2002-2021)
Papers: 980
Citations: 51531
Cites/year: 2712.16
Cites/paper: 52.58
Cites/author: 22868.54
Papers/author: 434.20
Authors/paper: 2.87
h-index: 99
g-index: 203
hI,norm: 60
hI,annual: 3.16
*Count: 76

Results

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	Cites	Per year	Rank	Authors	Title	Year	Publication	Publisher
h	8103	450.17*	2	JO Kephart, DM Ch...	The vision of autonomic computing	2003	Computer	ieeexplore.ieee.org
h	2369	263.22*	911	D Zissis, D Lekkas	Addressing cloud computing secu...	2012	Future Generation comput...	Elsevier
h	1907	105.94*	963	F Berman, G Fox, T ...	Overview of the book: grid compu...	2003	Making the Global Infrastr...	Wiley Online Library
h	1221	67.83*	4	AG Ganek, TA Corbi	The dawning of the autonomic co...	2003	IBM systems Journal	ieeexplore.ieee.org
h	1152	88.62*	6	MC Huebscher, JA ...	A survey of autonomic computing...	2008	ACM Computing Surveys (...	dl.acm.org
h	889	59.27*	878	S Dobson, S Denaz...	A survey of autonomic communic...	2006	ACM Transactions on ...	dl.acm.org
h	575	35.94*	382	MN Bennani, DA M...	Resource allocation for autonomi...	2005	... on autonomic computin...	ieeexplore.ieee.org
h	573	33.71*	128	WE Walsh, G Tesau...	Utility functions in autonomic syst...	2004	... Autonomic Computing ...	ieeexplore.ieee.org
h	569	71.13*	222	NR Herbst, S Koun...	Elasticity in cloud computing: Wh...	2013	... on Autonomic Computi...	usenix.org
h	454	26.71*	3	M Parashar, S Hariri	Autonomic computing: An overvie...	2004	International workshop on ...	Springer
h	453	28.31*	8	JO Kephart	Research challenges of autonomic...	2005	Proceedings of the 27th in...	dl.acm.org
h	449	26.41*	940	EM Maximilien, MP...	Toward autonomic web services tr...	2004	... conference on Service o...	dl.acm.org
h	428	25.18*	7	SR White, JE Hanso...	An architectural approach to auto...	2004	... Computing, 2004 ...	ieeexplore.ieee.org
h	427	53.38*	427	A Patel, M Taghavi, ...	An intrusion detection and preven...	2013	Journal of network and ...	Elsevier
h	426	25.06*	14	JO Kephart, WE Wa...	An artificial intelligence perspecti...	2004	Proceedings. Fifth IEEE Int...	ieeexplore.ieee.org
h	416	27.73*	450	G Tesauro, NK Jong...	A hybrid reinforcement learning a...	2006	... Autonomic Computing	ieeexplore.ieee.org
h	384	27.43*	837	Y Wang	The theoretical framework of cog...	2007	International Journal of Co...	igi-global.com
h	374	22.00*	239	R Murch	Autonomic computing	2004		cds.cern.ch
h	353	29.42*	854	HN Van, FD Tran, J...	Autonomic virtual resource mana...	2009	... of Cloud Computing	ieeexplore.ieee.org
h	345	20.29*	22	G Tesauro, DM Che...	A multi-agent systems approach t...	2004	Proceedings of the Third ...	Citeseer
h	317	22.64*	598	QH Mahmoud	Cognitive networks	2007	John Wiley& Sons Ltd	Wiley Online Library
h	279	19.93*	815	B Jennings, S Van D...	Towards autonomic management ...	2007	IEEE ...	ieeexplore.ieee.org

Metrics Help

Publication years: 2002-2021
Citation years: 19 (2002-2021)
Papers: 980
Citations: 51531
Cites/year: 2712.16
Cites/paper: 52.58
Cites/author: 22868.54
Papers/author: 434.20
Authors/paper: 2.87
h-index: 99
g-index: 203
hI,norm: 60
hI,annual: 3.16
*Count: 76

