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Centre for Asset Integrity Management (C-AIM)

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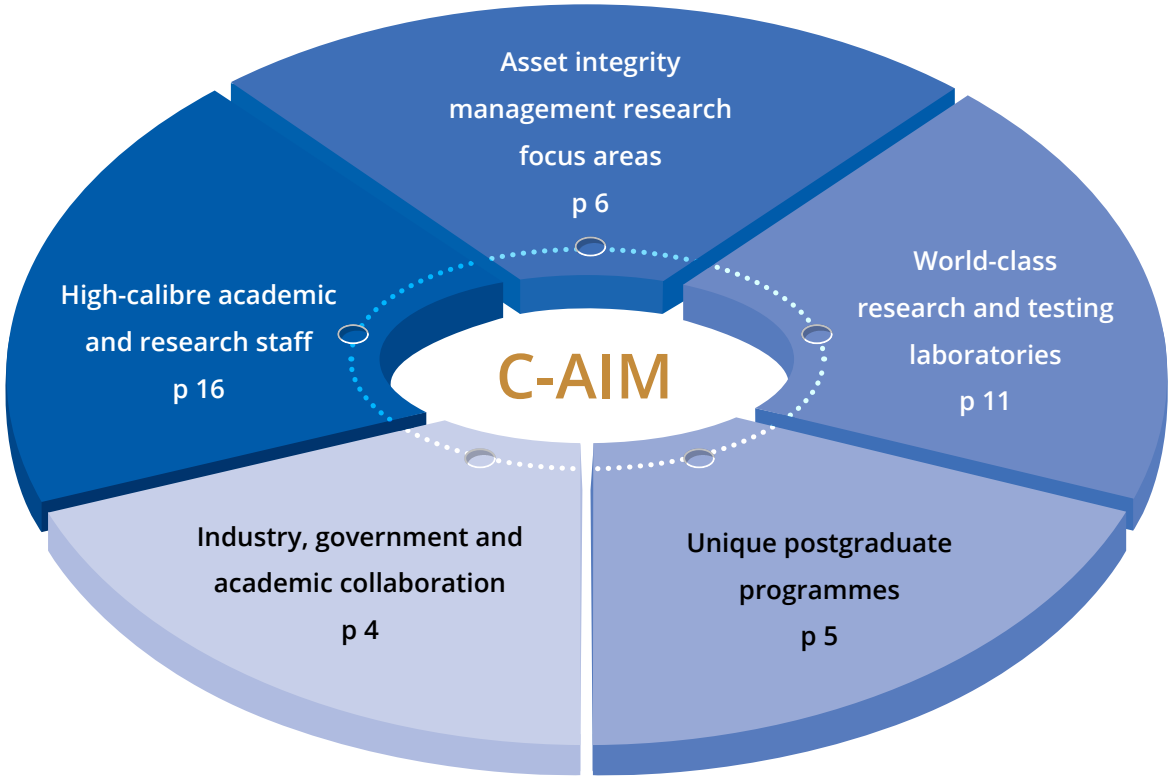
The Centre for Asset Integrity Management

The Centre for Asset Integrity Management (C-AIM) at the **University of Pretoria** is unique in that it integrates its analysis and testing capability in assessing the structural integrity and performance of physical assets, with sound scientific research to inform asset management decisions within the context of asset life cycles.

Key strengths include:

- Quality academic education: more than 80 final year and 50 postgraduate students.
- Twenty high-calibre academic, research and technical staff members.
- A unique multi-disciplinary postgraduate programme in physical asset management.
- Long term industry partnerships, e.g. Eskom, Exxaro, Weir Minerals and Rand Water.
- World-class research and testing laboratories.



Prof Stephan Heyns
Director: C-AIM

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Introduction

Globally there is a rapidly growing need to optimally manage physical assets over their entire life cycles, from design through operation and finally decommissioning. Traditional factors such as performance and cost drive this need, but factors such as health, safety and environmental impact are gaining importance and therefore need to be considered as well.

The management of physical assets such as plant equipment, buildings, aero structures, machinery and vehicles, focuses at a strategic level on establishing, operating and maintaining an asset portfolio that is aligned with the organisation's strategic objectives, within the context of the regulatory and broader organisational environment. At an operational management and technical level this necessitates the need for in-depth understanding of asset management principles and processes, enhanced by specialised technical knowledge and techniques related to aspects such as design analysis, data acquisition, condition monitoring, diagnostics and prognostics as well as finite element analysis – all within the context of asset life cycle management.

