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Very Early Smoke Detection Apparatus (VESDA), David Packham, John Petersen, Martin Cole: 2017 DiNenno Prize

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Abstract

The 2017 Phillip J. DiNenno Prize was awarded to the innovators of the VESDA smoke detection system. The initial technology was invented and patented by **David Packham** and **Len Gibson**, who worked with **John Petersen** on prototype development, field trials, and applications engineering. **Dr. Martin Cole** was responsible for the successful commercial development and many further patented technical developments. The VESDA technology and its pre-eminent role in the introduction of aspirated smoke detection (ASD) internationally has led to a major global impact on public safety.

The recipients of the 2017 Philip J. DiNenno Prize are **David Packham**, **John Petersen,** and **Dr. Martin Cole**. Ample commendation is given to their deceased co-inventor and passionate advocate **Len Gibson**. Other important contributions are noted, including technical and other staff from IEI, CSIRO, SSL and Telecom Australia.

Keywords: DiNenno prize, VESDA, Aspiration, Smoke detection

Introduction

The Phillip J. DiNenno Prize is intended to recognize "a technical achievement that has made a significant impact on public safety…". The invention and subsequent successful commercialization of the Very Early Smoke Detection Apparatus (VESDA) is the technical achievement recognized by the 2017 Philip J. DiNenno Prize. The VESDA aspirated smoke detection system was orders of magnitude more sensitive than traditional point type smoke detectors, and provided new opportunities for improving public safety across a wide spectrum of the built environment.

The creative spark for the VESDA invention came about during a remarkable series of huge bush fires ignited for research purposes in the forests of Western Australia in 1971. A laboratory nephelometer, mounted in an aircraft, was used to monitor very low concentrations of smoke in large bushfire smoke plumes. It seemed to offer great potential to detect similar low smoke concentrations from smoldering fires in high airflow telephone exchanges and early computer centres, where point type smoke detectors were being found to be inadequate for the task.

Several prototype nephelometer-based smoke detection systems were developed and trialled by initially sampling airflows in air-conditioning ductwork in several Australia telephone exchanges, transmitter facilities, a space tracking station and a hospital, and the principle of high sensitivity, very early warning smoke detection was borne. Later, small bore pipework or aspirated smoke sampling systems were added, together with three level alarms outputs, outside air compensation, and other patented developments.

The VESDA detectors, based on the nephelometer light scattering principles to detect smoke particles, used xenon-flash tubes as the light source and photo-multipliers as the scattered light receivers until 1980. Later developments, using photo-diode receivers, coupled with xenon, laser diode or subsequently pulsed LED light sources together with increasingly robust state-of-the-art electronics, came with commercialisation.

Development of the VESDA system market started in Australia, but quickly led to widespread use in North

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America, UK, Asia, and then globally for the protection of telecommunication facilities, data centres, IT fabrication plants and other high value or mission critical premises. As the technology and the applications engineering was developed further, the use of VESDA was extended into many other life safety, property protection and business continuity applications worldwide.

However, without the continuing passion and determination of the core group of innovators, namely **David Packham, Len Gibson** (now deceased)**, John Petersen** and **Dr. Martin Cole**, through the decade of the 1970s and beyond, this innovation would not have been brought to commercial success and the wide public safety benefits which have now been achieved.

Technical achievement

Detection is a critical component in any fire safety strategy for a building. The earlier the detection, the more time available for prompt action, whether for alerting occupants to evacuate safely and thus saving lives, or for minimization of the impact of fire and smoke on property or business operations. Very early detection to sense and terminate incipient fires before any appreciable smoke or heat occurs is ideal.

Through the 1960s and 1970s, point type ionization smoke detectors were becoming more widely available in Australia and throughout the world, although many earlier type heat detectors were still being installed (Johnson 1988). These smoke detectors were increasingly being required in Australian Government facilities such as airports, telephone exchanges, computer centres, Defence buildings and other mission critical facilities. This mirrored developments in North America and many other countries.

Computer and telecommunication facilities in that era were moving from electro-mechanical equipment to solid-state electronics. Increasing equipment densities and power consumption were leading to higher airflows being needed for cooling. **Len Gibson** and **John Petersen** at the Australian Post-Master Generals' Department (PMG) were finding that ceiling mounted smoke detectors were failing to detect fires early enough, particularly smouldering fires, before significant damage occurred to more sensitive electronic equipment. Often this led to serious service interruptions and major business and community impacts. Longer-term, insidious damage was often caused by corrosion from the HCl vapours being emitted from overheated PVC cable insulation.

Through this same decade of the 1960s, Australia suffered major bushfire tragedies in Western Australia in 1961, Victoria in 1962, Tasmania in 1967 and Victoria again in 1969, with many lives lost and vast areas of bushland and property destroyed. As a result, the Commonwealth Scientific and Industrial Research Organization (CSIRO) had established a Bushfire Research Group (Styles 2008) which was trying to find answers to the bushfire threat through the application of aerial prescribed burning for forest fuel management, and a better understanding of the nature, properties and behaviour of bushfire smoke in smoke plumes above large forest fires (Vines et al. 1971).