Results

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	Cites	Per year	Rank	Authors	Title	Year	Publication	Publisher
h	252	18.00*	640	JO Kephart, R Das	Achieving self-management via ut...	2007	IEEE Internet Computing	ieeexplore.ieee.org
h	245	16.33*	807	SW Cheng, D Garla...	Architecture-based self-adaptatio...	2006	... of the 2006 internationa...	dl.acm.org
h	234	14.63*	243	H Schmeck	Organic computing-a new vision f...	2005	... -Oriented Real-Time Dis...	ieeexplore.ieee.org
h	233	15.53*	1	A Computing	An architectural blueprint for auto...	2006	IBM White Paper	Citeseer
h	229	14.31*	5	R Sterritt	Autonomic computing	2005	Innovations in systems and...	Springer
h	218	12.82*	253	H Liu, M Parashar, ...	A component-based programmin...	2004	... on Autonomic Computi...	ieeexplore.ieee.org
h	215	19.55*	237	H Hoffmann, J East...	Application heartbeats: a generic i...	2010	... Autonomic computing	dl.acm.org
h	214	13.38*	21	R Sterritt, M Parash...	A concise introduction to autono...	2005	Advanced engineering ...	academia.edu
h	209	11.61*	13	X Dong, S Hariri, L ...	Autonomia: an autonomic comput...	2003	... , Computing, and ...	ieeexplore.ieee.org
h	206	13.73*	202	J Strassner, N Agou...	Focale: A novel autonomic networ...	2006		eprints.wit.ie
h	203	18.45*	19	S Dobson, R Sterrit...	Fulfilling the vision of autonomic ...	2010	Computer	ieeexplore.ieee.org
h	201	16.75*	47	C Cetina, P Giner, J ...	Autonomic computing through re...	2009	Computer	ieeexplore.ieee.org
h	197	12.31*	17	M Salehie, L Tahvil...	Autonomic computing: emerging ...	2005	ACM SIGSOFT Software En...	dl.acm.org
h	192	19.20*	893	H Psaier, S Dustdar	A survey on self-healing systems: ...	2011	Computing	Springer
h	191	21.22*	722	SW Cheng, D Garlan	Stitch: A language for architecture...	2012	Journal of Systems and Sof...	Elsevier
h	190	13.57*	405	JO Kephart, H Chan...	Coordinating multiple autonomic ...	2007	... Computing (ICAC'07 ...	ieeexplore.ieee.org
h	188	12.53*	9	S Hariri, B Khargha...	The autonomic computing paradi...	2006	... Computing	Springer
h	186	23.25*	12	P Lalanda, JA McCa...	Autonomic computing: principles, ...	2013		books.google.com
h	185	10.28*	10	R Sterritt, D Bustard	Towards an autonomic computing...	2003	14th International Worksh...	ieeexplore.ieee.org
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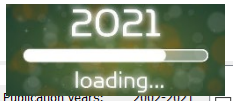
h	172	9.56	27	R Sterritt, D Bustard	Autonomic Computing-a means o...	2003	... and Workshop on the En...	ieeexplore.ieee.org
h	170	42.50*	375	S Pothumani, J Ha...	A novel economic framework for ...	2017	International Journal of Pu...	acadpubl.eu
h	170	28.33*	667	S Singh, I Chana	QoS-aware autonomic resource m...	2015	ACM Computing Surveys (...	dl.acm.org
h	170	18.89*	890	CZ Xu, J Rao, X Bu	URL: A unified reinforcement learn...	2012	Journal of Parallel and Dist...	Elsevier
h	169	9.39	38	R Want, T Pering, D...	Comparing autonomic and proact...	2003	IBM Systems journal	ieeexplore.ieee.org
h	169	15.36*	764	CS Yeo, S Venugop...	Autonomic metered pricing for a ...	2010	Future Generation Comput...	Elsevier
h	167	9.28	624	G Kaiser, J Parekh, ...	Kinesthetics extreme: An external i...	2003	... Autonomic Computing ...	ieeexplore.ieee.org
h	166	9.22	20	DM Chess, CC Palm...	Security in an autonomic computi...	2003	IBM Systems Journal	ieeexplore.ieee.org



