NAVIGATION

Newsletter of the Australian Institute of Navigation Inc

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Prof Chris Rizos, President AIN

The key event in the last month from an AIN perspective was co-sponsoring and co-hosting along with Defence a national-level Seminar in Canberra on 22 May on '*Civil and Military Operations in a Satellite Navigation and Satellite Communications Degraded Environment'*. The Seminar was a great success, with over 100 participants from across Defence, Government and the AIN. I presented on behalf of the AIN, and the Executive Secretary, AVM Kym Osley (retd) was the Master of Ceremonies for the day.

A more complete report on the Seminar appears within this newsletter and a full Summary of Proceedings will be published in the near future and sent to all AIN members as well as the Seminar Participants. Since the last Newsletter in March I have been active attending various international Conferences, and also am able to provide a short report on these.

The rapport that we have established with the School of Navigation Warfare at HMAS Watson and the School of Air Warfare at RAAF East Sale has continued to grow with further AIN awards being issued to the most recent Dux of the RAN Intermediate Navigation Course (congratulations to LEUT Rebecca Wheldrake, RAN) and AIN Awards for Navigation Excellence being presented to a graduate of the first two ACO courses for 2015. OFFCDT Liam Ryan won the AIN Award for Excellence in Navigation on 26 Air Combat Officer Course (ACO) and PLTOFF Timothy Sexton took the Award on 27 ACO.

In early May we joined the Nautical Institute and the Master Mariners for another joint dinner/speaker evening at the Occidental Hotel which was a great success with about 18 AIN members in attendance. Regretfully I was absent on business, and could not attend. But I definitely will be at the next one – as I am the guest speaker!

Coming up soon, and taking an increasing amount of my time, is the upcoming conference of the International Global Navigation Satellite Systems Society (IGNSS) 2015 planned for the Gold Coast on 14-16 July 2015. This is another opportunity to showcase the professional expertise that Australians have in the sciences of satellite navigation; and hopefully further attract members to, and interest in, the AIN.

As previously mentioned, in August we plan to join the NI and MM for another joint dinner/lecture – and this time I will 'sing for my supper'! I have been asked to present on 'Trends and Mega Trends in Navigation'. I hope some of you in Sydney can make it.

Since we are an active Institute again, and are sponsoring and organising seminars and conferences that promote research in the sciences of navigation and situational awareness, we need to once again reinstitute the AIN subscription fees from 1 July 2015. The fees will remain as in previous years at $75 per annum for full members, and $50 for senior members (over 60 years). Your support will help keep the organisation active and in the forefront of Navigation activities.

Prof Chris Rizos and the AIN Council, June 2015

AIN Dinner/ Lecture – 13 May 2015

The speaker for the evening was Captain Lindsay Cavenagh, who is a Senior Pilot with

Sydney Ports. Sydney Ports is responsible for the safe navigation of vessels into, and within, Sydney Harbour and Port Botany. CAPT Cavanagh provided an interesting update on piloting techniques, and the activities and challenges of piloting for Sydney Ports in Sydney Harbour.

There were two key points that most people took away from the presentation. The first one was the massive increase in size of vessels that they were now manoeuvring in the Sydney Harbour basin. They have only a few metres clearance in all directions, and even less clearance off the Harbour floor, for some of the big cruise ships and tankers. The second point was the 'e-navigation in a suitcase' that the pilots carried on board each vessel. It included e-charts and a variety of other navigation aids. Certainly a far cry from doing it manually a few decades ago! But of course there is now less room for error!

Some of the AIN attendees at the dinner/lecture – LEUT Julia Howlett, LEUT Mark Shannon, LCDR Mike Lobley, LCDR Gavin Telford and LEUT James Goold all from the RAN Reserve enjoyed the evening.

