HALL OF FAME

A Pioneer of Corrosion Science

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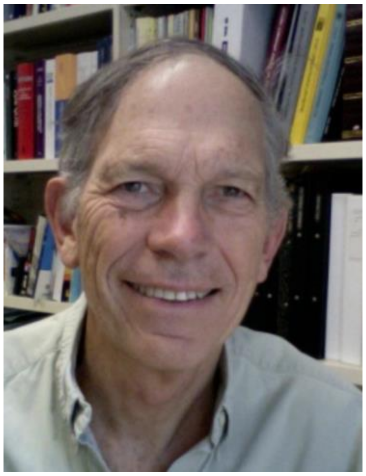

Brief citation

Robert Melchers is an Australian engineer who has specialized in structural engineering, structural reliability and in the last 25 years in corrosion research. He has been developing mathematical models for corrosion loss and pitting that can be used by structural engineers and naval architects for the design and management of infrastructure assets including ships and offshore structures. He has been involved in a number of major practical projects related to shipping and offshore facilities. He has given some 35 keynote presentations at numerous international conferences, both for structural reliability research and for corrosion research. His 1968 book 'Structural Reliability Analysis and Prediction' is the 'best-seller' in the subject area and is now in its 3rd edition. He has received numerous awards and was elected to the Australian Academy of Technology and Engineering in 2004 and became an Honorary Fellow of the Institution of Engineers, Australia in 2014. He has held two Australian Research Council Professorial Fellowships, a Discovery Outstanding Research Fellowship, two UK EPSRC fellowships, as well as gaining more than $A16 million in research grants. He continues to be very active in research at The University of Newcastle, Australia and to provide advice to industry.

Origins and early time (1945-1970)

Rob Melchers was born in Amsterdam, the Netherlands, just months before the end of WW2 during a period of acute food shortage. Despite this, his parents (father accountant, mother housewife) managed to raise him to a healthy young lad, soon joined by a brother. Continued economic depression in Europe led to the family emigrating to Melbourne, Australia, where young Robert went straight into primary school with no skills in (Australian) English, but with more than average mathematical and analytical skills. Unclear what career young Rob might follow led to a decision to send him to the local Technical School rather than the High school - as that might open up trade and practical possibilities.

His early teens were spent on his uncle's building and construction sites, all the while learning about practical issues, including site safety, mainly by losing lots of skin. At Technical school had excelled in a wide range of subjects including visual arts and after 4 years was pulled into the headmaster's office and encouraged to keep studying and to aim for a research job in one of the national government research agencies. It was perhaps inevitable that he chose to do Civil Engineering, underpinned perhaps by the economic security it offered in rapidly developing Australia and memories of the rawness of unemployment he had witnessed first-hand. He was admitted to Caulfield Technical College in 1963, edited the College newspaper in his spare time for 3 years and in 1966 topped his final year. Along with high performers from other Technical Colleges he was offered direct entry into the 3rd year of the 4-year Civil Engineering degree programs at both Melbourne University and the newly established Monash University. A chance meeting with Monash engineering student persuaded Rob to go there - a decision he has never regretted. He soon earned the nick-name 'Professor Rob' amongst his colleagues and topped the Final year of the degree program. He gained valuable long-vacation experience on major construction sites including the Snowy Mountains Hydroelectric Scheme and factory sites around Melbourne and also had spells with Public Works and with the Country Road Board. At University he was encouraged to aim for a higher degree, specifically at Cambridge. After a year or so working on a Master's degree at Monash and publishing his first (joint) papers, he gained a research scholar place at Peterhouse (the oldest of the Colleges constituting Cambridge University) with the aid of a Commonwealth Scholarship. Two and a quarter years later, in 1970, he graduated with a Cambridge PhD. His thesis was on optimal structural design. It gave the solution to what had been thought to be an 'unsolvable' problem in the theory of analytical structural optimization [1], eventually acknowledged by the (late) Prof GI Rozvany (Editor-in-Chief of Structural Optimization) as 'probably the most significant breakthrough in this field' [2]. Despite a heavy theoretical and experimental workload Rob and his wife Ros much enjoyed life in Cambridge, spent as much leave as possible touring the UK and parts of Europe and made many (life-long) friends, including Rob's PhD supervisor Peter Lowe, a remarkable but very modest academic.

