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White Paper

GPS GSM

Personal Emergency Location Devices for: the Aged, Disabled, Domestic Violence Victims and Lone / Remote / Isolated Workers

Personal Emergency Location Devices for Aged care, Disabled, Domestic Violence victims and Lone, Remote or Isolated Workers

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Overview

In our white paper, "**Personal Emergency Location Devices for the aged, disabled, Domestic Violence victims and Lone / remote or isolated workers**", we explore the issues that affect the performance of these various users.

For years, it has been generally considered that portable or personal emergency location devices have the same issues as vehicle trackers. This is only partly true but there are major issues that confront the design, performance and use of personal emergency location devices.

When releasing a product into the market place we find that there is little information and no expertise by manufacturers, suppliers or users. It is even harder to find consultants that have a good understanding, knowledge or ability to compare devices.

This document is aimed at educating and raising awareness to the unique issues of these personal emergency location devices.

Why the white paper ?

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Why is personal emergency location required?

Personal GPS emergency location devices can be used in many applications.

Domestic Violence Victims

- Monitor SOS alerts from victims of domestic violence that needs help
- Monitor against a sudden impact (fall)
- Monitor the response of a victim (Welfare timer)

Lone or Remote or Isolated workers

- Monitor SOS alerts from staff or a user that needs help
- Monitor staff or a user stays out of dangerous areas (geo fence)
- Monitor staff or a user to keep inside a geo area (safety or political reasons)
- Monitor staff or a user to keep below speed limits (inside a hospital, power station or a university they may have a speed limit of 40km)
- Monitor for the lack of movement (the person may be unconscious)
- Monitor against a sudden impact (fall)
- Monitor temperature in staffs/user's environment (maximum temperature e.g. limit maybe 50 degrees with a 5 minute limit or a Min 0 degrees with a limit of 5 minutes)
- Monitor the response of a worker (Welfare or Deadman timer)

Elderly / Disabled

- Monitor an SOS alert from a loved one that needs help
- Monitor an elderly person's location so they stay within a specified boundary (geo fence)
- Locate a loved one when they are overdue or missing, or even monitor their progress to and from the shops as they may get disoriented or confused about their location

Children

- Monitor an SOS alert from a child that needs help
- Monitor a Childs location so they stay within a specified boundary (geo fence)
- Locate a child when they are overdue or missing, or even monitor their progress to and from school

Sports Event Progress Tracking

- Small / light weight - with emergency response.
- Press the button when you reach a spot on the Track or Stage of the event.

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Background

GNSS

Global Navigation Satellite System **GNSS** is now the generic term for all satellite navigation systems (Constellations) that provide autonomous geo-spatial positioning with global coverage. This term includes the **GPS**, **GLONASS, Galileo, BeiDou** and other regional systems or satellite constellations. The advantage to having access to multiple satellites is accuracy, redundancy and availability at all times. If line of sight is obstructed, having access to multiple satellites is also a benefit.

The Russian Federal Space Agency developed **GLONASS** to compete with GPS, although it does not have the coverage of the GPS system. More recently **Galileo** the European Union's positioning system, India's **IRNSS**, Indian Regional Navigation Satellite System, Japan's **QZSS** Quasi-Zenith Satellite System and **BeiDou** the Chinese Navigation Satellite System are now being used in their specific regions.

GPS

Global Positioning System (GPS) is a global radio-navigation system maintained by the United States Government. There are 32 satellites in the GPS constellation, 27 in use and spares. See reference (1) Constellation Status.

GPS is currently the world's most utilized satellite navigation system.

The satellites complete a full rotation of the earth in 12 hours whilst sending radio signals from 20,000km.

There are three main elements of data transmission emitted from orbiting satellites.

The first element contains the GPS date and time, plus the satellite's status and indication of its health.

The second element contains orbital information (ephemeris data) which allows the receiver to calculate the position of the satellite. Whilst ephemeris data is very detailed, it is only valid for a maximum of four hours. If the signal from a satellite is lost while the ephemeris data is being acquired or received, the receiver must discard that data and start again. This can easily occur in weak signal areas.

The final element, called the Almanac, contains information and status concerning all GPS satellites and is valid for up to 180 days. It may take up to 12.5 minutes to receive the entire almanac from a single satellite.