The 18 AIN members who attended were Kym Osley, Debbie Osley, CAPT Ian Stanway, Joe Doyle, Ruth Doyle, Reg Chasney, LCDR Cal Johnson, Peter Sturt, Annette Sturt, Bernard Larkin, Bob Hall, LEUT Mark Shannon, LCDR Michael Lobley, LCDR Gavin Telford, LEUT James Goold, LEUT Julia Bowett, Martin Silk and LEUT Jacqui Kenyon. Great to see a number of new faces among our existing members.

Some of the AIN members at the dinner/lecture - Bernie Larkin, Reg Chasney, Joe and Ruth Doyle, Bob Hall, Peter and Annette Sturt

Notice of Technical/General Meeting Number 594 – Wednesday 12th August 2015 – from 6:00PM

Dinner and Presentation by Professor Chris Rizos, AIN President on '*Developments in Navigation – Trends and Mega Trends*'

Prof Chris Rizos has attended several international navigation conferences and seminars in 2015 and will summarise the key technological changes and developments in the navigation/ situational awareness sphere. This will include, but not be limited to countering GPS jamming, developments in satellite navigation and unique and new applications of navigation.

Dinner: The evening includes a two-course dinner plus tea/coffee (cost is $40 payable on the night). We will be joined by the Nautical Institute and the Master Mariners.

When: Wednesday, 12th August 2015

- From 1800 hrs – drinks in the Fairmont Restaurant Bar, Level 1
- 1830 hrs - Dinner commences
- 1945 hrs – Presentation commences
- 2100 hrs – expected conclusion

Where: Fairmont Restaurant Level 1 at the Occidental Hotel, 43 York Lane, Sydney NSW (very near the Wynard Station).

RSVP: to Kym or Debbie Osley, AIN Secretary, on kym.osley@defence.gov.au or kym.osley1@gmail.com (or 0466 253 100 (leave message)) by NLT Close of business on 7 August 2015. Partners and friends/colleagues welcome.

Seminar on Civil/Military Operations in a Satellite Navigation and Satellite Communications Denied Environment – 22 May 2015 at Canberra

All the speakers had highlighted the critical risk associated with a potential deliberate or unintentional GNSS outage and the significant impact it could have on the continuity of civilian and military operations. AVM Hupfeld in his opening remarks highlighted the need for a whole-of-Government approach to the issue, and that more need to be done to develop the capability to detect, localise and respond to GNSS degradation incidents, and that this needed to be practiced in regular cross-Government department exercises.

A Panel discussion at the Seminar – (left to right) – Mr Ian Mallett AFC, Professor Chris Rizos, Ms Marg Staib AM, CSC, Air Commodore Craig Heap, CSC, Air Vice-Marshal Mel Hupfeld AO, DSC

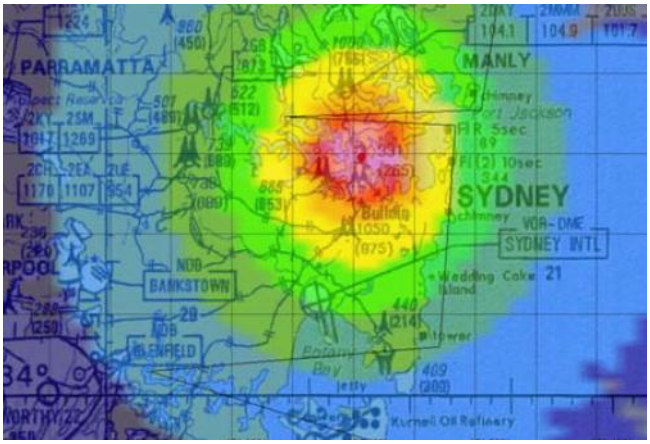
Professor Rizos highlighted the threats. Particularly worrisome is the 'inadevrtant jammer' and the risk of spoofing. He highlighted the need to protect, toughen and augment.

Ms Marg Staib, Mr Ian Mallett and AIRCDRE Craig addressed the risk to air operations from a civilian and military perspective. It is clear that air operations will proceed, but perhaps in some areas less efficiently. In both the military and civilian sectors, there is still adequate training in reversionary navigation and communication measures that will allow operations to safely continue.