Early experience (1971-1985)

After returning to Australia (where salaries were much higher than in the UK where he had been encouraged to stay) and with no money or a job, Rob eventually became the first-ever PhD employed by Australian consulting engineers Gutteridge Haskins & Davey in Melbourne. He worked on a wide variety of design, investigation and research projects, became the 'go-to' person for solving difficult and unusual structural and environmental engineering and computer programming problems and made life-long friends and contacts, many of whom went on to very successful careers.

After some soul-searching and with Ros's encouragement Rob decided to apply for one of the very few academic positions available at that time. After what would by current standards be considered a perfunctory interview he was successful and joined Monash University Civil Engineering Department in 1975. As the first graduate to join the academic staff it raised some interesting but pleasant enough interactions with the existing staff. In the wake of some significant bridge collapses it was agreed he would research structural safety issues. He was the first academic staff member to be awarded a research grant from the (then) Australian Large Research Grants Scheme (in 1978) for research on structural reliability and human error.

While working on notes for a graduate course on portal frames using plastic theory he delved further into its relationship with classical elastic structural theory and as a result discovered a completely new Reciprocal Theorem in the classical Theory of Elasticity. This discovery was celebrated by Prof. Jacques Heyman, the towering (in more ways than one) figure in plasticity at Cambridge in his 1996 book 'Elements of the Theory of Structures' (Cambridge) in which he links Melchers with three giants in the classical Theory of Elasticity - the book's Chapter 3 is entitled 'Betti, Maxwell, Müller-Breslau, Melchers'. [3].

In 1980, Rob was awarded a von Humboldt Fellowship at the Technical University Munich (Germany) for 8 months research in structural reliability, hosted by Dr GI Schueller. During that time he gained valuable new insights and also developed interaction with leading international researchers in structural reliability, including Dr R Rackwitz and Prof Ove Ditlevsen with whom he later worked over several months at the Danish Technical University, Lyngby.

Soon after, Rob developed the so-called ‘Importance Sampling’ technique for Monte Carlo estimation of structural reliability. This allowed major savings in computation-time and permitted solution of more realistic problems. Considered by others (such as Rackwitz) ‘the most robust’ of various proposed procedures, ‘particularly suited to non-differentiable convex safe domains’. For many years this was Melchers’ most cited paper [4]. He also spent 6 months at Imperial College hosted by Michael Baker whose book (with Thoft-Christensen) on structural reliability inspired Rob to commenced work on a more extensive manuscript originally aimed at graduate course work but that, in 1986, was published under the title ‘Structural Reliability Analysis and Prediction’. According to publishers Wiley it was a best-seller in the area. Two further editions followed, in 1995 and 2017.

During 1985 it was suggested by his German contacts that he apply for the recently vacated position of Professor of Civil Engineering at The University of Newcastle, Australia. He did and was successful.

Structural reliability (1986-)

Rob, his wife and two children arrived in Newcastle in early 1986 and he immediately took on the position of Head of Department and Chair and Professor in Civil Engineering (the only Professor in the Department of Civil Engineering and Surveying). At that time the Department had only one PhD student, and very limited research activity or output. Under his guidance and with the support of some newly arrived younger staff members the Department grew quickly to be research-intensive with a growing International reputation, while at the same time tripling student numbers. To date it remains the only Civil Engineering department in Australia with an ERA of 5 for all research assessments. With the cooperation of many colleagues Rob also overhauled the curriculum, and helped develop the new degree in Environmental Engineering. He also continued to take an active part in Institution of Engineers, Australia activities. He was Divisional President of the Newcastle Division, the founding Chair of the College of Structural Engineering, and founding Editor of the Australian Journal of Structural Engineering. For these services to the profession he was made an Honorary Fellow of the Institution of Engineers, Australia - their highest honor - in 2014.

Late in 1989, Newcastle was struck by one of the rare intraplate earthquakes that occur in Australia. There was much damage to buildings and infrastructure and also loss of life. Rob and his structural engineering colleagues spent days on building inspections and, after things had settled down a little began to organize a conference, at the University campus, to share various learnings. This became on of the most successful conferences ever held by the Institution of Engineers, Australia. Soon afterwards he was commissioned to lead a State government investigation of the reasons for the damage to buildings. This project was carried out again with academic colleagues and with engineers and earthquake specialists including from New Zealand and elsewhere [5].