In the mid-1980s the Department of Mechanical and Aeronautical Engineering commenced research in various fields related to physical asset integrity. This included structural fatigue testing, experimental modal analysis and vibration monitoring. Maintenance related initiatives were subsequently launched, culminating in the establishment of a Centre of Excellence in Maintenance Engineering in 2008, with industry support from Sasol, Eskom, Exxaro and Anglo American.

In 2012 Eskom established a Specialist Centre for Plant Asset Management as part of the Eskom Power Plant Engineering Institute (EPPEI) initiative, with a research focus on asset integrity management. This was followed by the establishment of the Rand Water Chair in Mechanical Engineering, as well as a cooperation agreement with Weir Minerals to establish a research focus on machine condition monitoring.

As a result of the cumulative growth of knowledge and expertise in this field, the Centre for Asset Integrity Management (C-AIM) evolved naturally and was eventually formally established during 2014 as a home for all the asset integrity management related activities in the department of Mechanical and Aeronautical Engineering.

This has created a very interesting research environment in which highly technical issues pertaining to structural and machine failures and remaining useful life, are integrated into well-founded management decisions. It is this integration of technical decisions in an asset management environment which positions the centre quite uniquely, and has resonated well within South African industry, through collaboration and support of the academic and research programme in the department.

Industry Collaboration

The Centre strives towards scientific excellence in areas of specific industry relevance. This implies working closely with industry partners in defining research topics that are aimed at solving specific industry problems in a highly scientific manner. The approach is collaborative, utilising the establishment of industry sponsored chairs in specific research areas as the primary mechanism. The Centre also actively participates in government programmes aimed at strengthening industry and academic collaboration.

Eskom	**Eskom Power Plant Engineering Institute (EPPEI) Chair in Plant Asset Management**	Established in 2012 and funded for five years, the centre will supervise 30 to 40 Eskom staff members who will study towards masters and doctoral degrees on a full-time basis. High impact research projects are underway that will deal with issues ranging from mill maintenance optimisation to fatigue life prediction of steam turbine blades.
exxaro POWERING POSSIBILITY; ANGLO AMERICAN; sasol; WEIR MINERALS	**Chair in Maintenance Engineering**	This Chair was established in 2009 and has enabled the centre to considerably expand its capacity (teaching and research) in the area of maintenance engineering. Numerous industry related projects are in process.
RAND WATER	**Rand Water Chair in Mechanical Engineering**	The Chair was established in 2014 and focuses strongly on the development of asset integrity analysis and management techniques for water distribution. Pipe integrity forms a large part of this activity.
THRIP TECHNOLOGY AND HUMAN RESOURCES FOR INDUSTRY PROGRAMME an initiative of the dti; NRF National Research Foundation managing agency	**Technology and Human Resources Industry Programme**	C-AIM has been participating with the THRIP programme for many years, which entails scientific industry relevant research programmes, co-sponsored by industry and government. This funding enables C-AIM to provide bursaries to top-calibre full time postgraduate students to conduct such research, as well as for the acquisition of hardware and software associated with such research.

Postgraduate Programmes in Physical Asset Management

Physical asset management spans many disciplines, both in the technical engineering domain as well as in the management domain. The University of Pretoria is proud to present two unique postgraduate programmes in physical asset management.

Mechanical Engineering Postgraduate Programme in Asset Integrity Management

To optimally manage complex physical assets requires a deep understanding of asset management principles enhanced by sound understanding of the structural integrity of these assets.

Mechanical engineers interested in the structural integrity of physical assets can contribute significantly to effective overall physical asset management, utilising expertise in fields such as mechanical design, finite element analysis, fatigue, structural testing, condition monitoring, non-destructive testing, and reliability centred maintenance.

Multi-disciplinary Postgraduate Programme in Physical Asset Management

Utilising the broad skills base of the Faculty of Engineering, Built Environment and Information Technology, the University has developed a postgraduate programme in Physical Asset Management which spans many disciplines across both the management and technical engineering domains.

Departments that participate in this programme include Mechanical and Aeronautcial Engineering, Civil Engineering, Industrial Engineering, Mining Engineering as well as the Graduate School of Technology Management.

Both courses consists of a course based Honours Degree followed by a research dissertation for Masters Degree purposes.

Unique to this programme is that students can construct their Honours Degree curriculum from a wide selection of subjects (modules) to underpin their Masters dissertation, with a strong specialisation in Mechanical Engineering.