David Packham was part of the CSIRO Bushfire Research Group which was internationally regarded and had published many papers on bushfire behavior and smoke characteristics. **Packham's** special interest was smoke from large natural fires (Taylor et al., 1968). **Packham** had studied the characteristics of smoke through the use of a laboratory nephelometer, a light scattering device built at CSIRO based on the available concepts of Alquist and Charlson in the USA and more particularly an original wooden box nephelometer designed for determining visual range for military purposes developed by Beuttell and Brewer in about 1943 (Alquist and Charlson 1967).

In 1970, **Gibson** visited CSIRO and met **Packham** to learn more about the properties of smoke and see if that knowledge could be used to help address his telephone exchange problems. It turned out that they had a mutual interest in aviation, and both flew missions as pilots in light aircraft over large bushfires and through smoke as fire spotters to aid the real-time mapping of forest fires for the Victorian fire authorities (Packham 1966).

A major bushfire research program conducted in 1970 by CSIRO (Vines et al. 1971) in the forests of Western Australia provided a serendipitous moment for the discovery of the invention of VESDA (Very Early Smoke Detection Apparatus). A special version of the light scattering nephelometer designed for visibility measurements was being used in an aircraft piloted by **David Packham** (CSIRO) and **Len Gibson** (Post-Master General's Department -PMG), **Gibson** having been seconded to the research program.

The aim of the CSIRO research was to study smoke development and behaviour (Vines et al. 1971), and to measure very low smoke concentrations in convective bushfire plumes thousands of feet above West Australian forests**.** **Gibson** had the "light bulb moment" when he asked **Packham** whether the nephelometer in the aircraft sampling bushfire smoke could be used to detect smoke from very small fires occurring in PMG telephone exchanges by sampling air flows in the building air-conditioning systems.

Back in Melbourne, some prototype VESDA smoke detectors were developed initially at CSIRO led by **Gibson,** Eccleston and **Packham**, based on the nephelometer concept (Gibson and Packham 1971). Support was provided by **John Petersen** and his technical team at the PMG (later Telecom Australia) in terms of applications engineering and experimentation with duct sampling systems and associated pumping and suction systems.

The VESDA smoke detector prototypes manufactured firstly at CSIRO, and later in several phases in the PMG workshops in Melbourne, utilized pulsed xenon flash tubes and photo-multipliers to detect broad wavelength, white light scattered off smoke particles carried into the detector labyrinth by air pumped out of an HVAC return duct. The high intensity light source and high sensitivity photo-multiplier receiver design enabled very low concentrations of smoke to be detected. The broad spectrum enabled the device to detect quite a significant range of particle sizes, the theory of which **Packham, Gibson** and others published in various reports and journal articles from 1971 to 1974 (Gibson and Packham 1971), (Gibson, 1973), (Packham et al., 1974).

Trials were conducted in telephone exchanges, remote transmitter stations, a NASA space tracking facility at Honeysuckle Creek, computer rooms, and at a Victorian hospital (Hamilton et al., 1976). **Packham, Gibson** and **Petersen** discovered they could detect smoldering fires many minutes earlier, and at smoke concentrations several orders of magnitude lower, than was the case with point type smoke detectors. Again they published their results, which included long term monitoring of installations and showed at what levels the alarm threshold could be set for reliable high sensitivity smoke detection balanced against the frequency of potential false alarms. (Packham et al., 1974).

Gibson and **Petersen** quickly understood at that time that some telephone exchanges, computer centres and Defence facilities had air-conditioning systems which could fail or could be shut down at times to save energy. As a result, detection from a return duct would be seriously degraded. They therefore conceived a small bore pipework sampling system mounted initially at ceiling level to draw air samples back from rooms to be protected, regardless of whether the air-conditioning system was on or off. They conducted many experiments as well as field trials in telecommunication facilities, to show such duct sampling and pipework sampling systems using the VESDA concept could still work extremely effectively in this manner, even in high airflow environments. (Neilson, 1976) They developed some empirical rules for sampling pipework designs.

A second part of the original VESDA invention and CSIRO patent was the concept of a twin channel device to detect the difference between particulate concentrations entering a telephone exchange, which could cause false alarms, and those smoke particles generated internally be a fire. **Gibson** and **Packham**, together with **Petersen** and others, also added a three level alarm system with variable time delays and sensitivity settings, and this together with the aspirating (sampling) pipework/fan system all became known as the VESDA detection system (Packham et al., 1974).

After nearly a decade of huge frustrations for the innovators, and Government false starts down the path of commercialization though ineptitude and lack of commercial interest at CSIRO and PMG (by now Telecom Australia), only the passion, persistence and belief in the potential of this VESDA technology of **Packham, Gibson** and **Petersen** led to them teaming up with a relatively small Melbourne electronics company, IEI Pty Ltd. and their Managing Director **Martin Cole** in 1978. **Cole** and his IEI team took the VESDA concept and prototype design and developed the first commercially successful Mark 1 E700 VESDA detector with improved, more stable electronics and a PIN-diode, instead of the photo-multiplier, as the scattered light receiver (Johnson, 1981).

The VESDAs were first manufactured by IEI in 1979 and installations started across Australia in telephone exchanges and other high value facilities with **Petersen** organizing VESDA installations within Telecom Australia and other facilities. After setting up his own private design and installation company Monit-Air, **Petersen** joined Cole at IEI in 1981 to lead the national sales effort and applications engineering. **Petersen** was also the driving force behind VESDA submissions and listing by approval authorities, and the necessary changes to the Australian detection installation standard AS1670, including the testing, approval and listing of the Mk1 E700 VESDA by Australia's Commonwealth Government test laboratory in 1981. (Johnson, 1981).