In 1991, he was invited to join AMOG Consulting as Founding and Non-executive Director and member of the Board with responsibilities in structural engineering and structural reliability. This resulted in involvement of many projects including the risk analysis for the Melbourne-Longford gas pipeline and later the sub-sea HydroTas power line across Bass Strait. He resigned from AMOG in 2004 to avoid potential conflicts of interest with research projects but remained as a consultant. In that period AMOG grew from a start-up to a $A12mil. turnover company with offices in Melbourne (HQ), Houston, London and elsewhere.

In the early 1990s, Rob was asked to consult for the Australian Liquefied Gas Association in their battles with State Government and national regulators who were insisting on much tighter regulations, potentially costing the industry many millions of dollars. Working closely with the industry technical experts and with international failure case data it was shown eventually that only very modest improvements were required and that these should be focused mainly on human error issues. As a result the industry saved a lot of money, and Rob had gained a reputation for brutal analytical analysis.

While all this was going on, Rob's research activity continued. He developed the 'Load space reliability' technique - a re-formulation of the structural reliability problem, now in the so-called Load Space, producing major savings in computation time. This became the springboard for many subsequent developments, also by others [6].

Corrosion modelling (early 2000-)

In the period late 1990s-early 2000s after a number of trips to the US and seeing much evidence of infrastructure deterioration considerably worse than anything he had seen in Australia or the UK, Rob turned his attention to incorporating structural deterioration into structural reliability estimation. To limit the scope, and because of his close proximity to the Pacific Ocean Rob decided to limit the scope to marine corrosion of steel, prompted also by becoming involved in a Monash University led large research project focused on the 'ships of shame' issue. As part of this several bulk carrier ships were examined in detail (whilst in port) for corrosion. A research project was set up for estimating in-situ corrosion losses [7], carried out by Graig Gardiner who was recruited by Defence Science and Technology Organization (the scientific advisors to Defence) even before he even graduated with a PhD.

On the fundamental corrosion research side Rob decided that his modelling work specifically for the longer-term development of corrosion had to break away from its traditional roots. It required probabilistic models based on field data and fundamental theory rather than mainly laboratory studies, short term observations and poorly based suppositions for extrapolation. Extensive longer-term experimental work, interaction with leading corrosion engineers world-wide and use of probability theory, eventually led to such models [8, 9], all the while supported by ARC funding. The models showed that long-term steel corrosion loss in seawater is not a 'rate' or a simple non-linear function of exposure time as had been assumed for over 60 years but that there is a change in underlying corrosion behaviour. This insight turned out to have a significant influence on much subsequent corrosion model development. It also threw new light on understanding corrosion behaviour for metals and alloys other than steel and for other exposure conditions [10].

In 2002, Rob was appointed the sole independent member of a Technical Review Committee considering welding and safety issues for the (then) latest Australian submarines. It involved examination of confidential design criteria and documents and in-situ inspections of the interior spaces of some submarines. For various reasons this was an extremely stressful project but vindicated by the outcome - an agreed plan for limited rehabilitation of some of the welds. .

On the research side, interaction with industry had indicted that a significant issue appeared to exist with Microbiologically Influenced Corrosion (MIC). Again using field data he and research student Robert Jeffrey provided the first clear demonstration of the multitude of bacteria in the corrosion products of steels exposed long-term in seawater. This work was awarded the 2004 TP Hoar Award by the UK Institute of Corrosion for the best paper in Corrosion Science in 2003 [11]. Subsequent work led to the Guy Bengough Award by UK Institution of Materials, etc. for '... an outstanding contribution to corrosion...' [12]. Shortly afterwards it became apparent that the Melchers corrosion model had been adopted by the International Ship Structures Committee for condition assessment of aged ships and offshore structures [13]. Further advances included adding pitting corrosion to the research portfolio, eventually showing, using Extreme Value Analysis that the classical use of the Gumbel Extreme Value distribution is inadequate for representing the deeper longer-term maximum pit depths [14].

The MIC developments led to an interest in the problem of Accelerated Low Water Corrosion, first found during the 1990s in UK and in French harbours and considered a major hazard for the viability of marine ports. UK research identified MIC as a possible cause but could not relate it to causal parameters. Based on earlier work on MIC it was decided to run a simple set of experiments using long steel strips vertically placed in polluted and unpolluted harbours along the East Australian coastline. After 3 years the results were clear - the ALWC effect was greater in seawaters with higher concentrations of Dissolved Inorganic Nitrogen (DIN) [15].