Listings for 2001-2021 ... by Rank

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☑	h	8103	450.17*	2	JO Kephart, DM Ch...	The vision of autonomic computing	2003	Computer	ieeexplore.ieee.org
☑	h	454	26.71*	3	M Parashar, S Hariri	Autonomic computing: An overvie...	2004	International workshop on ...	Springer
☑	h	1221	67.83*	4	AG Ganek, TA Corbi	The dawning of the autonomic co...	2003	IBM systems Journal	ieeexplore.ieee.org
☑	h	229	14.31*	5	R Sterritt	Autonomic computing	2005	Innovations in systems and...	Springer
☑	h	1152	88.62*	6	MC Huebscher, JA ...	A survey of autonomic computing...	2008	ACM Computing Surveys (...	dl.acm.org
☑	h	428	25.18*	7	SR White, JE Hanso...	An architectural approach to auto...	2004	... Computing, 2004 ...	ieeexplore.ieee.org
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☑	h	161	9.47	11	JA McCann, MC Hu...	Evaluation issues in autonomic co...	2004	... on Grid and Cooperativ...	Springer
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☑	h	209	11.61*	13	X Dong, S Hariri, L ...	Autonomia: an autonomic comput...	2003	... , Computing, and ...	ieeexplore.ieee.org
☑	h	426	25.06*	14	JO Kephart, WE Wa...	An artificial intelligence perspecti...	2004	Proceedings. Fifth IEEE Int...	ieeexplore.ieee.org
☑	h	130	9.29	15	MR Nami, K Bertels	A survey of autonomic computing...	2007	... International Conferenc...	ieeexplore.ieee.org
☑		71	4.73	16	HA Müller, L O'Brie...	Autonomic computing	2006		apps.dtic.mil
☑	h	197	12.31*	17	M Salehie, L Tahvil...	Autonomic computing: emerging ...	2005	ACM SIGSOFT Software En...	dl.acm.org
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		Cites	Per year	Rank	Authors	Title	Year	Publication	Publisher
☑		99	9.90	23	R De Nicola, G Ferr...	A language-based approach to au...	2011	International Symposium ...	Springer
☑	h	145	8.53	24	DM Chess, A Segal,...	Unity: Experiences with a prototyp...	2004	... Autonomic Computing ...	ieeexplore.ieee.org
☑	h	147	8.17	25	DF Bantz, C Bisdiki...	Autonomic personal computing	2003	IBM Systems ...	ieeexplore.ieee.org
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☑	h	185	13.21*	29	G Tesauro	Reinforcement learning in autono...	2007	IEEE Internet Computing	ieeexplore.ieee.org
☑	h	161	9.47	30	L Stojanovic, J Schn...	The role of ontologies in autonom...	2004	IBM Systems ...	ieeexplore.ieee.org
☑		91	7.58	31	FMT Brazier, JO Ke...	Agents and service-oriented com...	2009	... Internet Computing	ieeexplore.ieee.org
☑		97	8.08	32	AJ Ramirez, DB Kn...	Applying genetic algorithms to de...	2009	... on Autonomic computing	dl.acm.org
