PNT as A Single Point of Failure for Critical Infrastructure – The Problem and Solutions

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****** NAV2805 – Title ******

Good afternoon, ladies and gentlemen!

It's 4 years now since the *first* of these sessions - sponsored by *EUGIN, IAIN & IALA* - in *Rotterdam*. In that period, the question of the *resilience of satellite navigation* has moved from being seen as the obsession of a group of difficult *eccentrics*, to a topic that now dominates many navigation conferences. "*The problem*" is now clearly understood. "*The solutions*" have proved more elusive. I want to talk today about a *route to solutions* that appears to be developing *here in the UK.*

Our *focus* then is "PNT" - the Position, Navigation and Timing provided by GPS and similar satellite systems.

***** NAV2291 - RAE Report headlines ******

This has become so *essential* to both *critical* and *non*-critical infrastructure that this Royal Academy of Engineering report struggled to find a *single sector* of *transportation*, or commerce, industry or telecomms in *Britain* that does *not* now *depend* on satellite navigation.

****** NAV2664 – The whole lot of GNSS ******

When *governments* realised *how* dependent on this technology their *economies* had become, some set up their *own* satellite systems. So, GPS - which in the Cold War had inspired the Soviet GLONASS - now begat China's Beidou and Japan's QZSS, Europe's Galileo and India's IRNSS. Plus a host of *augmentation* systems: WAAS, EGNOS and other *funny* names.

These newer "*Global Navigation Satellite Systems*" – we now say "*GNSS*" - *had to be* compatible with GPS: they're versions of the *same technology*, and they're squeezed into the same *radio frequency bands* – so they are *rich* in *common modes of failure*. What *kinds of failure*?

****** NAV2804 – GPS & GLONASS failures ******

Here, the final *atomic clock* in GPS satellite **SVN23** *failed*, causing position errors that built up slowly to *kilometres*. Then we saw a *double failure* of *GLONASS* – suddenly, errors of 55 kilometres.

****** NAV1933 – Solar flare ******

On this day the *Sun* emitted *radio noise* so *intense* that GPS receivers *stopped working* across the entire sunlit side of the Earth.

****** NAV1979 – San Diego event ******

GPS *navigation* was *lost* for *two hours*, across the *San Diego area, due to accidental radio interference*. In the *city* there, many *mobile phone* sites that use *GPS synchronisation* were impacted.

****** NAV2681 – 26 January 2016 event ******

Recently a failure of the precise *timing that GPS delivers* took broadcasting systems off the air and impacted telecoms worldwide.

And ***intentional jamming*** appeared:

****** NAV2509 - Bob Cockshott's blue jammer ******

This little hand-held device, sold world-wide, has been carefully designed to block all the frequencies of *Galileo*, plus *Beidou* and *QZSS and all the GPS frequencies*. Oh, and of course, all the *augmentations* like EGNOS, as well.

****** NAV2806 – Hong Kong drones ******

A couple of weeks ago we saw a much more powerful jammer in the hands of a person of malicious intent cause substantial economic damage. We have *yet to see* high-powered jammers being operated by *technically-capable terrorists*.

****** NAV2347 – Korean jamming ******

But *several times now we have seen* a *sovereign state* – which shall be nameless - launch prolonged high-powered *GPS jamming* attacks on its neighbour, impacting *maritime navigation, aviation, cell-phones* and (no doubt the principal target) critical *military capabilities*.

****** NAV2652 – Spoofing threat ******

And now simple, low-cost, hacker-style *spoofers* have appeared. Spoofers transmit *false GPS signals* that *take over* a receiver. They can be used to drive a *ship off course*, to cover up a *vehicle hi-jacking* or shift the *GPS timing* used by *Stock Exchanges* or national *power grids*.

How should we *protect ourselves*? Well, *South* Korea has just announced ***it*** has adopted the eLoran *terrestrial* technology that has no common mode of failure with satellites:

****** NAV2540 – The eLoran technology ******

The *UK* took this ***US*** *eLoran* concept to a *successful prototype* system in the North Sea, with *10 metre accuracy* for shipping in key harbours. It delivered ***timing*** as *precise as that of GPS* across much of Western Europe. But many European *nations* were simply *not interested*. Why, *they* had invested in *Galileo*, which they believed *protected them* from the vulnerabilities of *GPS*.