GPS uses up to 32 Satellites at an altitude of 20,000km

The system was initially designed for use by the U. S. military but today, there are millions of commercial and civilian users of the GPS system around the world.

Users are allowed to use the Standard Positioning Service without any charge or restriction.

The GPS system utilizes a frequency of 1575.75MHz for non-military applications.

For those who require additional information regarding GPS transmission, see reference [2]

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How do GPS or GNSS location systems work?

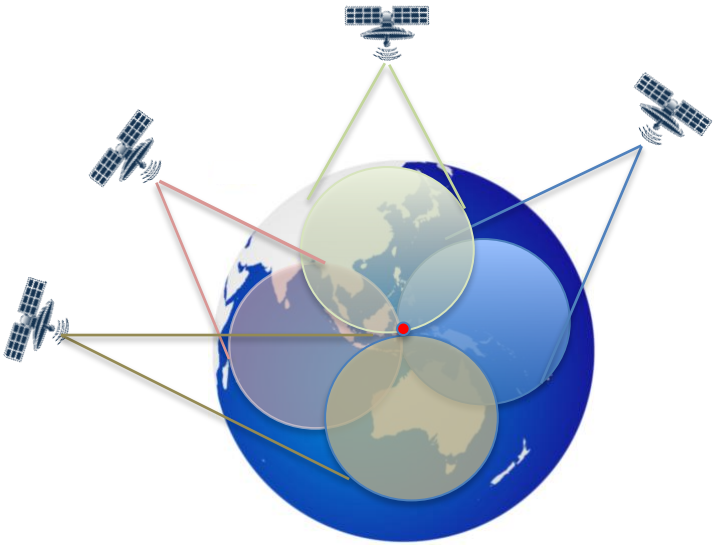


Figure 1: a pictorial description of triangulation.

GPS Satellites use atomic time which is one of the most accurate time references and is transmitted on a continual basis.

Data transmitted by orbiting satellites also includes a unique ID (PRN code), time of transmission and location of the satellite.

Data from multiple satellites is required to be simultaneously received, thus allowing computation of the receiver's position in three dimensions by calculating the time that the signal has taken to travel between the satellite and the receiver.

In order to obtain GPS location, the receiver (1) computes distance from the satellite and (2) decodes broadcasted data to obtain the Location of the satellite. These functions are computed for each satellite.

To determine distance between satellite and GPS receiver, the receiver calculates the time difference between transmission of data and its reception. This is enabled by the broadcasting of atomically accurate time information by the GPS satellite.

$$\text{Distance} = \text{Speed of light} \times \text{Time}$$

Where **speed** is 299,792 km/second (speed of light) and
time is time of transmission minus time the data is received.

Using this simple equation, the receiver calculates distance between the receiver and the satellite.

A receiver requires Distance to and the Location of at least **four** satellites (not three as commonly believed) to estimate four values; the longitude, the latitude, the altitude and the precise time. The combination of this information provides precise coordinates of the GPS receiver.

The Location and Distance to a given satellite determines a spherical area of space that the receiver is positioned (refer to Figure 1). The intersection of four such spheres determines the three earth coordinates: Longitude, Latitude and Altitude of the GPS receiver.

The main reason why a fourth satellite is required for accurate GPS location calculation is the monetary impracticality of the incorporation of an atomic clock in the GPS receiver. Location information from three satellites will provide accurate location information *only* if the designer incorporates a $50,000 atomic clock in the receiver to obtain precise time. The receiver's clock must be precise in order to calculate accurate Distance. Hence, the use of a fourth satellite and its transmission information is an economical solution. This additional satellite is used to help adjust the time in the receiver so that the locational spheres intersect at a precise location. The receiver will perform the necessary adjustment continuously, which enable accurate time comparable to an atomic clock.

Errors

Position errors can occur due to receiving weak reflected signals from adjacent buildings. Since the signal is "reflected" and not "direct", its transmission path is longer, thus influencing the simple distance to satellite calculation and location triangulation. The more satellites and the better the signal strength that can be received the more accuracy or Degree of Precision (DOP).

Passive GPS

A passive GPS tracking system will monitor location and will store the data of journeys based on time or distance. The tracker will log (using internal memory) the location of where a tracking device has been over the last eg 24 hours. This data can be downloaded via for example USB, BT or WiFi to a computer at a later date for analysis.