The SCORCH project (2010-2014)

In 2010, Rob and his research group joined the SCORCH (Seawater Corrosion Of Ropes and CHains) project managed by AMOG Consultants for the offshore oil and gas industry and funded through the international FPSO-RF (Floating Production Storage and Offloading Research Forum). The project was funded by nearly all the 'oil-majors' (e.g. Statoil, Exon-Mobil, Total, etc.), most ship and offshore platform Classification Societies (e.g. Det Norska Veritas, Bureau Veritas, American Bureau of Shipping, etc.) and the world's leading manufacturers of wire rope and mooring chain (e.g. Bridon, Vicinay-Cardenas). The project included corrosion tests of multiple full-scale chain links (76 mm and 120mm diam. steel) at Taylors Beach and in Darwin port, wear testing of full-sized chain sets (76 mm diam. steel), detailed forensic examination of full-sized wire rope (100 mm diam.) and interpretation and reporting of the observations and results. The project also required design and construction of some highly specialized, very large test rigs, including a 12m long, 400 tonne axial force chain wear test rig. Overall the SCORCH was an intense project, with significant (project-funded) contributions from the University's laboratory staff and selected research staff (post-docs.) and with reporting at 6 monthly progress meetings at the FPSO-RF meetings in Houston and elsewhere. This exposed the Newcastle corrosion group to major players in the industry and was to have longer-term benefits. The project was completed during 2014 and although some outputs have been restricted by confidentiality agreements other results are available [16]. There also are some results from spin-off tests for wear on scaled chains [17]. SCORCH led to involvement in the Deepstar project on detailed analysis of the microbiological corrosion of mooring chains, run in conjunction with microbiologists in the US and funded by Exon-Mobil and others. The SCORCH project also led to Rob being a sponsored speaker on the topic 'Marine corrosion of steel' for three (3) international technical seminars hosted by offshore mooring-chain manufacturer Vicinay-Cardenas and held in Bilbao, Singapore and Houston during 2010-2011.

Reinforcement Corrosion (2005-)

Although not the primary target of his research in marine corrosion, a study-leave period at the University of Aberdeen in 2003 for theoretical aspects of structural reliability led to an interest in reinforcement corrosion - a major problem in many coastal locations. It came about from a weekend coastal walk and the realization that a 1000 element precast reinforced concrete balustrade running for 1.5km along the foreshore at Arbroath in Scotland showed only limited corrosion of reinforcement despite having been exposed to the harsh North Sea environment since WW2 [18]. This did not fit the standard understanding of reinforcement corrosion. To throw some light on the issues involved, on his return to Newcastle Rob organized a large testing program of controlled seawater exposures. This commenced in 2004 and still running today. At various times samples from the identical multiple concrete mixes have been withdrawn for examination. Remarkably, one very experienced structural engineer, Dick van der Molen, suggested on a visit during the development of the tests that one set of concretes might be made with low-heat (sulphate-resisting) cement. These proved, eventually, to be the key to understanding the way chlorides contribute to eventually permitting long-term reinforcement corrosion [19], while close examination of the specimens and in particular the interface between steel and concrete showed that poor compaction in that region left air-voids that, when wet, caused localized corrosion of the steel and that this was made worse by the presence of chlorides. In other words, chlorides themselves were not to blame, as has been the conventional wisdom for many decades (and still thought to be the case by some researchers and many practitioners) [20]. Largely to try to dispel the old ideas and concepts, Rob has been giving presentations of the findings at a number of conferences [21] and many meetings for practicing engineers.

Many other real reinforced concrete structures have been examined over many years, or reports of them reviewed [22, 23], with broadly similar findings. One example is that of the reinforced concrete caissons built in the later part of WW2 in England and floated out to form a breakwater for the Mulberry B artificial harbour for the Allied invasion of occupied France along the Normandy beaches. The caissons, some 3 storeys high and 60m long were built within 6 months largely with unskilled labour and meant for service of only a few months, yet today, some 75 years layer, many are still in good condition from a corrosion point of view despite sever storm damage to what can only be considered to be slender caisson walls. Fortunately Rob was able to obtain a recent detailed report of the condition of the remaining caissons and extensive aerial (drone) photographs with the excellent cooperation of French authorities. He made several personal visits to various caissons in France and the UK, facilitated by the University of Portsmouth and Portland Harbour. With the excellent cooperation of Chris Hewlett (formerly UK Hydrographic Office) who had carried out underwater surveys of the caissons and has an in-depth historical knowledge of the caissons there is now a paper that essentially dispels the notion that the caissons are corroding away at a high rate [24]. Continuing damage from storms is a much greater threat.