☑		42	3.00	33	MR Nami, M Sharifi	Autonomic computing: a new app...	2007	... on Modelling & Simulat...	ieeexplore.ieee.org
☑		51	5.10	34	JO Kephart	Autonomic computing: the first de...	2011	ICAC	pdfs.semanticscholar.org
☑	h	126	6.63	35	R Sterritt	Towards autonomic computing: ef...	2002	27th Annual NASA Goddar...	ieeexplore.ieee.org
☑		92	5.75	36	P Lin, A MacArthur,...	Defining autonomic computing: a ...	2005	2005 Australian Software ...	ieeexplore.ieee.org
☑		68	4.86	37	M Litoiu	A performance analysis method f...	2007	ACM Transactions on Auto...	dl.acm.org
☑	h	169	9.39	38	R Want, T Pering, D...	Comparing autonomic and proact...	2003	IBM Systems journal	ieeexplore.ieee.org
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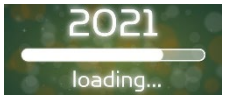
☑		45	3.75	40	R Calinescu	General-purpose autonomic com...	2009	Autonomic Computing an...	Springer
☑		82	4.32	41	SS Lightstone, G Lo...	Toward autonomic computing wit...	2002	ACM Sigmod Record	dl.acm.org
☑		48	3.69	42	C Klein, R Schmid, ...	A survey of context adaptation in ...	2008	... on Autonomic and ...	ieeexplore.ieee.org
☑		70	5.00	43	K Lee, R Sakellario...	Workflow adaptation as an auton...	2007	Proceedings of the 2nd ...	dl.acm.org
☑		43	4.30	44	M Maggio, H Hoff...	Decision making in autonomic co...	2011	... Autonomic computing	dl.acm.org
		Cites	Per year	Rank	Authors	Title	Year	Publication	Publisher
☑		99	11.00*	45	M Maggio, H Hoff...	Comparison of decision-making st...	2012	ACM Transactions on ...	dl.acm.org
☑		65	3.82	46	F Zambonelli, M M...	Spatial computing: An emerging ...	2004	Workshop on Autonomic C...	Springer
☑	h	201	16.75*	47	C Cetina, P Giner, J ...	Autonomic computing through re...	2009	Computer	ieeexplore.ieee.org
☑		44	2.75	48	R Sterritt, M Hinchey	Autonomic computing-panacea o...	2005	... and Workshops on the E...	ieeexplore.ieee.org
☑		56	5.60	49	A Rouvroy	Technology, virtuality and utopia: ...	2011	... , human agency and aut...	researchportal.unamur.be
☑		78	6.00	50	Y Cheng, A Leon-G...	Toward an autonomic service man...	2008	IEEE Communications ...	ieeexplore.ieee.org
☑		47	2.61	51	J Koehler, C Giblin, ...	On autonomic computing architec...	2003	IBM Research, Zurich ...	jana-koehler.dfki.de
☑		38	9.50	52	E Rutten, N Marcha...	Feedback control as MAPE-K loop...	2017	Software Engineering for S...	Springer
☑		50	3.57	53	DA Menascé, JO Ke...	Guest editors' introduction: Auton...	2007	IEEE Internet Computing	ieeexplore.ieee.org
☑		21	3.00	54	K Ahuja, H Dangey	Autonomic Computing: An emergi...	2014	... and Challenges in Intelli...	ieeexplore.ieee.org