Active GPS

An active GPS tracking system is also known as "real-time". The GPS device automatically sends the location information from the GPS device to a central server
in "real-time" at regular intervals or based on distance travelled or when movement is detected. This is a useful way of monitoring the safety, environment and behaviour of employees as they carry out their work.

This system can be used for fleet tracking or monitoring people, such as children or elderly. Hence, it allows a Parent or Carer to know exactly where loved ones are, whether they are on time and their location.

Glonass

As mentioned earlier, in addition to GPS, there are other Satellite Systems now in use and being developed. The term "Global Navigation Satellite System" (GNSS) is now commonly used to describe these networks.

The Russian Federal Space Agency "**Global Navigation Satellite System**" (GLONASS) was developed to compete with GPS, although it does not have the coverage of the GPS system. More recently the European Union's "**Galileo positioning system**", India's "**Indian Regional Navigation Satellite System**" (IRNSS), Japan's **"Quasi-Zenith Satellite System"** (QZSS) and the Chinese "**BeiDou Navigation Satellite System**" (BeiDou) are now being used in their specific regions.

Latest chipsets now allow for the use of multiple satellite constellations. GPS and Glonass as an example may be used in one country or region while GPS and Galileo may be used in another. This dramatically increases the number of available satellites for the new chipsets, which can handle more than 50 channels/satellites simultaneously, whereas older designs are limited to 20 channels/satellites. This improves the ability of the device to track in built-up areas "urban canyons" or valleys where only a small or limited view of the sky is available and therefore a limited number of satellites are in view.

LBS

The wider use of the 4G network allows for the use of the **Location Based Service** (LBS). There are two types of cell based location systems.

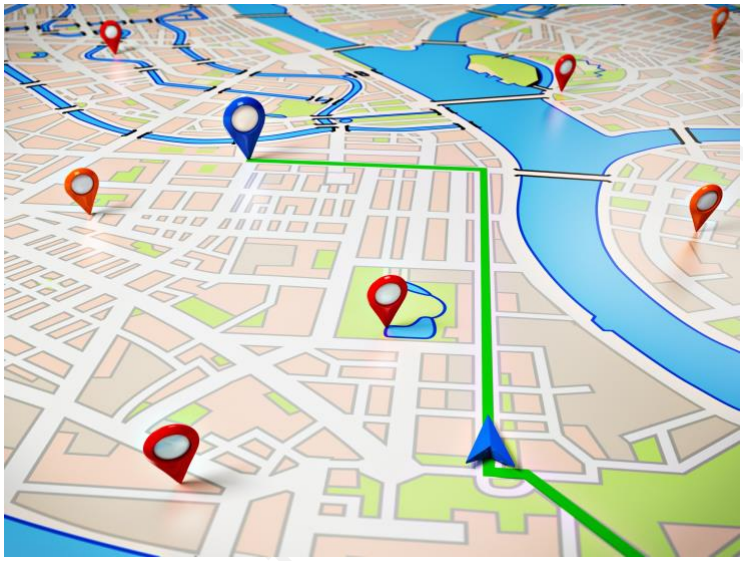
The LBS system does have major drawbacks. Best accuracy maybe approx. 50 metres but in areas where there are few cells e.g. regional areas where multiple cells are some distance apart and may be in line and not allowing triangulation. In these situations can give large location errors.

GSM Network calculated location

The GSM network using multiple cells to receive the devices GSM transmission can analyze the received signal and determine approximate location of the GSM device.

GSM Device calculated location

Device calculated location based on information received from the multiple cells. A 4G cell broadcasts MCC, MNC, LAC, CID, RXLEV. Multiple cells info can be sent to a reference server for the server to calculate approximate position.



WiFi positioning systems (WPS) or WiPS/WFPS

The use of WiFi in many mobile phones is now being used to give rapid approximate location. The WiFi MAC address, SSID with the Received Signal Strength Indicator (RSSI) can be used for indoor location and if multiple WiFi MACs can be detected with signal levels, the device can give approximate position inside providing there are enough WiFi hotspots or Access points. Obviously the WiFi MAC address, SSID and WiFi's location need to be known. This could be used to supplement the GPS when GPS location is not available.

Hybrid positioning systems

These are systems for finding the location of a mobile device using several different positioning technologies. Usually GPS (Global Positioning System) is one major component of such systems, combined with cell tower signals, wireless access points (AP), Bluetooth® or TV transmission towers.