Corrosion of cast iron and steel pipelines (2009-)

The type of corrosion found for reinforcement steel has has been shown recently to have direct parallels with the external corrosion of cast iron water mains (pipes) buried in soils [25]. (In Australia, the UK and many parts of the USA and elsewhere these pipes are internally cement-lined and internal corrosion is not a major issue). Discovering the parallel took some time, largely through a 10 year research project for the Australian water authorities, organized by Sydney Water with funding and presentations also in the UK and the USA. Many actual pipes were exhumed from various soils and the soil type and compaction and wetness conditions then examined. It was soon found that old notions about corrosion in soils had to be abandoned, in particularly the notion that it is mostly the result of microbiologically influenced corrosion, a notion that has held sway since the early 1900s soon after sulphate-reducing bacteria were first discovered [26]. Eventually very sensible and rather simple explanations were obtained, including the importance of soil compaction all around the pipe, particularly on the underside where most corrosion tends to be observed. Mathematical models calibrated to field data were soon established.

Since the presence of free water in soils is a key factor for in-soil corrosion, recent research has focused, with the aid of surveying academic Dr. In-Young Yeo, on the use of Lidar mounted on drones to estimate soil surface wetness and thereby impute the wetness at depth [27].

In 2009, at the invitation of Dr Damien Feron (Research Director at CEA, Paris) and with agreement of the other partners, Rob became a 'Visiting International Scientist for the 'Biocorr' Project funded by the European Community Marie Curie International Training Network. He was one of only two non-European research scientists - invited to covering the areas where European expertise was considered to be deficient - in Rob's case the mathematical modelling of microbiologically influenced corrosion. Most of this work was carried out during three periods of several months at SWEREA-KIMAB, Stockholm, 2011-2012, involved a post-doc. and much data supplied mainly by Statoil and produced some interesting insights and also preliminary models for longer term general, pitting and channelling corrosion for the internal corrosion of the pipes [28]. The project findings suggested that under-deposit corrosion could be a big factor in channelling corrosion. This hypothesis was tested subsequently in the laboratory at Newcastle by PhD student Xiang Wang, who also found that MIC was not the main corrosion driver as had been assumed. Instead, it indicated that operational practices, in particular periods of low flow, when debris can settle to the bottom of the pipes, may be the critical factor [29].

Because the condition of pipelines often is inspected (indirectly) using so-called intelligent pigs, extensive, many kilometres of traces of corrosion 'features' are obtained. These can be translated to corrosion pit depths and have opened up new ways of considering the Extreme Value Statistics of pitting corrosion [14]. Interestingly, similar findings were made with the modern availability of laser scanners for developing 3D maps of the corroded exterior surfaces of cast iron pipes buried in soils [30]. Together these data show that pitting corrosion occurs in steps, something suspected already some years ago [31] but now verified with extensive data and modern interpretations [32].

Now and the future

While it is always nice to reflect on what has been achieved in the past, equally important is where 'we' are now and where 'we' need to go.

The work on pipelines work is continuing, with a recent project for the National Decommissioning Research Institute, part of National Energy Resources Australia to develop, in conjunction with Prof Mike Tan of Deakin University, models for the long-term corrosion of abandoned or decommissioned oil and gas pipelines steel left on the seabed and potential candidates for salvage.

On-going and extensive discussions continue to be held with NAVAL Group (France) (contractors to build Australia's new submarines) for potential joint corrosion research projects focused on corrosion-resistant alloys. In preparation for this Rob has paid two visits to Cherbourg shipbuilding yards and their corrosion test facilities and meeting with Australian representatives in the Australian compound in Cherbourg (2017-2019 - on-going) (all subject to security clearance). Also, he was commissioned earlier by Naval Group (France) to provide a detailed report on corrosion conditions along the Australian coast and in Australian harbours, for a variety of metals and alloys and their longer-term performance.