Innovative and patented improvements in subsequent models by **Cole** saw the development of robust hardware and electronics, improved low-power aspiration and new pipework design rules in the Mk2, followed by 'designer' polycarbonate cabinetry with a unique high-efficiency, high-pressure purpose-designed aspirator in the Mk3 models of VESDA, again with approvals and listing at the Australian Government Laboratory. (Timms, 1984), (Johnson, 1984). As well, **Cole** had the drive to implement innovative high quality product design and advanced automated manufacturing techniques in 1985 as the basis for international sales and distribution. (Styles, 2008).

More innovation by **Cole** and the R&D team at Vision Systems Ltd. from 1995 led to the introduction of laser technology used in the VESDA LaserPlus detectors (Cole, 2009).

All these developments allowed VESDA systems to provide high sensitivity smoke detection and respond to the challenges from the transition to very high energy and full digital equipment systems in telecommunications and many other industries the 1980s and 1990s. This provided the market opportunity for major exports of the VESDA technology to the USA and UK as well as Japan, Italy, New Zealand, and subsequently worldwide distribution.

At the same time, **Cole** knew IEI and their distributors, as well as system design engineers, needed to be able to do a better job of designing the pipework sampling for aspirated systems where HVAC systems could be turned off. He was not satisfied with the basic empirical rules developed from the work of **Gibson** and **Petersen,** nor with his own charts published in 1983, nor with some further attempts by Notarianni (Notarianni, 1988) and others (Cole, 1999a). Supervised by Monash University, **Cole** set about conducting his own fluid dynamics research. This culminated in his Master's project and the development of the world first reliable design software for aspirated smoke sampling systems with Aspire™ (Cole, 1991). Later, through his PhD research, **Cole** discovered new theories for disturbed airflows and developed more accurate software with Asyst™ (Cole, 1999a).

Development of the first laboratory test and approval standards in Australia, well as modification of Australian Standards and later internationally recognized standards such as NFPA 75 for fire protection of IT equipment and NFPA 76 for fire protection of telecommunications facilities to allow for ASD systems, greatly helped the demand for and acceptance of this very high sensitivity VESDA smoke detection. There was also a much wider spread of use of VESDA beyond telecommunications and computer facilities into many life safety applications which has seen this VESDA and other ASD technologies continuing to have a huge impact on public safety in very many countries around the world up until the present day.

Impact on public safety

The VESDA innovation transformed the fire detection and alarm industry and inspired a whole new Aspirated Smoke Detection (ASD) area of technology. From the start of VESDA manufacturing and commercial release in 1979, by 1998 there were some 50,000 installations of VESDA worldwide (Cole, 1999a). By 2014, Xtralis indicated that the number had grown to over 750,000 installations, incorporating many millions of individual VESDA units.

At the time of VESDA commercialization, there were other pipework sampling systems and technologies, such as the UK STAMP (ionization) system and Environment One, a cloud chamber based device. However, their market penetration was very small. As the number of VESDA systems grew exponentially, it eventually spawned other competitive ASD technologies, such as Stratos (AirSense), HART (Hartnell), Analaser (Fenwal), and FDA (Siemens) encouraged by the market acceptance and the commercial success and performance of VESDA (Cole, 1999a, b).

VESDA has always been amongst the market leaders of ASD technologies which now provide protection to many thousands of facilities worldwide, including global telecommunication businesses, and international data centres, as well as clean rooms and many other high value facilities. As an example, VESDA systems provide detection in over 3 billion square feet of space, and protect more than $200 billion in assets and over 1 million people (Ming He, 2013).

Largely through IEI and early VESDA customers such Telecom Australia and later Nohmi Bosai in Japan, and AT&T in the US, standards have been developed or updated to recognize the role of VESDA and ASD systems as Very Early Warning Fire Detectors (VEWFD) for the protection of telecommunication facilities (NFPA 76) and IT facilities (NFPA 75). Similarly the fire detection and alarm installation standards such as NFPA 72, AS 1670 and other international recognized fire detection standards such as the European EN54-Part 20 have been updated to cater for VESDA technology and similar ASD developments.

The impact of ASD systems in terms of lives saved, asset damage reduced, heritage values saved, and business interruption minimized is not that easy to quantify. The challenge is that VESDA will typically detect fires in the smoldering or incipient phase, often as a result of overheating or ignition of very small amounts of material and a fire size less than 1 kW (Meacham 1993). The benefit comes from detecting such small fires that many minutes, or hours in some cases, of extra time is provided for evacuation of building occupants, or for action to be taken much more safely to extinguish or control much lower energy fires. The comparison needs to be made against risk to lives and losses in similar facilities which might occur with point type smoke detectors or sprinklers, at much larger fire sizes, or where there is no fire detection at all.

One way of looking at the impact of ASD systems such as VESDA is through the continuing innovations which have progressed from the original technology development. It started with the conceptual innovation and applications engineering of **Packham**, **Gibson** and **Petersen**, and the subsequent manufacturing and commercial innovations of **Cole** at IEI. What followed was the impetus created which gave support to on-going investment of subsequent commercial owners and developers of a number of ASD systems which has demonstrated and confirmed the power and benefits of the original idea of very high sensitivity, very early smoke detection. These on-going technical developments for an ever widening range of applications have made ASD the choice of major customers for very many different projects internationally.