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Old Technology Devices

Many old technology devices are still being sold. Advances in technology since the early 2000's provides greatly enhanced performance in comparison to earlier devices.

Battery

Older battery technologies such as NiCad or nickel metal hydride had problems with battery life, standby time, recharge time, memory effect and number of recharge cycles.

GPS chipsets

GPS technology was mainly focused on the SiRF Star 3, which was released in the early 2000s. At the time this was a major leap forward in size and performance from early generation discrete systems. Since then, later technology has greatly exceeded the performance of this chipset in many areas.

The limitations of the earlier versions of GPS chipsets became very obvious when used in a Personal Tracker/Emergency location device. Poor battery life, poor tracking or location near buildings and virtually nonexistent tracking inside buildings. The devices were bulky and if larger battery was used to extend battery life to achieve a full days use without the need to recharge the battery, the extra weight made impractical for a normal user as it was heavy and bulky for a pocket or pouch. Longer term, the battery memory effect virtually reduced the battery capacity and run time of the product.

Antenna

Antennas were mainly large ceramic and somewhat directional. This was compounded by PCB layout.

Low Noise Amplifier (LNA)

A low noise preamplifier was required to give maximum performance of the SiRF Star 3 that is around -159dBm although few products achieved this figure.

Current consumption

The current consumption of the LNA and Sirf3 chip was in excess of 70mA (this does not include the GSM modem current consumption or processor). When using for example an 800mAh battery together with long TTFF and high reacquisition times gave a personal location device very poor battery life.

Time To First Fix (TTFF)

The TTFF was often more than 90 seconds (open sky). If the device was moving when trying to first fix, this could take many minutes depending on environment. See earlier reference to receiving Ephemeris data.

UDP versus TCP

Many trackers use UDP as a way of transmitting data to the server.

For event transmission, the use of UDP is fast but comes at a price. There is no guarantee delivery occurs unless extra transmissions are used to acknowledge the received data. The use of TCP is recommended for SOS type events.

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Latest Technology

Batteries

Developments in batteries has increased capacity, reduced size and virtually eliminated memory effect.

Currently Lithium Ion and Lithium Polymer batteries are more widely used than other battery types. Driven by mobile phone use, there is an ongoing race to reduce the size while increasing the capacity of batteries and decreasing recharge times.

Antennas

Antennas have become miniature with lower power LNA and higher sensitivity chipsets that have increased the sensitivity by 6dbm.
Newer antenna design has made the antennas less directional. With a personal tracker this is very important as the orientation of the device will never be optimal. Currently -162 to -167dbm is common amongst the newer designs.

Reference servers

GPS reference servers are now available to allow the downloading of the current Ephemeris data and Almanac data for a few days (or even up to over 30+ days) ahead.

The GPS Almanac, as part of the data transmitted by each GPS satellite, contains coarse orbit and status information for all satellites in the constellation, an ionospheric model, and information to relate GPS derived time to Coordinated Universal Time (UTC).

This data will allow the GPS device to start up as if in a "warm start" mode and get a fix much faster than the “TTFF” of other "cold start" devices.

2G versus 3G or 4G

Older systems use 2G (and the majority of devices sold still do), but there is a major drawback when tracking using a 2G modem. The 2G modem can only do voice **or** data … **but not both** simultaneously. So while tracking the movement in an emergency you cannot talk to the user at the same time…**its one or the other**.

3G and 4G devices have separate voice and data channels so tracking data can be sent at the same time as a voice call. This is important in many personal emergency location applications. e.g. If an SOS is received from a device …verification may be required to enable a "scale up” in the response or clarify the type of SOS response. Verification is normally done with the voice channel using one way "listen in" or two way hands free. So for example, a security guard may create an alarm or SOS. To verify the alarm or communicate with the guard you can call the guard to but you still
want to simultaneously track the device.

The other major advantage of 3G and 4G over 2G is the faster session setup time and transmission time.

2G/3G GSM network usage

“Network closure of the 3G network imminent".
Many countries have announced the dates they intend to shut down the existing 3G GSM network. This will occur in all countries as the race for 4G expansion and the use of 5G increases

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Current trackers use 3G but only a few use 4G

Since more than 99% of tracking and emergency location systems use the GSM network are using 3G. This creates both a problem and an opportunity for upgrading older generation devices to the latest generation 4G with GNSS receivers and with that upgrade comes latest technology batteries, antennas and GPS chipsets with superior performance.