Unique to this programme is that students can construct their Honours Degree curriculum from a range of technical, management and industry related subjects (modules) to underpin their Masters dissertation.

The following are typical examples of subjects (modules) that can be selected – please note that the selection of combinations of modules are subject to certain conditions

- Condition based maintenance
- Control systems
- Experimental structural dynamics
- Fatigue
- Finite element methods
- Maintenance practice and operations
- Mechatronics
- Non-destructive testing
- Maintenance management
- Asset management
- Reliability engineering
- Project management
- Systems engineering
- Vibration based condition monitoring
- Infrastructure management
- Fossil fuel power stations

C-AIM Research Focus Areas

Critical assets identification:

Companies operate a huge variety of assets with very diverse attributes. With limited human and financial resources it is imperative to focus on those assets that may have the most significant and immediate impact on the business. Utilising advanced statistical analysis and modelling techniques asset criticality is determined based on a variety of factors.

Data acquisition:

Asset integrity management increasingly requires measurement of system parameters such as solids, liquids and gas flow rates, pressure, temperature, oil condition or vibration, together with detailed data of the operating conditions. Some of the advanced techniques include the utilisation of non-contact sensors for condition monitoring as well as acoustic emissions in specialist applications.

Diagnostics:

Understanding failure modes and criticality is crucial in identifying optimal condition monitoring approaches. Detailed models to link features extracted from system response and performance measurements are indispensable in the diagnosis of systema faults, for example developing condition monitoring techniques which separate deterministic and stochastic machine behaviour under widely fluctuating conditions.

Design for reliability and performance:

It is essential that both during the manufacturing as well as the operational (consider modifications) phase of an asset's life, sophisticated techniques are used to ensure that asset design is optimal. Some of the sophisticated techniques that can be utilised are finite element modelling of complex structures, scanning laser vibrometry and digital imaging.

Lifecycle decision support:

When considering life cycle management decisions, the focus extends beyond immediate failure towards understanding the long term operational and maintenance implications. An important aspect of the current research therefore entails integration of condition information with improved understanding of the degradation mechanisms, to manage maintenance interventions, risk, inventory, and end-of-life decisions.

Condition monitoring:

While progress has been made in the diagnostic analysis of complex industrial assets and imminent failures can often be identified, there still are significant research challenges. Examples of these include having to deal with fluctuating operating and process conditions in systems, optimising of on-line condition monitoring and inspection techniques for a variety of equipment.

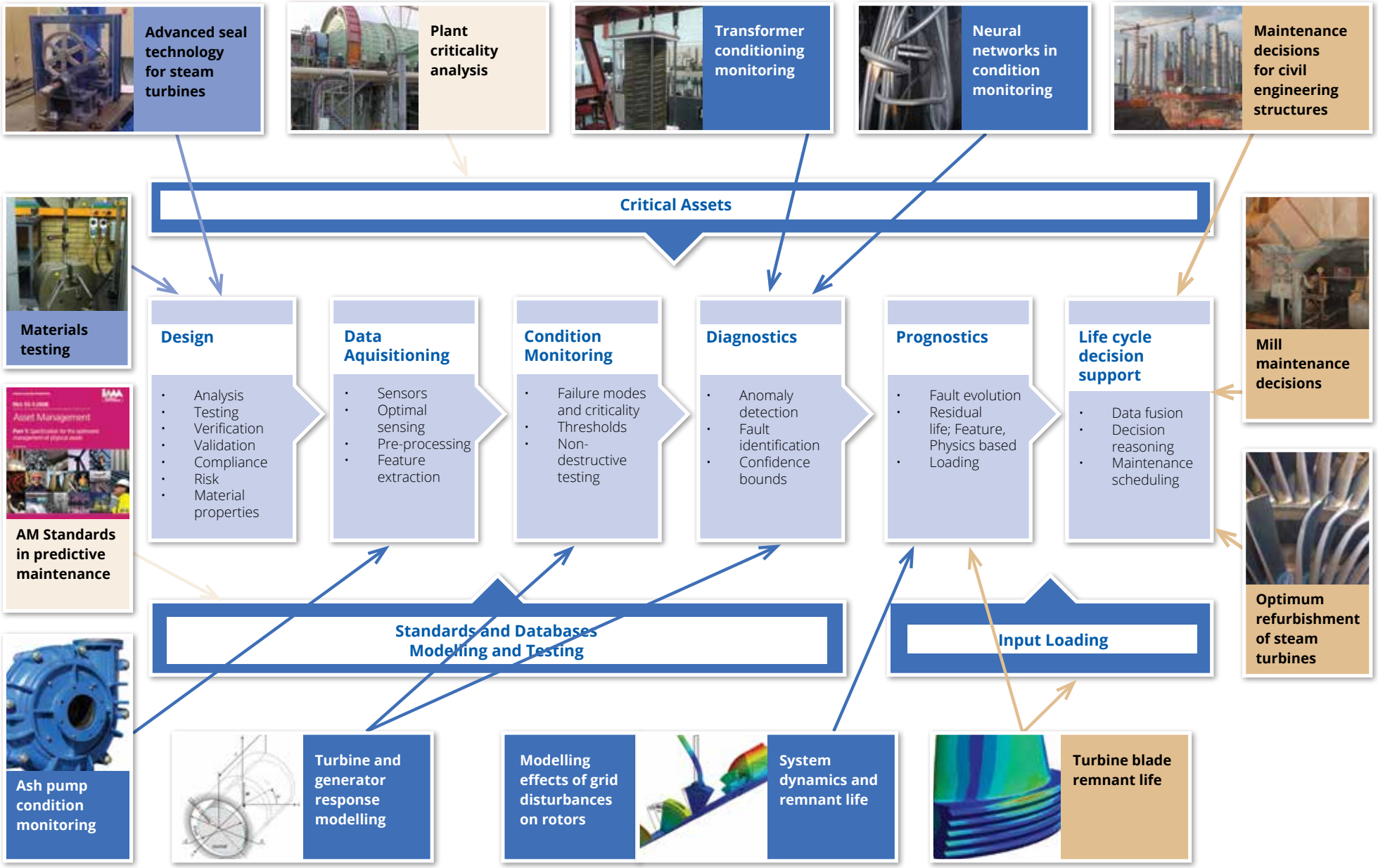
Prognostics:

Maintenance decisions based on the outcomes of condition based time-to-failure estimates often contain a strong element of uncertainty which suggests a need to integrate traditional condition assessment and statistical reliability models. This requires evolving from making intuitive decisions based on experience, towards more sophisticated prognostic models capable of dealing with complex equipment with many interrelated failure modes.

Standards and databases:

Realisation of the importance of optimal utilisation and life cycle management of expensive physical assets is rapidly growing in a cost-sensitive competitive society. Symptomatic of this is the emergence of new asset management standards such as PAS55 and ISO 55000. It is important to fully understand the implications of such standards on its business.

C-AIM Research Focus: Example of how postgraduate research projects in the power industry maps to the C-AIM research focus areas.



C-AIM Testing and Analysis Facilities

The Sasol Laboratory for Structural Mechanics was established in the early 1980s as part of a joint initiative by the Department of Mechanical Engineering and Sasol to establish the University of Pretoria as a leading South African research centre in applied mechanics.

Today this laboratory is actively used by the Centre for Asset Integrity Management and is home to the structural fatigue and durability testing, structural dynamics, vibration monitoring, diagnostics and prognostics activities of C-AIM. The laboratory was recently expanded to add a very substantial capability in rotating machinery dynamics.

Fatigue tests on a large truck

Durability testing using large electrodynamic actuator

Fatigue and durability testing

The laboratory is equipped with a very good infrastructure of servo-hydraulic actuators and controllers with a dynamically isolated reaction floor, and is able to perform complex multi-actuator tests as well as simple single axis tests. This allows sophisticated fatigue and durability tests to be done.

Special expertise includes the ability to reconstruct field measured responses using these actuators. This entails the field measurement of responses (for example automotive or machine accelerations and strains) and the subsequent construction of actuator drive signals to reproduce these responses in the laboratory. This also includes a unique ability to deal with non-linear behaviour in such systems. Various research projects on inverse methods are currently being conducted to develop these capabilities further.

The servo-hydraulics infrastructure is further enhanced by a large electrodynamic shaker which extends the frequency ranges over which durability testing can be conducted to almost 3 kHz.

Structural dynamics and modal analysis

The laboratory also has excellent infrastructure for structural dynamic investigations. Apart from the shakers, instrumented modal hammers and the like which are required to perform experimental structural dynamic investigations, the laboratory also has Polytec PSV-400 and PSV-300 scanning laser doppler vibrometers, as well as a portable laser vibrometer.