VESDA in its various forms from the early 1980s until today have been installed not only in telephone exchanges, computer rooms and IT fabrication plants, but in cultural/historic buildings, high tech manufacturing, prisons, hotels, healthcare, logistics warehouses, airports, railway stations, trains, mining, oil/gas facilities and private homes. Some examples are the US Capitol, NASA Space Station, Disneyland, the Vatican, Big Ben, Sydney Opera House, New York Public Library, St Paul's Cathedral (London), and Beijing Olympics Stadium. (Ming He, 2013). In many cases the VESDA systems are not only protecting important assets and financial business streams, but in many cases, they are the first line detection and alarm systems protecting very large numbers of occupants, giving valuable extra time for evacuation and emergency services response.

The installation of VESDA in telecommunication facilities, telephone exchanges, data centres, high technology manufacturing, industrial control rooms and other related facilities appears to have a primary focus on asset protection and business or operational continuity. However, the very early smoke detection by VESDA also provides life safety protection for the employees working in these buildings as they have much smaller fires to tackle and extinguish.

In addition, with telecommunication facilities, and now data centres with VOIP, if those facilities fail due to fire, this can indirectly affect many life safety related functions such as people contacting the emergency services and aged care duress systems. And a lack of early detection in many mission critical buildings, particularly Government facilities, can potentially impact national defence, national security and all emergency services operations, which is where VESDA and ASD performance is crucial.

Similarly, if fires in control systems in industrial plants go undetected or are detected late by other than VESDA and ASD systems, high hazard processes in chemical, nuclear and other industrial plants can get out of control and endanger lives, as in incidents such as Flixborough (Venart, 2004) in the UK. VESDA and ASD has become standard practice for control rooms and systems in mission critical and industrial facilities.

For telephone exchanges in particular, a number of significant fires occurred internationally in telecommunication facilities having just point type fire detection and without VESDA or ASD, with major impacts upon their operational delivery as well as major asset damage. These fires led to significant damage and interruption to public infrastructure at major telecommunication facilities such as Civic/Canberra in Australia (Canberra Times 1961), Bairnsdale in Australia (Rigby, 1970), Hottiger in Switzerland (Pluss and Purt 1971), and Hinsdale in the US (Wiggins, 1988).

In the particular case of the Civic Telephone Exchange in Canberra, a failure to detect a fire in 1961 led to over 500,000 pounds (~US$2 million) damage, and long service delays, with some properties without telephone service for up to months for normal or emergency use. (Canberra Times 1961).

In the Hinsdale case near Chicago in 1988, some 40,000 subscribers lost their telephone service, and O'Hare Chicago Airport, Holiday Inns, and the Federal Reserve bank were cut off as well as many other disruptions occurred, with some estimates of business interruption costs up to US$1 billion. (Isner, 1988). There has not been similar incidents with such major losses in countries where established standards such as NFPA75/76 have been developed and since high sensitivity smoke detection of the ASD type or similar have been properly installed.

A particular fire investigated in a major Government computer centre in Canberra occurred in 1984 in which some AUD$40,000 damage occurred and very serious business interruption with national financial implications resulted. It was a high airflow environment and was fitted, at the time of the fire, with point type ionization smoke detectors. Subsequent testing in-situ by Johnson and the staff of Scientific Services Laboratory (SSL) showed that an aspirated pipework sampling system connected to a VESDA detector gave alarms a significant number of minutes before the conventional point type detectors did in some tests, and in some test fires, the point type detectors did not operate at all. The additional time for staff to be alerted and be able to take action was critical and as a result VESDA systems were recommended and installed. (Johnson, 1986).

A further illustration, documented by IEI, was the case of a major Queensland telephone exchange which had a disastrous fire in 1986, with downtime revenue losses of over AUD$2.5 million, plus capital equipment replacement costs. Two subsequent fires in 1994 with VESDA installed were quickly identified and extinguished with minimal impact and no service interruption. If the VESDA had failed to detect the fire and it had developed in the telephone exchange concerned, the majority of the telecommunications traffic not only for the public but also for the emergency services in the whole state of Queensland would have been disrupted. (IEI, 1986).

In 2002, at a university school of psychology, an electrical fire in a wall cavity of a computer laboratory failed to set off a conventional detection system in the laboratory. However, some smoke penetrated to the main university computer room above and was detected by a VESDA LaserPlus system. While the laboratory suffered some damage, 8 out of the 13 computers in the laboratory were saved. However, far more importantly, the very early detection in the main computer room meant no loss of vital university records, data and equipment critical to university functioning, or exposure of staff or students (Leslie, 1992).

At the Swanbank Power Station, a major fire in an ash plant control cubicle in 1995 caused extensive damage and downtime when the cabinet was completely burned out. As a result, VESDA smoke detection systems were installed in all equipment control cubicles. In 1996, another fire occurred, but was quickly detected and extinguished by control room operators. Only three cable terminals and one wire were burned, with minimal disruption (Anderson, 1996).

In 1995, in the office of New Zealand sporting goods company, a financial controller was working late at night with his phone on “do not disturb”. A very small fire occurred in a capacitor in a light fitting in the adjoining warehouse and was detected by a VESDA smoke detection system. Off-site staff were alerted and eventually got through to the financial officer, who switched off the electricity and a service technician came and replaced the light fitting. The company claims that the incident was close to escalating which could have destroyed large quantities of stock as well as computer and other records, and been a commercial disaster for the company, as well as impacting on the staff member potentially exposed (IEI, 1995).