Indoor Positioning

Indoor and outdoor location using GNSS, WiFi and Bluetooth® and Dead Reckoning (DR).

Most Personal emergency location devices need to work outdoors although this does not mean it needs to be waterproof. But people also work indoors, so the devices needs to work to some degree indoors to enable the location to a building or position inside the building.

As technology advances there is more accuracy and sensitivity for outside use but that does not mean better indoor performance. Bluetooth®

The use of transponders (Wireless access points, Bluetooth® beacons) and similar wireless systems will help to locate the device near know Bluetooth® Beacons, WiFi modems and access points (AP). This should only be used if the access points or Bluetooth® beacons are known and are whitelisted to be used by the device.

Dead Reckoning (DR)

The use of Dead Reckoning will help when these APs or Bluetooth® beacons are not available. This will dramatically help in supplementing the location indoors. In shopping centres, airports, hospitals or government buildings, the use of wifi in the offices may be adequate but in corridors, lifts, carparks or tunnels the dead reckoning will add significantly to the total system performance.

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Running Costs

SIM Costs

There are other considerations when using and designing a GPS tracking device and location system. The carrier SIM card costs can dramatically affect the running costs and therefore the viability of the system.

The sim cost can include SIM card monthly fees, the use of **Data**, **Voice** and **SMS**.

The interval between transmissions of location data, size of each packet, the use of sms and the use of phone calls will all effect the monthly sim card costs.

The use of phone calls to and from the tracking device as well as adding increased cost, dramatically reduces battery life.

Consider why the call is needed and whether it is better via another form of communication.

Server Costs

Then the monthly server hosting, software licensing fees will also add to the total running cost of the system.

Mapping Costs

Mapping service providers charge for the use of their services. Depending on usage these costs can be substantial so this needs to be known and calculated in the total running costs

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Legislation on "Lone and Remote Workers"

The following countries have enacted lone worker legislation:

- Australia
- Canada (Provinces of Alberta, British Columbia, Manitoba, Saskatchewan)
- France
- Germany
- The United Kingdom
- Spain

In Australia, state governments are following the trend from other countries in putting pressure on employers to "continuously monitor the wellbeing of lone and remote workers".

http://en.wikipedia.org/wiki/Lone_worker

Victoria has passed legislation making it Industrial manslaughter if a company and its management are negligent in their duty of care for Lone and Isolated workers. These new manslaughter laws came into effect July 1, 2020, in Victoria, with large fines and prison time for negligent Employers. Worksafe has created a special unit to investigate deaths in the workplace.

The use of emergency location systems for lone and remote or isolated workers

The use of monitoring systems and equipment (Panic Alarms, Man-down (fall / impact) Detectors, Pendant Trackers) is becoming widespread and there is an ongoing need for practical, reliable products and systems.

A lone worker may be ...
A person working at home such as telemarketers, affiliated marketers, writers, workers in the oil, gas and energy Industries including subcontract workers like surveyors, land managers, drillers and midstream or downstream workers such as refinery workers and drivers.
Construction workers.
Real estate agents.
Mobile workers such as traveling salesmen, truck drivers, delivery staff, health care workers, service and installation technicians.
People who work in any type of Manufacturing facility.
People working outside normal hours such as security guards and cleaners.
Utility workers such as meter readers or technicians.
Self-employed people.
People who work apart from their colleagues such as receptionists, retail clerks, service station attendants

It is also important to think of the practical side of the use of the device.
The physical shape, weight and operation need to be easy to reach, easy to operate and easy to recharge. The Housing /Case design, indicators and user feedback are important to the overall use of the system.

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What can be Monitored?

There are many things that can be monitored but not all are relevant to all user requirements.

- Monitor for and SOS alert from staff needing help.
- Monitor staff stay out of dangerous areas (geo fence).
- Monitor staff to keep inside a geo area (health, safety or political reasons).
- Monitor staff to keep below speed limits (e.g. inside a hospital, power station or a university they may have a speed limit of 40km).
- Monitor for the lack of movement (the person may be unconscious).
- Monitor against a sudden impact (fall).
- Monitor temperature in workers/user's environment (maximum temperature e.g. limit maybe 50 degrees with a 5 min limit or a Min 0 degrees with a limit of 5 minutes).
- Monitor the response of a worker (Deadman timer).
- Location of the worker.
- Worker environmental sensors.
- Hi Sound level.
- Cancel alert.
- User feedback to show progress of timers and limits eg temperature
- Low battery or battery status
- Charging status.
- On/Off environmental monitoring outside hours.