Now, this presentation will focus on the ***UK's*** way of addressing the *protection* & *resilience* of its *Critical Infrastructure*. Of course, the *UK*, as ever, needs to be *different*, think *Brexit*!

****** NAV2769 – GO-Science montage ******

UK Critical National Infrastructure is handled at *Cabinet* level. And because it is a highly *technical* matter, decisions such as the role of eLoran, fell into the lap of the Government's *Chief Scientific Adviser*, at that time the fine moustachioed figure of Professor Sir Mark Walport. A man who gives "scientific advice to the Prime Minister". So now the issue had gone to the *highest level of our administration*, well above the individual *departments* that in various countries have scrapped and bickered over these vulnerabilities – and *done very little* about them.

******NAV2737 – London Economics – Title ******

Government first *followed the money:* they commissioned an *economic* assessment of the *impact* on the UK of a disruption to satellite navigation. Given the … widespread use, plus the vulnerability, of GNSS just what would happen if it were disrupted, temporarily? They estimated the loss of *Gross-Value Added* and *utility benefits*, including *damages*. They considered a *standalone* event of *whatever cause*.

The results were clear and dramatic!

****** NAV2773 – LE – Summary ******

The *economic impact* on the UK of a *5-day disruption of GNSS* was estimated at *£5.2 billion pounds*, 5.8 billion Euros. A lot of money in any currency. “5 days” is one of our standard periods for assessing Critical National Infrastructure. Notice: this is not a loss of *GPS* but of *GNSS*, so switching to Galileo is not a solution.

******NAV2738 – LE – Loss table and summary message ******

They *examined the impact* in each of these many domains: but 88% of it fell into just three: *road transport*, *emergency* and justice services and *maritime*.

******NAV2739 – LE – Road ******

In *road transport*, there is an immense *loss of utility*. When *navigation devices* fail, those *many* industries that now *depend* on them are *directly impacted*. But the economists predicted that the resulting *increase in congestion and journey times* would delay *all* drivers. They estimated the total *loss* in the *Road* sector at £1.9 billion.

****** NAV2740 – LE – Emergency and Justice ******

GNSS is built into our *first responder services* at multiple levels of *despatching* and *navigation* that would be affected directly. Plus *they too* will be slowed down by *congested roads*. So, £1.5 billion.

****** NAV2741 – LE – Maritime ******

Maritime: this one came as a *surprise* to those of us who are *navigators*. In our blinkered way, we had thought only about the loss of *safety*, the cost of *collisions*. But the *financial loss* turns out to be dominated by *slowing down* the *supply chains* that carry goods internationally for our industry and commerce. You don't need a port to be *closed*, just *disrupted* - £1.1 billion.

****** NAV2742 – LE – Migration technologies & Strategies ******

As for *mitigations*, the report concluded that there is *no silver bullet*. For *timing*: the better your clocks, the longer you can survive interruption. But "the most applicable mitigation strategies for the largest number of applications" – the *best bang for your buck* - are *eLoran* and the new system Satelles. And wherever you need very high location accuracy over a local area, maybe *Omnisense* or *Locata*.

****** NAV2743 – LE – Contribution of Public Funding ******

Finally, should the *government* put *its hand* in its pocket or just *leave* the solution to others? These economists say a resounding: "*yes*"; "there's a *strong economic case* for government intervention, with benefits of 4 to 5 times the *public investment*".

Now look, like all products of the "dismal science" that is *economics*, you and I may *disagree* with the *details*. But the *message* is *loud and clear*: a *loss* of GNSS can cost you *billions per day*. Our industry here is now that important!

This *London Economics* report

****** NAV2770 – Blackett – Foreword and Aims ******

was followed recently by *this study* of *Critical Dependencies on Satellite PNT*. Its aims: to lay out the breadth, scale and implications of our reliance on this "invisible utility", in our *critical national infrastructure*. To *understand* them and to *improve* our *resilience* so as to realise the *full* ***benefits*** *of GNSS.* Now, *this* report was produced by the *Government Chief Scientific Adviser* himself and approved at ministerial level.

****** NAV2771 – Blackett – What is it? ******

It's what we call a Blackett Review – *something so British that I'd never heard of it either* - a government *expert panel* for consulting departments and agencies, academia and industry on a challenging *technical* problem in the *security* domain. Sir Mark Walport *chaired* the review. I was one of the *experts*.

The report makes *10 specific recommendations* to the Cabinet Office which I do suggest you study offline, because they're pretty *indigestible*; here's *my* quick-fire *summaries* of them.