Professor Chris Rizos setting the scene and outlining the risk to GNSS

However, the main risk comes from a late detection of the jamming or spoofing, with attendant breakdown in navigation, or aircraft separation- or a reduction in weapon effectiveness for the military. There is a need for a system of identifying and localizing the jamming, and for positively informing airmen of when GNSS and communications may be unreliable.

Size comparison of a one Watt GPS jammer!



The area of Sydney that could be adversely affected by a one watt GPS jammer!

MAJGEN McLachlan and Commander McLean discussed the risk to land operations for both the military and civilian applications respectively. Commander McLean noted that the AFP needs to do a more holistic review of the risk represented by a GNSS degradation to their operations and to address this as they would any other risk.

Major General Gus McLachlan discussing the potential significant impact on land operations.

The AFP can cope with a shorter term interruption to services, but a longer term interruption would present a bigger problem. The AFP believe there should be a more collaborative approach across Government to addressing the risks.

Vice-President Bob Hall (left) and CAPT Peter Sturt (right) in deep conversation at the 22 May Seminar in Canberra

Army have started the journey, but much more needs to be done. Exercises will need to be conducted to test the readiness to operate in a GNSS degraded environment, and these exercises would need to be several days long to ensure the correct lessons were learned.

The risk to maritime operations were also looked at through both a commercial and a military lens. 10% of shipping trade is through Australian ports. Precise navigation is now essential for some large ship operations, and for some drilling and other high accuracy operations. An over-relaince on electronic navigation can be a safety issue, and lessons from this over-reliance need to be fed into training.

Air Vice-Marshal Kym Osley, Secretary of AIN, presents Mr Nick Lemon, AMSA, with a plaque of appreciation from the AIN

A key issue is the human factors-related issue of how to warn of GNSS failures and prompt the crew to revert to backup means of navigation. The issue is very much less about the technology of navigation and the GNSS degradation, and

more about understanding the human interface on the ships.

CMDR Prentice explained the criticality of GNSS-based PNT to achieving the networked maritime force, and the fact that in the 'all up' system of systems, many of the systems on a naval vessel rely on some direct or indirect link to GNSS. There are 116 systems on the LHD that require a GNSS feed.

Graceful degradation through the limited to the denied operational environments is required and must be planned and trained for. The way ahead is to reduce the reliance on GPS by providing some reversionary systems and alternatives to ensure that situational awareness can be maintained for as long as possible.

Air Vice-Marshal Kym Osley wrapping up the Seminar

The Seminar concluded by looking at what Defence is doing to reduce the risk. CAPT Burningham outlined a number of projects that Defence has initiated to reduce the risk from GNSS degradation. But there are no quick fixes. There are a number of Concept and Technology Demonstrators that are underway under the auspices of Capability Development Group and DSTO. There is also significant ongoing international engagement, particularly in the Five Eyes Community. Australia is gaining good access to risk mitigation activities that other partners in the Five Eyes Community are working on.

A readily available GPS jammer that plugs into the cigarette lighter in a car. This is similar to the one that a Melbourne taxi driver was caught by police with recently near Tullamarine Airport, Melbourne. Luckily it was not in operation at the time.

Dr Mark Knight highlighted the strong links between Defence/DSTO and industry through the CTD program. Again there are a number of CTDs underway, but these will not necessarily be quick fixes and much work still needs to be done. Key CTDs are addressing the vulnerability of current receivers, and also are seeking to allow for tactical level geo-location of GPS jamming systems. Both of these CTDs have application in both the Defence and civil sectors.

The next step is for the Agencies represented at the Seminar to develop an effective risk mitigation strategy. At a minimum this should include a more holistic Government and industry approach to continuity of civil and military operations in a space degraded environment. Much of the challenge is about the policy and human factors aspects of GNSS degradation, and not the technical aspects. Thus a key aspect will be determining and implementing appropriate policy, and creating a cross Government exercise and training regime to ensure Australia is as ready as it can be in the event of a serious degradation in space-based PNT.