Rehabilitation of existing or deteriorated infrastructure is also an issue. An extreme example is the rehabilitation of the severely tsunami-damaged nuclear reactor at Fukushima, Japan and the actions that should be taken. To help with this Rob was invited by Dr Damien Feron, Research Director at CEA (Commissariat à l'ènergy atomique at aux ènergies alternatives), France, to join expert panel and present a paper on microbiological corrosion at a 2-day seminar held close to the reactor site. It reviewed what is currently known but it became clear there is an urgent need for better understanding of the interaction of corrosion, including microbiologically influenced corrosion, and the effects of low-level nuclear radiation.

A further issue is maintaining existing infrastructure longer. If deterioration and corrosion can be slowed or delayed the potential savings to society, in terms of cost, lower rate of use of materials, energy and green house gas generation will be important. One on-going project in this area is ARC and industry funded, focused on ships and offshore structures subject to severe sea-states as well as corrosion and fatigue [33].

Water pollution is well-known to be an issue for living things but it also can shorten the lives of infrastructure through fostering the metabolism of bacteria and other micro-organisms [34]. Yet the standard antidotes, such as biocides and copper-based (or worse) paints are increasingly not tolerated. This applies to shipping and offshore structures as well as coastal and harbour infrastructure. Clearly we need to think sideways for better solutions.

Awards, honours and other activities

Rob has been fortunate to receive numerous awards and honours for his research and also for his wider activities. The more recent of these include:

- TP Hoar Prize 2004 (Inst. of Corrosion, UK) for best paper in *Corrosion Science* (with R Jeffrey).

- The Guy Bengough Award 2007, Institute Materials, Minerals and Mining, UK, for “a paper published by the Institute which makes an outstanding contribution to the subject of corrosion... ”. And again in 2018 for a paper with R. B. Petersen.
- PF Thompson Memorial Lecturer, Australasian Corrosion Association Conference, Nov. 2009.
- Corrosion Medal 2009 Australasian Corrosion Assn. “... the Association’s most prestigious award ... bestowed for outstanding scientific or technological work...”
- Marshall Fordham Research Paper Award, Aust. Corrosion Assn., awarded 5 times: 2017, 2012, 2007, 2002, 1999.
- Jin S Chung Award 2012 (International Society of Offshore and Polar Engineers) for “...in recognition of outstanding creative and innovative contributions to ocean and Arctic science and engineering...”
- John Connell Gold Medal 2013 Institution of Engineers, Australia. “... a significant contribution to the standing and prestige of the structural engineering profession.”
- National Eminent Speaker, Structural Engineering College, The Institution of Engineers, Australia, National Tour, May 2014.

Rob was a member of the (Intl.) Civil Engineering Risk and Reliability Association and its President and Past-President [1999-2011], and for many years on the Executive Committee, Intl. Assn. for Structural Safety and Reliability [1985-2012], a member and also president of the Newcastle branch of the Australasian Corrosion Association, and for many years involved in various ways with the Institution of Engineers, Australia, being Newcastle Division President and later founding Chair of the national College of Structural Engineers, as well as founding Editor of the Australian Journal of Structural Engineering.

He has delivered more than 35 keynote lectures to date and provided much advice to industry. He has reviewed research proposals for grant bodies in many countries. His h-index is 45 (Web of Science), 55 (Scopus), with more than 200 citations per year. Details of his outputs whilst at The University of Newcastle can be found at: http://www.newcastle.edu.au/profile/rob-melchers.

Rob was elected to the Australian Academy of Technology and Engineering in 2004 and became an Honorary Fellow of the Institution of Engineers, Australia in 2014.

He has interacted with many remarkable people - his academic colleagues both at Monash University, such as (the late) Profs Paul Grundy and Noel Murray, and at the University of Newcastle, Profs Mark Stewart and Mark Masia as well as Yuri Totoev and Peter Kleeman and some in other universities such as Prof Iwona Beech (Montana) and the late Boris Chernov (Vladivostok). Also, he has been fortunate in his research students and working with really talented post-docs, Dr Robert Jeffrey, Dr Igor Chaves, Dr Robert Petersen, Dr Tony Wells, Dr Mukshed Ahammed, Dr Iulian Comanescu, and more recently Dr. Peter Richardson. And last but not least, to ‘keep the show on the road’, there is the great support of dear wife and soul-mate, Ros.

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