What does the Rank column indicate?

"Rank" is simply the order in which the data source returned the results, with higher-ranked (i.e., lower-numbered) items returned before lower-ranked (i.e., higher-numbered) ones.

Depending on the data source, this usually means that the higher-ranked ones were a better match for the search terms, which is not the same thing as being more highly cited (in the "Cites" column). On the other hand, some other data sources do return more highly cited results first, so for those data sources the "Cites" and "Rank" orders more or less correspond.



- Run Harzing's Publish or Perish with queries "Autonomic Computing
  - Uses Google Scholar; finds top 1000 papers in terms of citation counts

Papers:	998	Cites/paper:	30.06
Citations:	29999	Cites/author:	12836.40
Years:	11	Papers/author:	470.45
Cites/year:	2727.18	Authors/paper:	2.78

h-index:	75	AWCR:	4494.42
g-index:	140	AW-index:	67.04
hc-index:	51	AWCRpA:	1881.16
hI-index:	25.45	e-index:	101.85
hI,norm:	44	hm-index:	50.95

Metrics	Help
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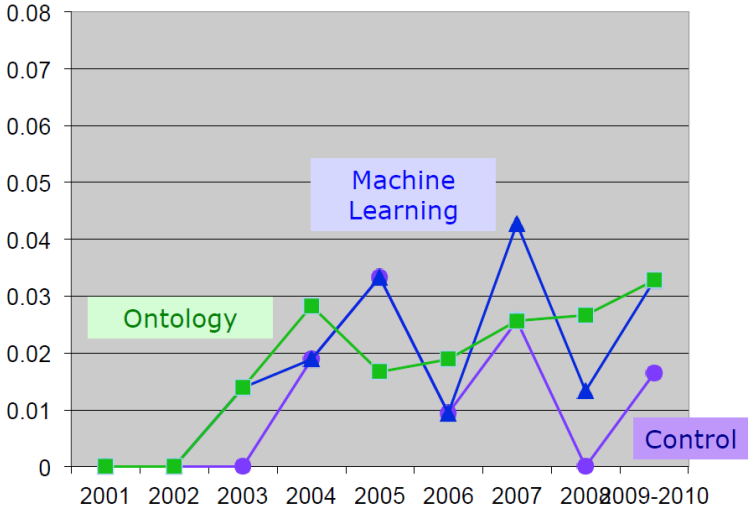
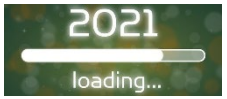
First decade (2011) vs Second decade (2021)…

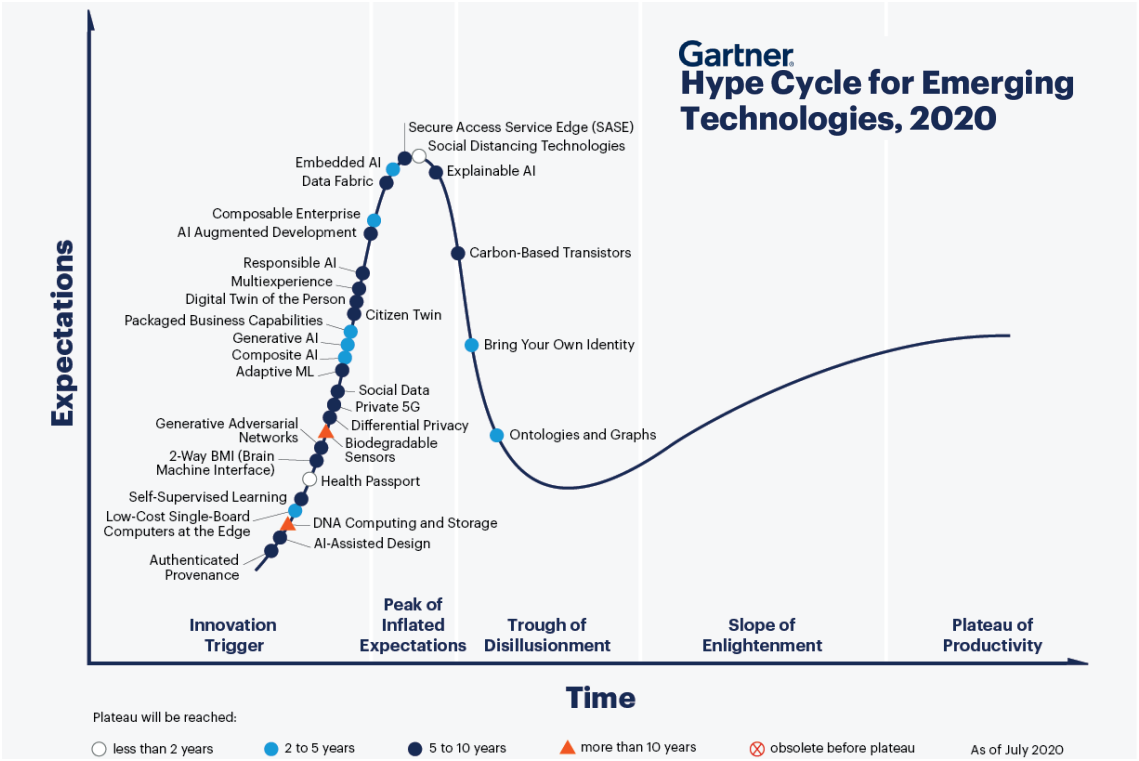
- Ignore paper # as the tool only reports the top 1000
- Citations have grown from 29,999 to 51,531
  - – should we have expected doubling at least, or 3x given Kephart's trebling in the same period? => Sign of slow down?
- Cites/year constant though
- Cites/paper similar growth rate to citations 30 -> 52.5
- H-index grown slightly 75 -> 99
- AC field not grown as much as may have expected in second decade, then again the hype (& funding) long gone …