The Seminar Key Outcomes/Actions that will be progressed jointly by the Australian Institute of Navigation and Defence are:

- **S**hare Information. Further develop cross-Government GNSS-related forums to better share developments in dealing with GNSS degradation.
- **P**lan. Ensure that natural and human–induced GNSS degradation is adequately addressed in Government and Department contingency plans and risk registers.
- **E**ducation. Develop a program for better educating the public of the dangers of jamming or interfering with GNSS.
- **C**ritical Infrastructure. Seek to have GNSS recognized as critical infrastructure in Australia.
- **T**raining. Review cross-Government exercise programs and training courses to ensure that they adequately stresses staff and processes in preparation for responding to a serious degradation in space-based PNT.
- **D**etect. Create an Australian national system (equipment and processes) for detecting and geo-locating GNSS jamming.
- **O**wnership. Defence and the Australian Institute of Navigation to find the most suitable cross-Government group to accept and progress these key outcomes/actions.

So for 2015-16 the AIN has a definite professional role in pursuing SPECTDO!

Intermediate Navigation Course Graduation – 29 May 2015

The Vice-president of the AIN, Mr Bob Hall attended the Graduation of the RAN Intermediate Navigation Course on 29 May 2015. The Dux of the Course was LEUT Rebecca Wheldrake, RAN, who was presented with the AIN Dux award (a plaque and a book prize) by Mr Bob Hall. A total of 9 Officers graduated the Course and will post to a mixture of Patrol Boats and Minehunters. It was a challenging two weeks at sea (particularly having to steer around all of the Vivid Festival vessels)!

LEUT Rebecca Wheldrake, who is the Dux of the most recent Intermediate Navigation Course

26 and 27 Air Combat Officer Courses Graduate – Winners of AIN Excellence in Navigation Award

The 26 and 27 ACO Courses graduate in the first six months of this year. The graduations of the Courses were low key affairs due to the low numbers. However, the graduates achieved very good results and a member on each course was selected for the AIN Award based on their performance during the apllied phase (where air navigation principles are taught). AIN Plaques for Excellence in Navigation were awarded to OFFCDT Liam Ryan on 26 Air Combat Officer Course (ACO) and PLTOFF Timothy Sexton on 27 ACO.

OFFCDT (now PLTOFF) Liam Ryan with Chief of Air Force at his graduation from 26 ACO Course.

Liam has now been promoted to PLTOFF, and is well into his introductory fighter training at

76SQN at RAAF Williamtown. He will start his F-18F course later this year.

Timothy was promoted to FLGOFF after his graduation and has recently arrived at RAAF Williamtown for his introductory fighter training before starting his F-18F conversion course. We wish them both all the best!

PLTOFF (now FLGOFF) Timothy Sexton is congratulated by the Commanding Officer SAW, Wing Commander Craig Stallard on his graduation from 27 ACO Course.

14-16 July 2015 – International Global Navigation Satellite Systems Society (IGNSS) 2015- Gold Coast

Just another reminder that the IGNSS 2015 conference is being held at the Outrigger Hotel, Gold Coast, Queensland, on 14-16 July 2015. The subjects being addressed at the conference include; alternatives to GNSS; GNSS system providers and issues; and UAV navigation.

Dr Todd Humphreys

AIN is participating in the conference through the involvement of the President of AIN, Prof Chris Rizos, on the IGNSS Society Advisory Committee, and through the AIN sponsorship of the travel/accommodation costs of Dr Todd Humphreys, from the University of Texas, Austin.

Dr. Humphreys specializes in the application of optimal detection and estimation techniques to problems in satellite navigation, autonomous systems, and signal processing. He directs the Radionavigation Laboratory at UT Austin. His recent focus has been on secure perception for autonomous systems, including navigation, timing, and collision avoidance, and on centimetre-accurate location for the mass market.

Locata – An Australian Navigation Initiative

Locata Corporation is a Canberra-based company that has developed a terrestrial PNT system (called LocataNet) that replicates and augments the signals transmitted by GPS, but at the 2.4GHz frequency band. It is more resistant to jamming because of the higher power signals from the ground emitters. It also enables centimeter- level accuracy. Designs for low-cost dual-mode GPS/Locata receivers have been developed.