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Warning

General comments or things to be aware of:

There are many things that can be monitored but not all are relevant to all user requirements.
It is not good idea to allow/promote users can regularly chat to carers using the device. Battery life is extremely important on a mobile PERs device. It should only be used for emergency.

Making outgoing calls from device is dangerous and it is preferable to send alerts to carers and let carers ring back the device based on coverage, variation in availability/roster of carers and holidays etc.

Sim should be controlled by Carers or Monitoring Centres to continuously monitor functionality against reaching any data, sms or voice call limits.

GPS may not function well when inside or near a building. If the device is not doing regular GPS updates to keep the GPS satellite data fresh (warm start) then when the SOS is pressed, the location may not be able to be obtained. Often when this occurs the device will send the last known location. Unfortunately, this may have been 3 months ago in another state…. This will happen.

Watches can have specific issues: Poor battery life, Poor GPS performance, small speaker can give poor audio performance.

Many vendors say we can get multiple days from the battery. If you have GPS turned off (see issue raised above), and don't use GPRS only using SMS then battery life looks great except there is no supervision (device may be dead).

Using SMS increases battery life but at high risk.. SMS does not have a guaranteed delivery or acknowledge if received, so device does not have knowledge of receipt.

Smaller antennas in the watches mean.
Most watches don't work properly on 4G Band 28 (700MHz). This applies to other mobile PERs devices. This is an excellent frequency and used by Telstra and Optus as it has good in building penetration and refraction over hills. This frequency is used extensively in regional areas to get better range. Unfortunately, low frequency means longer wave length and therefore bigger antennas and a small device like a watch it is very difficult to get this working. Many device venders find it too hard to get the Band 28 functioning.

WiFi is used a lot by devices with poor gps performance (including most watch makers) as it can be used to reduce battery use. BUT it is extremely inaccurate and often based on an old WiFi data base. (5-10 years old).

Having tested some 25 watches and other small personal emergency location devices, virtually all use old an data base.

Example, press SOS and the device may show 6 houses up the street or does not show on map at all as the WiFi modem is not registered on the database.

From tests we have found this is unfortunately very common.

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About the Company and the author

MCM Electronics Pty Ltd
Together James Neville and William Gribble founded MCM Electronics Pty Ltd in May 1985 with the mission, "To design and manufacture high quality innovative electronic security and communications products, giving personalized service to our customers and become a "technology" and "service" leader in the security and communications industry." That's over 30 years in business.

William retired in 2006 giving James an opportunity to move the company into new directions and markets. MCM is still an Australian Owned company based in Penrith NSW, serves a dynamic market and customer base, providing a diverse range of standard and custom products ranging from low to high volume.

One of the industry's most respected and dynamic companies, MCM supplies products to suit the Residential, Business and Financial markets. The staff at MCM bring decades of combined experience in the areas of design, manufacturing and support of electronic products.

MCM Electronics is the market leader in the field of GPS tracking, GPS/GSM Personal and vehicle location devices, IP, Ethernet and GPRS dual path communications for alarm systems, manufacturing a range of panels and adapters. MCM has continued to dominate in the field of alarm transmission systems and networks.

MCM is a member of A.S.I.A.L. the Australian Security Industry Association Limited see http://www.asial.com.au and is an industry representative on the Australian Standards see http://www.standards.com.au. MCM products are designed to meet Australian Standards and have been tested and certified to meet the requirements of the A.C.M.A. see http://www.acma.gov.au

MCM has been developing tracking and personal emergency location devices since 2004 and has a large client base with partnerships leading software developers.

MCM was awarded a "Platinum Membership" from the industry association ASIAL acknowledging MCM for its valued contribution to the security industry over many years. In 2019 James Neville was awarded the Individual Technical Achievement of the Year.

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Endoresements

- The Health Services Union (HSU),
- Wesley Mission

References

(1) http://www.navcen.uscg.gov/?Do=constellationStatus

(2) http://www.gps.gov/