A very small fire occurred in an IT monitor in the Engineering Office of Queensland Rail in 1996. A VESDA system gave an early Alert signal. The staff in the building were able to be evacuated very quickly and safely. The monitor was removed and the night shift personnel were able to return to their work within 45 min (Batalibasi, 1996).

All of these incidents demonstrate that, where before the VESDA innovation there were major losses in a range of mission critical facilities, the installation of VESDA and other ASD systems have saved lives both indirectly and directly in many cases, and saved property, reduced business interruption and contributed enormously to public safety.

Significant individual contributors

A Prize nomination is expected to be “a single technical development to enhance public safety and its implementation by one or several individuals who made significant contributions to that development”.

Technical developments usually evolve from a continuum of work performed by many investigators, inventors and entrepreneurs – each improving on or taking ideas from the works of others. The VESDA innovation came about through serendipity and a wonderful 1971 conjunction of Australians at the forefront of scientific laboratory instrumentation, bushfire research and the demand for smoke detection with great sensitivity to protect new technology in telecommunication facilities. And the two original inventors, **Gibson** and **Packham**, came together through a shared interest in aviation and fire safety.

David Packham

David Packham was the fire scientist behind the invention of the VESDA smoke detector. **Packham** was part of the CSIRO Bushfire Research Group which was internationally regarded and published many papers on bushfire behavior and smoke characteristics. **Packham’s** special interest was smoke from large natural fires.(Vines et al., 1971). He experimented with the development and dropping of incendiaries from aircraft into forests to study large scale fire plumes and smoke behavior (Baxter et al., 1966).

Packham had studied the characteristics of smoke through use of a laboratory nephelometer, a light scattering device built at CSIRO based on the available concepts (Alquist and Charlson 1967). Eccleston at CSIRO built a scaled down version of the nephelometer under **Packham’s** direction, based more directly on the wooden box nephelometer built by Beuttel and Brewer in about 1943, for the forest fire research program over Western Australia in 1970 in which **Packham** and **Gibson** flew the research aircraft through huge fire plumes and gained further knowledge of the properties of smoke (Vines et al., 1971).

The development of the first VESDA prototypes made by CSIRO and later in the PMG Workshops in Melbourne was led scientifically by **Packham**, who understood the mechanisms of smoke particle physics, scattering coefficients, the importance of multi-wavelength white light on particle detection, and the operation of photo-multiplier sensors (Gibson and Packham 1971).

Packham also provided the scientific foundation to many trials of the prototype VESDA technology in a range of telephone exchanges from 1971 onwards, which led **Packham** and Gibson to believe that, as a result of their investigations, the “nephelometer has an application as a smoke detector to give very early warning on incipient fires” in telephone exchanges (Gibson and Packham 1971).

Packham was responsible for the discriminator and three level VESDA alarm concept, based on a concept he and **Gibson** had seen for emergency management in the aviation industry. Also, **Packham** was in part responsible for the two channel (A minus B) comparison of outside versus inside air which was patented. These elements of the invention were important to discriminate between small smoldering fires and false alarms from contaminants with a device like VESDA which was two orders of magnitude more sensitive to smoke than conventional point type smoke detectors. (Packham et al., 1974).

Other contributions by **Packham** was the design of measures for VESDA calibration with gases of known scattering coefficients, the design of extended field trials for improved statistical understanding of setting alarm levels based on background monitoring, (Hamilton et al., 1976), and helping with design of experiments on the use of small bore piping (aspirated smoke detection ASD) for installations where HVAC systems might be turned off.

In some real sense, however, perhaps **Packham's** greatest contribution to the ultimately successful innovation was his part with **Gibson** in the passionate and continuing belief and advocacy of the technology over a decade to finally find a successful commercialization partner in IEI, despite years of frustration and government bureaucratic obstacles by CSIRO and PMG and their successors.

Len Gibson (deceased).

Len Gibson (deceased) was the fire safety officer at the PMG who had the "light bulb" moment that led to the invention of the VESDA. However, he passed away in 2008. As a result, he cannot be nominated for the Award but is hugely important to recognize as one of the four key people responsible for the VESDA innovation.

Gibson was originally a PMG telecommunications technician and a volunteer fire firefighter with the Country Fire Authority (CFA). He was also an aircraft pilot, and developed a strong interest in aerial observation of fires, flying for the CFA over Victorian bushfires.

Gibson met **Packham** when he visited CSIRO, probably to discover more about bushfires and smoke to help his understanding of exposure of PMG facilities in country areas. **Gibson** seized an opportunity to join the CSIRO forest fires research team in WA in 1970. It was while flying over these huge fire plumes, that **Gibson** had the inventive idea which became VESDA.

Back in Melbourne, **Gibson** created and organized many opportunities for trials of the nephelometer in telephone exchanges, experimented with duct and pipework aspirated systems, helped test VESDA prototypes, pushed PMG to look at commercial production opportunities, and remained involved, with a passion for the technology, and its development and marketing for many years.

Gibson was a co-author with **Packham** and others of a number of technical papers. (Gibson and Packham, 1971; Packham et al., 1974; Packham et al., 1975).

Like **Packham**, **Gibson** was recognized by CSIRO/PMG as the co-inventor, in assigning his rights to the Commonwealth Government of Australia in 1973.