More specifically, 'LocataNet' is a ground-based local positioning system that provides positioning information which is indistinguishable from GPS to an appropriately configured receiver. The LocataNet achieves this without the satellites, atomic clocks or ground support structure required by traditional GPS satellite-based systems.

To create a LocataNet, LocataLite radio transceivers are deployed around a defined area. These devices collectively function like a grounded version of a GPS satellite constellation, transmitting radiolocation signals that Locata receivers use to generate a positioning solution, outputting latitude, longitude and altitude, using trilateration in the same way as a traditional GPS receiver. LocataLites can be designed to transmit at any practical frequency or power level. The first commercially deployed designs operate in the same ISM band as Wi-Fi, and each LocataLite generally covers an area of up to 10 kilometers in radius in open environments.

LocataNets provide all of the Position, Navigation and Time (PNT) functions provided by a GPS satellite constellation, but in a local area, such as an open-cut mine, harbor, military range or other area. This allows operators to set up controlled

positioning networks to locate, automate and direct objects with centimeter-level accuracy. Locata's duplication of PNT is made possible by the company's patented nanosecond-accurate TimeLoc synchronization technology.

They also have developed the VRay antenna. VRay is an 80-element spherical antenna that provides precise positioning in dense urban environments and indoors where traditional GNSS receivers are susceptible to large multipath errors. By switching on each element for just over one microsecond, the VRay correlator design in a Locata receiver creates virtual beams which mitigate multipath effects by focusing on the direct received signal and filtering out multipath bounces. Because the VRay can sweep many beams simultaneously around an area it also determines the angle and strength of received signals and this information is used to derive the precise 3D attitude of the receiver platform as well.

In a partnership with the U.S. Air Force Institute of Technology (AFIT), the VRay is being developed for use with GPS receivers as part of a Co-operative Research and Development Agreement (CRADA) signed in April 2013. AFIT will design and test several GPS-based variants of Locata-patented antenna and correlator technology to develop the VRay for military GPS use cases.

Military Applications: Locata has been awarded a multi-year sole-source contract with the United States Air Force 746th Test Squadron (746 TS) to deploy a LocataNet and provide positioning information when GPS is jammed across a 2,500 square mile area of the White Sands Missile Range in New Mexico. TMC Design, a certified Locata Technology Integrator (LTI) has been let the contract to design, integrate, install and test Locata's Non-GPS Based Positioning System (NGBPS) at the White Sands Missile Range location. Before the contract was granted, the USAF proved through independent testing that the LocataNet delivers accuracy of eight inches or less to aircraft up to 35 miles away. Locata's NGBPS system will provide the 746 TS with enhanced validation capabilities in GPS denied environments while operating mobile and airborne position, navigation and timing (PNT) equipment and navigation warfare (NAVWAR) systems. Locata is the core component for the USAF's Ultra High Accuracy Reference System (UHARS) which will be deployed at White Sands in 2014 to improve performance of military systems in GPS-denied environments.

Mining Applications: In partnership with Leica Geosystems, the first commercial LocataNet is deployed at Newmont's Boddington Gold Mine (BGM) in Western Australia.[14] In this environment, Locata's technology provides positioning for automation of mining machines as the pit gets deeper and traditional satellite-based GPS coverage becomes unreliable because fewer satellites are in view in the pit, particularly near the mine's pit walls.

Automotive Applications: The Insurance Institute for Highway Safety (IIHS), in partnership with Perrone Robotics,[15] in December 2013 completed the installation of phase 1 of a two-stage Locata network as the first portion of a $30 million upgrade to the Vehicle Research Center (VRC). Locata is the sole-source of positioning information for the precision robotics control required by the VRC for the U.S. testing of next-generation vehicle collision avoidance systems.[16] As part of the upgrade, VRC researchers are installing new robotic and high-precision positioning technology for both their outdoor track and 300-by-700 foot indoor testing area.