Equipment like these are ideal for very high resolution experimental modal analyses on light structures such as automotive door panels, or in particular turbomachinery blades. Turbomachinery dynamics investigations currently form an important part of the research being conducted in this laboratory, especially for enhancing the understanding and modelling of turbomachine dynamic behaviour and detection of minute changes in these dynamics, in order to provide early warning of impending blade failures.

The laser doppler vibrometery for structural dynamics is enhanced by another non-contact optical measurement technique, namely photogrammetric image correlation system. The laboratory uses multiple high speed cameras to view vibrating structures such as turbine blades, from various vantage points simultaneously. Using suitable optical targets (such as paint marks) on the vibrating structures, allows very detailed understanding of the blade responses. Collaborating with the CSIR, the laboratory is capable of doing studies of this nature up to frame rates of 500 000 frames per second.

These studies are becoming increasingly important in laboratory investigations of turbine remaining useful life, an area in which various masters and doctoral students in the laboratory are active. The laboratory uses various sophisticated finite element packages for detailed linear and non-linear numerical investigations.

Testing dynamic behaviour of turbine blades

Structural dynamics testing using non-contact optical measurements

Vibration based condition monitoring

Vibration monitoring research in the laboratory has prompted the development of a variety of rotating machine fault simulators, which are used in the accelerated testing of machine elements and the development of new condition monitoring algorithms. These facilities have been highly instrumental in the development of algorithms for specialised monitoring applications such as varying speed and loading conditions, and gearbox vibration analysis. The laboratory has also been very active in the use of artificial intelligence in vibration monitoring.

A notable project deals with the use of turbomachine blade tip timing measurements for blade root damage detection. The lab has developed techniques which perform significantly better than all the published algorithms which are currently known in the literature.

An interesting extension of our research in vibration monitoring, is the work on road condition monitoring. This entails the measurement of vehicle vibration and the interpretation of these vibration levels in terms of the condition of the road. Current research explores artificial intelligence models such neural networks to learn the relationships between observed vibration measurements and road condition. These techniques have now been successfully implemented in various mining applications.

Noise studies

Since noise often goes hand-in-hand with vibration, the laboratory has a well-developed acoustic measurement and modelling capability.

Updating of numerical models based on experimental investigations

The unique combination of experimental and computational capabilities makes it logical for the laboratory to focus significant resources on the study of techniques to update finite element models and improve their correlation with measured response characteristics, so that these models could be used for reliable design and structural modification studies.

C-AIM Academic Staff

Stephan Heyns: Professor and Director
BSc (Mech Eng), MEng (Mech), PhD

Stephan is responsible for the overall strategic direction and management of C-AIM. He has more than three decades of experience in mechanical engineering and asset integrity management. He is internationally recognised (NRF rated researcher) as a leader in vibration based condition monitoring and structural integrity testing.

Nico Theron: Associate Professor
BEng (Mech), MEng (Mech), PhD

Nico is the Rand Water Chair in Mechanical Engineering and therefore coordinates the research done specifically for Rand Water. He is also the Departmental postgraduate coordinator. His research interests are in control of mechanical systems and structural dynamics. He has a keen interest in computational mechanics.

Schalk Kok: Associate Professor
BEng (Mech), MEng (Mech) PhD

Schalk is a specialist in computational mechanics with specific focus on material modelling and optimal design. He has experience in implementing user material models in finite element software and calibrating such models using experimental data. He received a Fulbright scholarship to pursue his PhD in the USA in 2001 and is a NRF rated researcher.

Jasper Coetzee: Associate Professor
BSc (Mech), B. Com, MEng (Indust), PhD

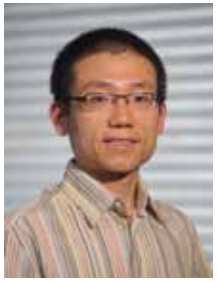
Jasper is responsible for Strategic and Logistical Management aspects as well as advanced aspects of Maintenance Engineering. He has more than four decades of experience in maintenance engineering and management. He is internationally recognised (member of the International Foundation for Research in Maintenance - IFRIM) as a leader in the Physical Asset Management field.

Nico Wilke: Senior Lecturer
BEng (Mech), MEng (Mech), PhD

Nico is an optimisation researcher in the C-AIM group. He has a decade of experience in solving engineering optimisation problems. Specifically, his area of speciality is in finite element based structural design optimisation and solving inverse problems for model identification.