John Petersen

John Petersen was another person critical to the ultimately successful VESDA innovation through his work on applications engineering, standards development, authority approvals and installation practices, as well as his strong belief in the technology and continuing persistence.

Petersen was a senior technical officer in PMG and later Telecom Australia, working on design and installation practices for fire detection and alarms and other building systems. While **Packham** and **Gibson** were trying to solve the scientific and commercialization issues, Petersen led the Telecom Australia team on the further development and manufacture of the dual channel VESDA prototypes and pre-production models. **Petersen** and his group understood that for a practical smoke detection device to be commercially successful, it would need to be robust, would compensate for long term drifts, could be connected to conventional fire alarm panels, and be cost effective to manufacture, install and maintain.

Petersen organized trials of VESDA prototypes in various states, including the Perth trials (Neilson, 1976) in which various duct/pipework configurations were investigated. **Petersen** and **Gibson** were also responsible for designing and conducting many experiments with small bore pipework and pumps that provided the initial basis for aspirated smoke detection systems installed on ceilings and linked to VESDA detectors for areas where HVAC operation was intermittent.

Petersen and his team also designed and built the first single channel VESDA detector that was not bound by the CSIRO patents as he realized that in large telephone exchanges, each VESDA unit did not need its own exclusive comparison channel for outside air in multi-storey buildings, and single channel devices would be cheaper.

It was **Petersen** who showed **Martin Cole** and IEI the single channel prototype he had developed which became the basis of the first commercial IEI unit. He foreshadowed the later replacement of the xenon flash tube and photomultiplier with more robust and reliable solid state devices to minimize maintenance replacements.

Totally frustrated with the CSIRO/Telecom commercialization process, **Peterson** left Telecom Australia and started his own company Monit-Air to undertake the applications engineering and establish the installation practices to provide VESDA systems with market acceptance. He helped Telecom Australia install into their telephone exchanges some of the initial 40 commercial E700 VESDA units manufactured by IEI. **Petersen** also saw wider applications and successfully designed and installed VESDA systems in power stations, computer rooms, cable risers and electronics stores.

Martin Cole at IEI realized the great importance of **Petersen** to the application and future sales of VESDA and recruited him in 1981 to join IEI as leader of its sales and applications division. As part of that role, **Petersen** led the efforts to have the Australian Standard AS1670 recognize high sensitivity ASD systems, and gain SSL Government approvals critical to customer acceptance for both the VESDA detection equipment as well as the ASD smoke sampling systems.

As part of his marketing role, it was **Petersen** who gained letters of approval for VESDA from fire authorities and other market influencers, and had VESDA added to Government procurement procedures and project tender lists. **Petersen** also pushed hard to get IEI to solve early technical problems with VESDA to maintain industry reputation, and helped IEI to publish full technical documentation including technical handbooks, specifications and installation guides to gain further industry acceptance. (Cole, 1985a, b).

Dr. Martin Cole

Dr. Martin Cole was primarily responsible for the commercialization of the VESDA concept and was the enabler for the innovation and its ultimate success which continues to dominate the high sensitivity, aspirated smoke detection market to this day.

Martin Cole studied electronic engineering, and while still a college student at the Royal Melbourne Institute of Technology (RMIT), set up his own electronics company to manufacture laboratory test equipment and process control equipment.

Later he joined with two partners to form Integrated Electronic Industries (IEI) Pty Ltd. **Cole** had the role of Managing Director and was responsible new product development. They manufactured intrusion detectors and other security products and systems. **Cole** was the engineering entrepreneur.

While Wormald, FFE, AWA, SEC and British Aerospace all investigated the manufacture and/or commercialization of the CSIRO/PMG VESDA technology throughout the 1970s, only **Cole** and his electronics company IEI, aided by CSIRO and PMG, were able to develop the first commercially successful E700 VESDA smoke detection system in 1979/80.

The nephelometer prototypes of PMG/Telecom Australia were relatively high cost, suffered long term drift, lacked ruggedness, and were unsuited to volume manufacturing. **Cole** and his IEI team designed the Mk1 E700 VESDA with a solid state PIN-diode as the light receiver rather than a photomultiplier.

Indeed, the photomultiplier-based design was considered so unreliable in the field over the long term, that the initial VESDA production run of 40 units was recalled by IEI and the photomultipliers were replaced with these solid-state receivers at no charge. With this innovation, together with enhanced electronics, the reliability of VESDA improved and sales and installations in Australia grew.

However, **Cole** understood the science of smoke and light scattering (Cole, 2009), as well as engineering and manufacture of alarm systems, and saw that significant further improvements were required for greater sales to the Australian fire protection industry, and particularly for export. **Cole** applied that knowledge to the development of the Mk2 E700 VESDA with improvement to features including greater reliability, miniaturization, reduction in fluid kinematic losses, solid-state detection, signal processing, controls, displays, battery standby operation, ruggedness, cost reduction, and larger scale manufacture (Cole, 1983). This work and subsequent developments led to some 11 groups of patents in relation to VESDA being awarded to **Cole** from 1983 to 1995 (Cole, 1999a).