BMW Group, tests experimental driving goggles that display navigation information

BMW Group thinks computerized headsets such as Google Glass could be the next big thing. BMW has unveiled a prototype of goggles that would turn the world into a digital display, making it easier to follow navigation directions and park in a BMW or Mini.

The prototype glasses, which strongly resemble old-fashioned aviator goggles, show the kind of information that's generally found on a BMW head-up display, such as the speed limit and the vehicle speed.

But they do much more. In navigation mode, the glasses project a sweeping line that tells the driver when to turn. In parallel parking mode, they tap into camera feeds from the vehicle to offer an unobstructed view of the curb, helping the driver get as close as possible without scraping the wheels.

Using see-through technology, Mini eyewear shows relevant navigation and other information in the driver's direct field of vision.

When the project began, BMW archrival Mercedes-Benz was working with Google to test how Google Glass could be used to help drivers get around.
BMW wanted to build a headset that went a step further. Rather than merely displaying information in the corner of the driver's eye, BMW wanted to anchor that information to reality by tracking the driver's gaze and making the information pop up appropriately based on the location of objects in the real world.

Produced at scale, a pair of goggles should cost roughly the same as a high-end smartphone.

Mini's augmented reality eyewear.

BMW and Qualcomm had to solve some tricky engineering problems. For one: figuring out the exact position of the goggles, so the images could be pegged to the real world. They decided to write the history of the Mini brand on the headliner of the car in special ink; by looking up at the ceiling with an infrared scanner, the glasses know the exact location and angle at which they're positioned.

The driver wearing the glasses can control them by pushing a button near the right temple. While the vehicle is being driven, the glasses are synced to the vehicle. If a driver sees a prompt about an incoming text message, he can push a button on the steering wheel to have the message read aloud.

Presentation of Historic Astrograph by AIN to the School of Air Warfare – 22 May 2015

A previous AIN President, Bruce Grant, before retiring to the Northern Rivers, passed a early navigation device called an "Astrograph" in to the safe keeping of the AIN.

The Astrograph 'instrument' is a hand made box, 71 cm x 65cm x 13cm. The AIN thinks that this would be able to be used in a Sunderland in WW2, but would have been too large for a Catalina.

The Astrograpgh was a device used for air navigation from about 1935 through to the early 1950s. In simple terms it allowed an air navigator to directly plots astro-readings to get position lines and fixes without doing sight reductions/trigonometric calculations.

On the front there is a polar scale with Longitude and Latitude, which may be scrolled. Superimposed on the clear acetate sheet that is scrolled is pre-computed lines that correspond to specific stars that might be used for navigation along that particular route. The Astrograph that AIN has is for Perth to Coco Island.

The main purpose of the Astrograph is to provide an instrument which, after sextant readings on two particular stars have been obtained, will eliminate laborious calculation, reduce to a minimum the amount of work necessary for the observer to locate his position, and, what is important, produce quick results when the observer is travelling fast in an aircraft.

The AIN Astrograph on display at the 22 May 2015 Seminar at ADFA. It was presented to the Commanding Officer of the RAAF School of Air Warfare later that day and will be on permanent display at SAW.

The Astrograph was invented by the UK and used in Allied bomber and maritime reconnaissance aircraft throughout the war. A map of the constellations printed onto a translucent sheet of film was rolled through the device under the glass plate and lit from behind. It was used in conjunction with an astrocompass. The astrocompass would provide the heading of the aircraft with respect to the declination of a particular star and the astrograph would be used to identify which star you were using.

The AIN Astrograph on display at the 22 May 2015 Seminar at ADFA. It was presented to the Commanding Officer of the RAAF School of Air Warfare later that day and will be on permanent display at SAW.

Navigation-related Australian Concept Demonstrators Under Development

The Capability & Technology Demonstrator Program is run by Capability Development Group. CTDs are *"A collaborative activity conducted under contract between Defence and industry to deliver a demonstration of the capability potential of new technology"*. CTDs typically develop demonstrators to around the TRL 3-6 level.