****** NAV2745 – Blackett – Recommendations 1-7 ******

- First, Cabinet Office – not some department – *Cabinet Office* requires all *Critical National Infrastructure* ***operators*** in the UK to audit and report their dependence on GNSS.

- Then, we add this vulnerability to our National Risk Register, *in its own right*; at present it's just a dimension of *space weather*.

- 3: We take this PNT resilience into account in allocating *radio spectrum*, something that is a very hot political topic in Washington – *Ligado* - and could become so in Europe.

- Number 4 calls for *legal* sanctions against folk who jam or spoof GNSS – lock 'her up!

- 5: is about *monitoring interference* at our key sites, like ports.

- 6 - one of great interest to me: we *must* employ *GNSS-independent backup systems*!

- 7: Then report back to *Cabinet Office,* via a cross-government group.

****** NAV2746 – Blackett – Recommendations 8-10 ******

- Nearly done with this "death by Powerpoint" list: we must *specify performance standards* for our CNI, *map our national testing facilities* and make them available to users and *coordinate our academic and industrial expertise in PNT.*

In summary: *Cabinet Office* – at the top of government - has taken *ownership* of the problem. On a personal note: throughout the Blackett consultations with multiple *departments* and *agencies of government*, *my own observation* was of *acceptance* of the vulnerabilities of GNSS and *agreement* on the *need* to tackle them.

****** NAV2747 – Blackett – Mitigations 1-4 ******

But what actual *mitigations* were recommended? Well, as you would expect: *very different* for each *sector,* as prescribed by the *specialists* in that sector. *Telecoms, Finance and Energy* all depend on GNSS

timing, so better hold-over clocks and more robust time distribution. *Emergency* services look for *multi-constellation receivers* with *inertial* backup. But notice: every sector here includes "a *terrestrial radio system*".

****** NAV2748 – Blackett – Mitigations 5-8 ******

And that's the case, too, for the traditional *navigation* sectors: road, *rail, maritime and aviation*. *Terrestrial radio systems* have been "successfully demonstrated", "eLoran meets international standards", "would maximise safety". Plus, *of course*, the *specialist* requirements that will always be so *different* as between, say, *rail* and *aviation*.

****** NAV2772 – Noakes letter re eLoran ******

So, those are the *recommendations*. And, by the way, the day following publication of the Blackett Report the government released a response to a study into the viability of *eLoran* as a *mitigation*. They said: "The Government is *supportive* of any progress towards initiating and maintaining an *operational eLoran network* that can provide PNT services, and they'll *lend support* where appropriate to aid its establishment and continued use."

****** NAV2774 – So, what happens now? ******

Where does *government* go from here? Specifically, what *action* – "*if anything*" the cynics will say – will the *Cabinet Office* take, since *they* now *own the problem*?

****** NAV2775 – BRIG and PNTTG ******

Well, Cabinet Office almost immediately set up a *Blackett Revue Implementation Group*. It reports to the *National Security Council*. It brings together senior policy advisers from across government; it has been meeting at roughly 6-week intervals; it's their job to deal with the *How* and the *Who* to fix the problems.

But *they're* not *specialists* – they're all *Latin scholars, civil servants*. So, they have set up a *Technical Group* – rather as in the US (though rarely in *Europe*) – of government, industry and academia to provide *technical* input and policy advice.

****** NAV2803 – RNTF Prioritizing document ******

There is a parallel *very active debate* on this matter in the *US* currently. *The Senate* is expected to vote tomorrow on the authorisation of *eLoran*. You may want to *download this document*, issued by the non-profit Resilient Navigation and Timing Foundation.

****** NAV2802 – Title again ******

Those of us who've been *concerned* about the *resilience of GPS* and later *GNSS* – and I first spoke on this matter *24 years ago* – have come to realise that *satellite navigation and timing* are now so deeply *embedded* in all our national systems that solutions cannot be found at the level of *individual* government departments or agencies, where the "*Tragedy of the Commons*" applies: that is, *no-one* wants to take on the *problems* that belong to *everyone*. The solutions can *only* be found at the *highest level* of government. Now, I don't know whether that will *happen* here in the United Kingdom, but I am *optimistic* that at last we do have the *attention* and *commitment* at the *only* level of government that can *protect* and provide *resilience* to all our *Critical National Infrastructure*.

Thank you.

17.5 minutes at a good clip

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