Coenie Thiart: Senior Lecturer
BSc (Mech Eng), MEng (Nuclear)

Coenie is a lecturer for postgraduate Maintenance and Condition Monitoring. He is involved in the evaluation and improvement of labyrinth seal technology for the power generating industry. He has three decades of experience in the nuclear and high speed flow and simulation field.



Bo Xing: Senior Lecturer
BSc (Mech Eng), MSc (Mech Eng), DIng

Bo is responsible for the e-maintenance research within C-AIM. He has many years of academic research and industry working experience in manufacturing, robotics and computational intelligence. His present research interest is mainly focused on miniature robot design and analysis for in-pipe inspection.

Helen Inglis: Senior Lecturer
BSc(Eng)(Mech), MS (Mech Eng), PhD

Helen models the behaviour of materials using mathematical and numerical methods. She is interested in understanding the links between underlying physical mechanisms and the material response which can be observed. Her experience in modelling fibrous and particulate composites spans more than a decade.

Francesco Pietra: Senior Lecturer
MSc (Aero Eng), MSc (Mech Eng)

Francesco has more than ten years of experience in structural Finite Element Analysis (ANSYS). His FEA specialisation fields are: Non-linear Simulation, Dynamic Simulation (Vibration), APDL, Thermal Simulation. He has extensive experience in simulating the residual stresses due to advanced manufacturing processes.

Karl Grimsehl: Lecturer
BSc (Mech Eng), BEng (Hons)

Karl is a lecturer in Machine Design, Vibrations and Impact of engineering. Prior to joining UP he worked in industry for five years developing medical devices. His innovative approach to engineering is reflected in the two provisional patents for which he is signed as co-inventor. Current fields of interest are design and design optimisation.

C-AIM Research and Project Staff

Abrie Oberholster: Research and Project Engineer
BEng (Mech), MEng (Mech), PhD

Abrie is responsible for the optical measurement laboratory as well as the rotating equipment laboratory of C-AIM. He has over 10 years' experience in mechanical engineering and he specialises in condition monitoring of rotating machinery under both stationary and non-stationary operating conditions, modal analysis and non-contact measurement applications.

Jan Eksteen: Research and Project Engineer
BEng (Mech), MEng (Mech), PhD

Jan is involved in the structural integrity testing activities of C-AIM. He has professional experience in system identification, system model inversion and service load simulation (also referred to as response reconstruction) for use in structural integrity testing. He has also had extensive exposure to test jigging design, software coding, finite element analysis, technical acoustics and robotics path planning.

Alewyn Grové : Research and Project Engineer
BEng (Mech), MEng (Mech)

Alewyn is responsible for contract research and consultation to industry. His speciality includes finite element analysis, structural mechanics and dynamics as well as field measurement and testing. He has 10 years' experience in the relevant field and has completed various projects in the power, mining, transport and petrochemical industries.

Rudi Kroch: Research and Project Engineer
BEng (Mech), MEng (Mech)

Rudi is involved in vibration and technical acoustics within C-AIM. These areas of expertise are often combined in practice to find the source of bothersome noise. To achieve this, Rudi is proficient in sound and vibration measurement and analysis, including acoustic finite element analysis. In addition, Rudi is responsible for the Roll Over Protective Structure and Falling Object Protective Structure testing.

Johann Clarke: Research and Project Technician

Johann is an experienced test technician with specialised expertise in structural fatigue and characterisation testing using servo-hydraulic actuators and associated control systems. He is also experienced in field testing with large multi-channel configurations.

C-AIM Support Staff

George Harley: Programme Manager
BEng (Indust Eng), MBA

George is the programme manager of C-AIM and responsible for the day-to-day operations thereof. Before joining UP he spent 15 years as a strategic management consultant and researcher and before that seven years at an electricity utility. He specialises is technology management, industry research, strategy and business planning as well as innovation policy.

Herman Booysen: Instrumentation Technician

Herman is responsible for the instrumentation and control systems in the laboratory. He has more than twenty years experience in most instrumentation used in mechanical engineering such as strain gauges, displacement sensors and other testing equipment. He is also involved in designing electronic and electrical hardware and the installation and commissioning of such systems.

George Breitenbach: Mechanical Technician
NTD (Mech)

George is experienced in optical measurement techniques such as laser vibrometry and digital image correlation. He has more than 30 years of mechanical experience with particular exposure to rotating machinery.

Phuti Matsaola: Technologist
BTech (Mech)

Phuti specialises in mechanical testing and supports final year and research staff and students with their testing work. His specialities include structural and noise testing in the laboratory, as well as in the field.

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