Cole saw the opportunity for the IEI E700 VESDA systems to form part of a fire protection system for a much wider applications beyond telephone exchanges and computer rooms. Through the 1980s and 1990s, **Cole** led the further development of concepts for sampling at the ceiling, within equipment cabinets and from ductwork and produced a series of design guidelines. This included ductwork sampling for hotels, apartments, hospitals, prisons, dormitories, schools, trains and ships, as well as smoke detection for cable tunnels, transformer halls, control rooms, broadcast transmitters and switchboards (Cole, 1999a).

With the technology proving successful in Australia, in 1983 **Cole** started exporting to USA, UK and NZ and later set up his own IEI companies in those countries, as well as other distribution channels in Japan and Europe to deal with growing export orders.

Cole was not satisfied by the ad-hoc design of the aspirating system crucial to VESDA performance where HVAC systems were absent or could be turned off. He investigated small bore pipework systems for smoke sampling through his own research and developed the world first reliable design software Aspire™ (Cole, 1991) and later through his PhD research the software Asyst™ (Cole, 1999a, b).

Through this work, **Cole** developed a whole new approach to aspirators, backed by a Master of Engineering research degree at Monash University. The unique and patented aspirator was incorporated in the Mk3 E700 VESDA.

After **Cole's** firm IEI merged with Vision Systems Ltd. (VSL) in 1995 (Styles, 2008), **Cole** as part of the VSL R&D team replaced the xenon flash tube with a solid state IR laser for greater reliability and minimal maintenance. This became the second generation VESDA technology (Cole, 2009).

This VESDA technology was sold to Xtralis, and more recently to Honeywell, and Cole was no longer involved.

However, **Cole** independently developed the third generation, dual wavelength technology for smoke detection using powerful blue and infra-red LEDs which he sold to Siemens in 2007. (Cole, 2009).

Graham Strahan, Peter Patroni:

Martin Cole had two fellow Directors at IEI Pty Ltd. who had associated roles but not the major influence over the VESDA innovation. **Cole** was the Managing Director and took personal charge of the design and development of the VESDA technology and its international marketing. His production manager and Technical Director was Graeme Strahan, while Peter Patroni was Sales and Marketing Director for security products throughout Australia. Their major business as an electronics company was the design, manufacture and assembly of security systems, and VESDA, at least initially was a small part of the IEI business and much more driven by **Martin Cole**. However, Strahan and Patroni no doubt played a contributing role to the commercial success of IEI.

SSL- McDevitt, Rigby, Cooper, Johnson, Timms

The testing for type approval was undertaken at what became Scientific Services Laboratory (SSL). Some key SSL staff such as Bill McDevitt, Ivan Rigby, Russell Cooper and Peter Johnson had undertaken very significant research into the performance of heat and smoke detectors which led to the development of Australian Standards CA15 and later AS1670 for smoke detectors.

Rigby and Cooper had also conducted a significant number of investigations of fires and failures of conventional point type smoke detectors in telephone exchanges, such as at Tally Ho and Bairnsdale (Cooper, 1969) (Rigby, 1970). One of the first applications of an early VESDA with an aspirated system was conducted in an SSL investigation at Nowra Avionics Workshop in 1978 (McDevitt et al., 1978), and SSL staff developed test methodologies to evaluate VESDA detectors and aspirated systems for type approval and national listing in 1981, 1983 and 1984.

Johnson published a number of papers on the applications of VESDA systems in high airflow computer rooms and telephone exchanges to demonstrate the effectiveness of the early warning to limiting damage and downtime (Johnson, 1983, 1986, 1988).

However, while the SSL approvals and technical papers written helped pave the way for greater acceptance of the VESDA technology and aspirated systems in the marketplace both nationally and internationally, it could not be said that the SSL staff were integral to the VESDA invention and commercialization.

Telstra staff

The PMG, when it de-merged into Telecom Australia and Australia Post, had a number of key fire safety officers who continued the work of **Gibson** and **Petersen** in promoting VESDA and trialing it in existing telephone exchanges or installing IEI systems in new facilities. These included Rob Llewellyn, who became Chief Fire Safety Officer for Telecom Australia. Again, while they helped promote the technology in different ways, they were not fundamental to the VESDA innovation.

Other IEI staff

A range of other IEI staff played important roles in the promotion of the VESDA technology into the global marketplace and helped drive standards development, applications and market development strategies. Key people included Frank Vandemeer, who was appointed by IEI as national marketing manager and later took over the management of IEI (UK). A major influence in the US was Bill MacDonald who was the first manager of IEI (North America).

CSIRO

Packham's work on bushfire smoke which informed his work on the properties of smoke and the role of the nephelometer in the field of building fire protection was enhanced by his working collaboration with world renowned bushfire researchers at CSIRO including Dr. Alan King, Dr. Robert Vines, David McArthur and others. Special mention is required of Tony Eccleston, a CSIRO electronics specialist who built the scaled down nephelometer to fit into the aircraft for the WA forest fire test program. Finally the work of CSIRO experimental officer M. Linton contributed to the early experimental work with VESDA and early papers and other publications.

Conclusions

The 2017 Phillp J. DiNenno Prize was awarded to the innovators of the VESDA smoke detection system. The technology was invented by **David Packham** and **Len Gibson**, who worked with **John Petersen** on prototype development, field trials, and applications engineering. **Dr. Martin Cole** was responsible for the successful commercial development and many further patented technical developments. The VESDA technology and its pre-eminent role in the introduction of aspirated smoke detection (ASD) internationally has led to a major global impact on public safety.