AC Paper Trends 2001-2010: AI Technologies

- Relatively small but sustained effort on AI technologies for autonomic systems



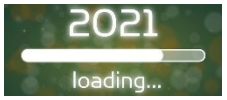




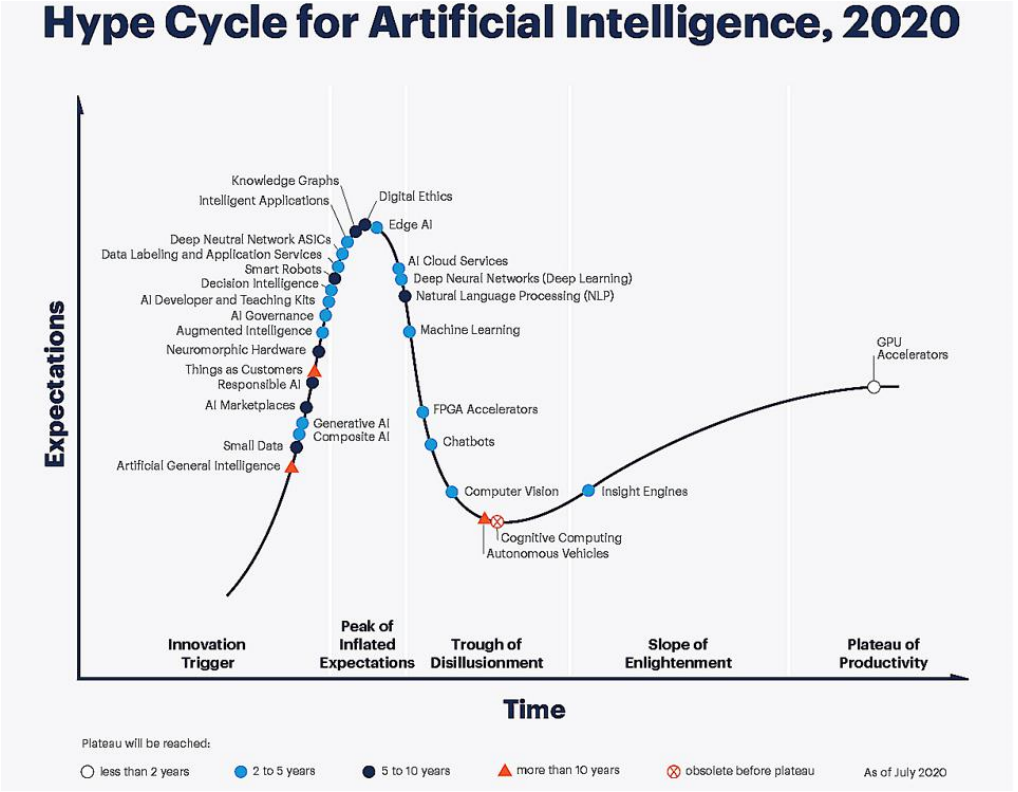
Speaking of hype, the 4th wave of AI has been on the Hype curve these last few years …

Seeing real industrial application of AI. AI has been highlighted as a necessary contributor from the birth of AC although the Engineering side took off first … and ventures into AI community via IJCAI in 2003 & 2005 didn't have the AI researchers rushing to join in …

But is now the time for properly addressing the learning side of AC?