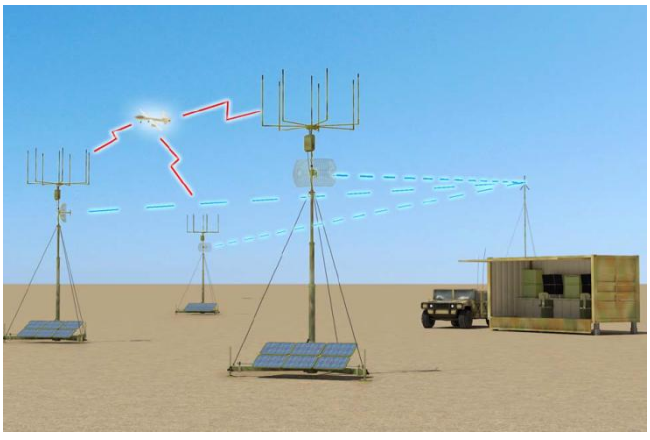
Each year a new round is opened with a call for proposals around April/May. Announcement of the successful proposals is made in April the following year.

In round 18 (2014), GPSat Systems Australia submitted a successful bid to develop a capability to detect and geolocate GPS jammers and spoofers – Project CTD 2014-03.

In round 12 (2008), BAE Systems Australia successfully bid for a project to develop a miniaturised GPS anti-jam system with jammer DF capability – Project CTD 2008-05. That project culminated in a successful demonstration of the mini-GISMO Space-Time Adaptive Processor (STAP) anti-jam unit at Woomera in 2010.
The CTD program is sponsored by CDG but managed by the CTD Program Office within DSTO.

CTD 2014-03 – The Geolocation of GPS RFI to Support Defence Operations

GPSat Systems Australia is developing a capability to detect, geolocate and track GPS interference signals, including jamming and spoofing signals within the GPS L1 and L2 bands (20 MHz bands centred on 1575.4 MHz and 1227.6 MHz). The system will consist of sensor nodes deployed around a facility, such as an airfield or military base, and a central processing WiFi or fibre. Jammer geolocation will be via a combination of Angle of Arrival, AOA (each sensor node is an array) and Time Difference of Arrival, TDOA. Although some aspects are unique to GPS – frequencies, bandwidths, spoofer detection – the system could be extended to other signal types, including other GNSS signals.



Antenna arrays at each sensor node produce high gain steerable beams to search for weak jamming and spoofing signals. When a signal is detected, each node will be tasked to steer a beam towards the signal. Initial geolocation may

be derived from these Angles of Arrival, AOAs. Time stamped data sets will then be sent back to the central processor to form Time Differences of Arrival, TDOAs. AOA and TDOA information will be combined to form the final geolocation solution – AOA and TDOA have natural synergies.

Real GPS signals arriving from valid directions will be removed from the received signal to allow extremely weak jamming signals to be detected – i.e. TDOA processing will not be contaminated by valid GPS signals. This also allows spoofing signals to be detected – the only GPS like signals remaining.
AOA and TDOA have natural synergies. AOA works well with narrowband signals. TDOA works well with wideband signals.

The performance goals of the system are:
- Signal detection down to GPS signal levels (–130 dBm into a 0 dBi gain antenna). Weak signal detection is necessary to detect weak jammers and spoofers at long range.
- Target position error less than about 10 m, 95% for sensors up to 5 km from the jammer or spoofer (assuming HDOP < 2).
- Concurrent operation against 2 spoofers, or 2 jammers and 1 spoofer.
- Portable and deployable within a few hours.
- Map display with moving tracks for jammers/spoofers.
- Geolocation speeds of the order of 10's of seconds.

The field demonstration and project completion is expected within 24 months of contract signature, which is planned for mid-August 2016. The partners in the project are:
- GPSat Systems Australia – Prime.
- UNSW – GNSS algorithms and signal processing.
- University of Adelaide – Array processing and weak signal detection.
- Others – RF, digital and antenna hardware development.