The recipients of the 2017 Philip J. DiNenno Prize are **David Packham**, **John Petersen** and **Dr. Martin Cole**. Ample commendation is given to their deceased co-inventor and passionate advocate **Len Gibson**. Other important contributions are noted, including technical and other staff from IEI, CSIRO, SSL and Telecom Australia.

Timeline

1940s First light scattering instrument developed for measurement of visibility through air by the Royal Air Force UK.

~1943 Wooden-box nephelometer built by Beuttell and Brewer for visual range measurements for military purposes.

1961 Major disruptive fire in Civic Telephone Exchange, Canberra.

1962 **Packham** joined CSIRO Bushfire Research Group.

1966 **Packham** publishes paper on mapping for forest fires through smoke.

1967 **Gibson** promoted to Regional Fire Safety Officer at PMG with responsibility for telecommunication facilities.

1967 Ahlquist and Charlson developed laboratory nephelometer for monitoring air pollution.

1969 **Gibson** publishes paper on application of aircraft to bushfire control and **Petersen** develops an approach to smoke testing of detection systems in telephone exchanges.

1970 Eccleston at CSIRO builds the first nephelometer for WA bushfire test progam.

1970 The idea of the future VESDA comes to **Gibson** flying with **Packham** over WA forest fires in CSIRO research program.

1970 **Cole** and Partners start Integrated Electronics Industries (IEI).

1971 Vines, **Packham**, **Gibson** and others publish their seminal paper on the nature and properties of bushfire smoke.

1971 **Gibson** and **Packham** conduct their first experiments in telephone exchanges with nephelometer demonstrating high sensitivity smoke detection.

1971 **Packham** and **Gibson** publish first CSIRO/PMG report on successful test program.

1972–3 Prototypes developed by **Petersen** and further experimental test programs conducted in a range of PMG facilities for proof of concept by **Gibson** and **Petersen.**

1973 Three level alarm concept and aspirated pipework system concept developed by **Packham**, **Gibson** and **Petersen.**

1973 CSIRO granted patents for VESDA invention in Australia, and applications made for other international patents.

1973 **Gibson** and **Packham** assign their rights of invention to the Commonwealth Government of Australia.

1974 The first full scientific paper on the complete VESDA concept published by **Packham**, **Gibson** and Linton.

1974 CSIRO/Telecom Australia (formerly PMG) start their push for VSEDA commercialization (unsuccessful).

1976 Extensive test program at HMAS Albatross, Nowra, by CIRL (later SSL) using an aspirated VESDA system.

1976 **Petersen** worked with Standards Australia to clarify that aspirated VESDA systems could be installed in compliance with the installation standard AS1670.

1977 **Gibson**, **Petersen** and **Packham** link up for the first time with **Cole** at IEI for potential commercial development.

1978 First production run of 40 Mk1 E700 VESDA units manufactured by IEI.

1979 Petersen leading the first installations of VESDA in Telecom Australia properties.

1979 **Gibson** and **Petersen** conducts experimental research into aspirating system design and developed design principles.

1980 First VESDA System Equipment Manual developed by **Cole** at IEI, and VESDA Installation Guide developed by **Petersen** at IEI.

1981 **Petersen** joins **Cole** at IEI as National Sales Manager to drive applications and sales.

1981 Mk1 E700 VESDA approved and listed by CIRL, later named Scientific Services Laboratory (SSL).

1982 Mk2 E700 VESDA version extensively re-engineered by **Cole** for commercial export.

1983 **Cole** granted extensive patents for Mk2 VESDA.

1983 **Cole** and IEI started marketing VESDA into UK and North America, and later Japan and Italy.

1984 Mk2 E700 VESDA and aspirated system approved and listed by CIRL (SSL).

1986 Johnson publishes paper in *Fire Technology* on test program and successful implementation of VESDA in major Canberra computer centre.

1991 **Cole** develops the science and fluid dynamics engineering design basis for airflow in small bore, aspirated pipework systems for smoke detection with publication of his Master's thesis and develops Aspire ASD pipework design software. **Cole** also invents the high-efficiency, purpose-built aspirator for high pressure (>300 Pa), low power (2 W), long service life (>10y) and rapid response.

1991 **Cole** teams up with Nohmi Bosai (Japan) to help buy-out his two original IEI partners.

1995 IEI and the VESDA rights are acquired by Vision Systems Ltd. (VSL).

1996 Vision Systems launches new-generation VESDA LaserPlus, based on new patents.

1999 **Cole** departs VSL. He completes further research and PhD on modelling of disturbed flow regimes in aspirated pipe systems and develops Asyst ASD pipework design software, resulting in much more accurate simulation of individual sampling-point sensitivities and response times.

2005 **Cole** completes his invention of Monitair™, the 3rd-generation ASD using powerful dual-wavelength LED's to discriminate between smoke, and dust or steam. **Cole** earns the Engineers Australia, National Engineering Excellence Award for Innovation. The largest markets for Monitair are China, Taiwan and South Korea.

2006 Vision Systems Ltd. sells Vision Fire and Security (VFS) Division, including VESDA technology, to Pacific Equity Partners and VFS is re-branded as Xtralis.

2007 Siemens acquires the rights to Monitair, and **Cole** leads the development of Siemens' own version, known as FDA (Fire Detector Aspirated). This includes a new mini-aspirator design for small areas.

2016 Honeywell acquire Xtralis and the rights to VESDA

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