This renewed interest in AI offers the potential for renewed interest in Autonomic Computing beyond the existing researchers.
Autonomicity can be presented as the separation of concerns i.e. (self-) management from that of the task/mission in **Autonomy**. Both will benefit from new developments and funding in AI.

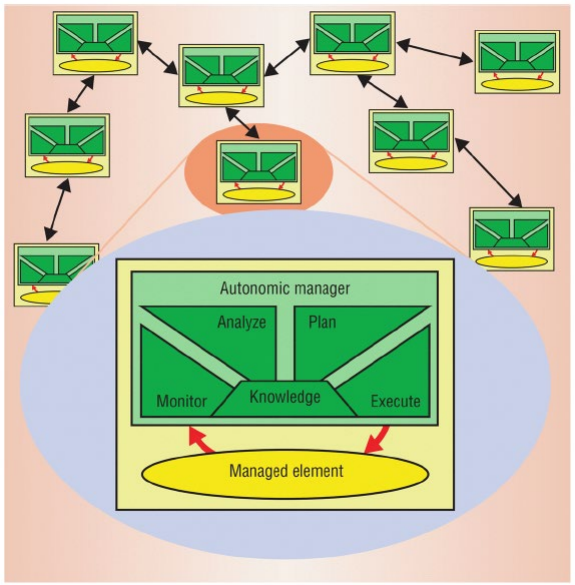


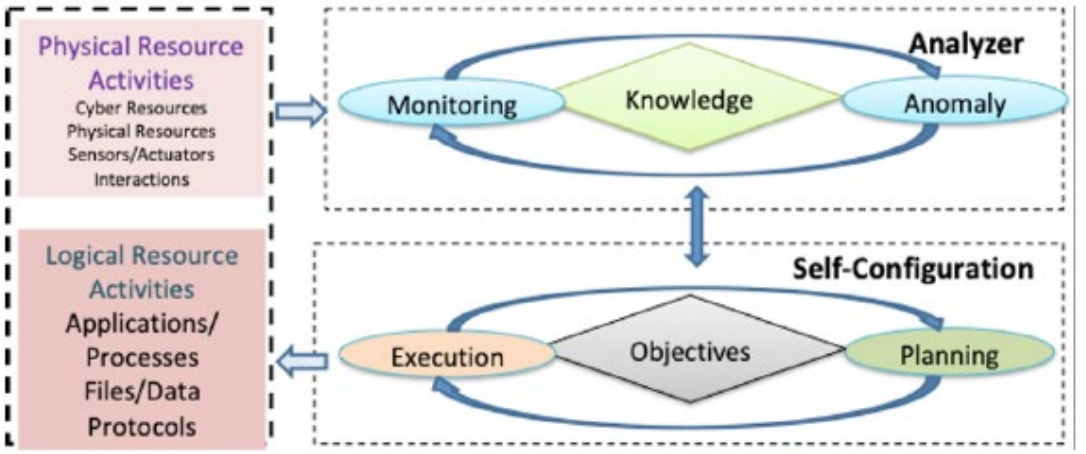
Concern about Trustworthy in Autonomous Systems (TAS) and Assured Autonomous Systems is of current interest, as expressed by UKRI funding (for instance), and an argument can be made that it can be (partially) achieved through Autonomic Computing.

And like the control loop in the MAPE we come full circle …
Autonomous & Autonomic Systems, if only we had a TC to push that agenda ;)…

Conclusion, Summary & Discussion

A fantastic amount has been achieved in the last 20 years within **Autonomic Computing**.
So much so we have focused on the community, committee and citations level and comparing with Kephart's 1st decade keynote in 2011, and not had time to consider the technical level, such as has the original Self-CHOP & MAPE (MAPE-K) changed from the original vision & blueprint?





An interesting adaption from the original blueprint MAPE (left) is work from Prof. Hariri's team in splitting the MAPE into separate M&A and P&E control loops (right), with the acknowledgement that self-{Healing, Optimising, Protection} of the self-CHOP all require going through the self-Configuration, while the Knowledge (self-awareness) aspect is in the analyzer loop and "objectives" (policies?) being in the self-config loop.