A prototype was developed by GPSat Systems and the Universities of Adelaide and NSW using ARC funds. That system had a 2 MHz bandwidth at GPS L1 only.
A civil system designed to cover the GPS L1 (C/A-code), GPS L2 (L2C) and perhaps L5 bands could be developed to protect civilian infrastructure that has a dependence on GNSS, including airports, waterports and harbours, city centres, etc. A permanently installed system should allow the nature and location of any potential interference or jamming events to be determined within seconds, allowing the event to be responded to while it is still happening.

CTD 2008-05 – Miniature GPS Anti-Jam System

Between 2008 and 2010, BAE Systems Australia developed a STAP beam-former to protect GPS receivers against multiple broadband L1 and/or L2 GPS jammers.

Key design objectives were:
- To minimise size, weight, and power for employment within space, weight and power constrained platforms such as mini-UAVs, dismounted soldiers, etc.
- To interface with a wide range of GPS receivers by replacing existing Fixed Reception Pattern Antennas.
- To provide jammer AOA information relative to the platform body.

Anti-jam protection is provided through adaptive null steering using an eight element antenna array:
- Provides protection against narrowband to broadband (24 MHz) GPS jammers.
- Multiple modes offered to optimise resource usage: 4+4, 7+1, 1+7, 8+0, 0+8.
- Provides protection against up to seven broadband jammers.
- Through the use of STAP, protection may be provided against even more narrowband jammers.

Dr Knight stated that when calibrated, the system can provide quite accurate (3 to 8 degrees) Angle of Arrival (AOA) measurements for multiple GPS jammers. The system's anti-jam and jammer AOA performance is classified, but is comparable

to much larger Military Off-The-Shelf systems. It is relatively small and light weight (about .5 kg) and is low power (9.7 Watts). A reduced bandwidth civil version might be developed for the GPS L1 C/A-code and L2C to protect civilian infrastructure that has a dependence on GNSS, such as GBAS for airports, power distribution systems, communications systems, etc.
in near real time.

Solar Activity and Satellite Navigation

Quite obviously in state-versus-state war-like situation, several nations now have the potential to damage the GPS (or GNSS) constellation through space attack. However, parts of the GPS ground control could be damaged or disrupted through a natural disaster (such as an earthquake) or by terrorist or military action, though the impact is unlikely to be significant because of the highly distributed nature of the ground control elements.

GNSS has always been vulnerable to loss-of-signal-lock (or interference) during extreme ionospheric storms. A very severe storm could disable the satellites themselves, but this is a rare event. The solar event of 1859 has been the largest such natural event in the industrial age. The solar storm of 1859, also known as the Carrington event, was a powerful geomagnetic solar storm. A solar coronal mass ejection hit Earth's magnetosphere and induced one of the largest geomagnetic storms on record. The associated "white light flare" in the solar-photosphere was observed and recorded by English astronomers Richard C. Carrington and Richard Hodgson.

Studies have shown that a solar storm of this magnitude occurring today would likely cause widespread problems for modern civilisation. In the 1859 event, telegraph systems all over Europe and North America failed, in some cases giving telegraph operators electric shocks. Telegraph pylons threw sparks. Some telegraph operators could continue to send and receive messages despite having disconnected their power supplies.

The solar storm of 2012 was of similar magnitude, but it passed Earth's orbit without striking the Earth. In June 2013, a joint venture from researchers at Lloyd's of London and Atmospheric and Environmental Research (AER) in the United States used data from the Carrington Event to estimate the current cost of damage of a similar event to the US alone at $0.6–2.6 trillion!

AIN Webpage

To date the Secretary has had problems sorting corruption of the data on the AIN website. Help is now at hand (in the form of his son who is an IT/telecoms guru) who should be able to sort the website issues in the near future. One of the first things to be posted there will be all the presentations from the recent AIN/Defence Seminar. The website is at www.ain.org.au – but give it a week or two before checking!

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