Conclusion, Summary & Discussion

This presentation also focused on a personal reflection concerning the establishment, running and sunsetting of the IEEE Technical Committee on Autonomous & Autonomic Systems – much of which has already been concluded in that section.

A common reflective thought throughout has been "right time, right place, luck…" and I have absolutely no illusions if any of these had been out of place it wouldn't have happened (for me) and that one couldn't plan a career path like this (IEEE certainly don't want every young academic seeking tenure attempting to set-up at TC). But a generic lesson certainly is; do your research to the best of your ability and be open minded and ready to jump when opportunities arise. And then enjoy the ride!

Do I believe the TC could still be in existence if someone else had been founding chair? – probably! I was young(er) and naïve(r). That said, I may be being too self-critical, the financial crisis in 2009 was real and the downsizing occurred (half the TCs at the time were sunset?!). TC-AAS would have needed to be more established than 2 years realistically would have allowed. Then again, an IBMer as chair and the sponsorship directly into the TC level and not at the conference level may have done the job; but the pattern had already been set prior to the birth of TF/TC-AAS. In the end though I didn't go seeking the role (I didn't imagine the potential existed) the chair of TAB spotted the opportunity, and the rest is history/his-story…

The excellent aspect going forward for the community in the next decade, is that the field's two prestigious technical meetings – ICAC & SASO – have merged…

Conclusion, Summary & Discussion

COVER FEATURE

The Vision of Autonomic Computing

COVER FEATURE

Jeffrey O. Kephart
David M. Chess
IBM Thomas J. Watson Research Center

OUTLOOK

FULFILLING THE VISION OF AUTONOMIC COMPUTING

Simon Dobson, *University of St. Andrews, UK*
Roy Sterritt, *University of Ulster, Northern Ireland*
Paddy Nixon and Mike Hinchey, *Lero—the Irish Software Engineering Research Centre*

Efforts since 2001 to design self-managing systems have yielded many impressive achievements, yet the original vision of autonomic computing remains unfulfilled. Researchers must develop a comprehensive systems engineering approach to create effective solutions for next-generation enterprise and sensor systems.

BACK TO THE FUTURE

In its autonomic computing call to arms, IBM compared what the IT industry faced in 2001 to what occurred in the US telephony industry in the 1920s. At that time, the rapid expansion and infiltration into daily life of the phone aroused serious concern that there would not be enough trained operators to work the manual switchboards. Analysts predicted that by the 1980s, half the country's population would have to become telephone operators to

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In 2010, as we approached a decade, we published an intentional follow up to Kephart & Chess seminal article in Computer – with a lot less impact! "Fulfilling the vision of Autonomic Computing".

A key point made: "Over the years, the AI field has fallen victim to unrealistic expectations, and we see similar warning signs in the autonomic computing field. Yet from the beginning there has been a successful focus on evolutionary research, tightly linked to applied industrial problems. Additional funding and industrial collaboration are crucial to future success, but something more is required: Researchers must develop a long-range, overarching strategy to realize the vision propounded by Kephart and Chess."

"Yet in some ways that success is deceptive. Researchers have devised innovative autonomic solutions to individual problems, but the larger, more difficult task of combining more difficult task of combining these point solutions into wider autonomous systems remains. More consideration must be given to integrating solutions, and to choosing solutions from the range of possibilities— to trustworthy and assured autonomous and autonomic systems engineering, in other words."

"Without the development of such an approach, we will simply rediscover the risks of feature interaction at a higher level, and in a way that is so dynamic as to be resistant to debugging and testing. We are confident, however, that the foundation exists to construct a systems theory and practice from which we can engineer trustworthy autonomous solutions for the next generation of enterprise and sensor systems."

Much of this is still the case, although great success has occurred with Cloud Computing & A.C.

A.I. is now living up to expectations…

The next decade should see that fulfilment of the Autonomic Computing Vision.

We can only achieve so much…

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Thank you.
Questions?
Comments?