Institution:
University of Cambridge

Unit of Assessment:
UoA9

Title of case study:
Cambridge Positioning Systems Ltd (CPS)

1. Summary of the impact (indicative maximum 100 words)

An entirely new radio location technology developed at the University of Cambridge Cavendish Laboratory underpinned developments within silicon and software company Cambridge Silicon Radio (CSR) of "Enhanced GPS" (eGPS) which has been incorporated into mobile phones, other mobile devices, and server technology. The server technology is now a central strategic element in CSR's "Location as a Service" business and by 2009 was powering 40 per cent of the available market worldwide.

2. Underpinning research (indicative maximum 500 words)

Dr Peter Duffett-Smith (Lecturer from 1985, Reader from 2004), University of Cambridge Cavendish Laboratory, devised a location tracking method based on measuring the signals from public broadcast stations. Between 1980 and 1990 Duffett-Smith and his research group developed a prototype location technology 'CURSOR' which used the broadcasts by AM local radio stations to track moving vehicles. Post 1993, these techniques were developed further by the group and applied to mobile phones [1]. These systems needed to use signals received simultaneously by the mobile receiver, whose position was to be determined, and a second receiver (location measurement unit: LMU) whose position was known. A crucial development by Duffett-Smith, code-named 'Matrix' [2] and 'Virtual LMU' [3], did away with the need for the LMU, opening the way for moving mobile phones to track themselves independently. The Virtual LMU ideas were incorporated also into computer servers which assisted the mobile phones to find their positions. These ideas underpinned the research group's subsequent development of techniques which allowed the transfer of accurate time information within a mobile terminal from one place and time to a later place and time [4]. Manufacturers of mobile phones had discovered that the Global Positioning System (GPS), which used the signals from orbiting satellites, did not work very well indoors where the satellite signals were weak. Duffett-Smith's accurate time-transfer technology was then applied to provide accurate time and position information, code-named Enhanced GPS (eGPS), to assist the GPS receivers in the recovery of the weak signals [4, 5]. Duffett-Smith's other research developments during this period included various enhancements to the ways in which a mobile's position could be calculated, and the application of CPS technology to CDMA systems [6].

3. References to the research (indicative maximum of six references)
(best three marked *)

1. Duffett-Smith, P. J. & Hansen, P. *Positioning system for digital telephone networks (GSM CURSOR 2).* US patent number 7,593,736, granted September 22nd 2009.

2. Duffett-Smith, P. J., Hansen, P. & Brice, J. P. *Improvements in Radio Positioning Systems (Matrix).* US patent number 6,529,165, granted March 4th 2003. *

3. Duffett-Smith, P. J., Hansen, P. & Brice, J. P. *Improvements in Radio Positioning Systems (Virtual Location Measuring Unit).* US patent number 7,359,719, granted April 15th 2008 *
4. Duffett-Smith, P. J., Pratt, A. R. & Bartlett, D. W. *Transfer of Calibrated Time Information in a Mobile terminal.* US patent number 7,852,267, granted December 14th 2010. *
5. Duffett-Smith, P. J. & Pratt, A. R. *Integrated navigation system.* Patent application PCT/EP2007/059429, publication number WO2008/034728, published March 27, 2008
6. Duffett-Smith P. J & Macnaughtan, M. D. *Precise UE positioning in UMTS using cumulative virtual blanking*. Third international conference on 3G mobile communication technologies. IEE conference publications, 489, pp 355-359, 2002, DOI: 10.1049/cp: 20020419.

* References which best represent the quality of the underpinning research

4. Details of the impact (indicative maximum 750 words)

Duffett-Smith founded spin-out Company Cambridge Positioning Systems (CPS) in 1995 in order

to commercially exploit his tracking technology, developed in the Cavendish Laboratory, where he remains still as an academic member of staff. The company's products, navigation and positioning systems were based entirely on the research described above. Cambridge Silicon Radio (CSR) acquired CPS in 2007 for $35 M. Key CPS Research and Development personnel, including Duffett-Smith, moved from CPS to CSR to form a new location unit within CSR, which has continued the development and extension of CPS ideas and know-how to benefit CSR's products. As CSR's CTO says in his letter (all text in italics below are from this letter[1]) ' *From 2007 the CPS team remained a unit within CSR's CTO organization and has been mandated to study, propose and implement advance location algorithms covering all non GNSS positioning methods. Thanks to CPS's current indoor location solution, including novel and unique methods for autonomous learning. CDR's current silicon and software solutions, SiRFStarV, SiRFusion and SoftFusion are all using these algorithms for providing location solutions in isolation or in combination with other sources of information. These algorithms can be traced back to CCPS's original methods.'* And also ' *CPS bolstered CSR's intellectual property portfolio by adding a significant amount of new Patent families, covering both terrestrial and GPS related inventions in the field of location technology. More than 20 patents were added and a significant number of applications in process which have since been granted*.'

In 2008 CPS incorporated CPS's eGPS technology into one of its Bluetooth/GPS chips. The technology provided assistance to a software-based GPS engine incorporated into mobile devices. This chip improved the performance and usability of GPS inside buildings and other shielded spaces. The eGPS technology was developed during the period 2001-2009 by CPS with Duffett-Smith's active engagement with the project since it was derived directly from the Cavendish research described above.

CPS servers deployed by a major customer of CSR served 40 per cent of the available market worldwide by 2009. The computer servers employed CPS-written software, based on VLMU, Matrix, and eGPS, to enable location-based services on mobile phones. Users would not have been aware of the details of the computations going on behind the scenes, but would have experienced better performance than would otherwise have been the case, such as quicker response times and more-accurate positioning. '*CPS brought a strong server component, which was incremental to CSR's expertise. The server technology has subsequently been developed into what is now a central strategic element to CSR's business, namely its 'Location as a Service' (LaaS) business. CPS servers were deployed by a significant CSR customer to facilitate various location services, and in or around 2009 were powering around 40% of the available market, according to the data available to us.'*

CPS technology enabled CSR to offer hybrid positioning systems to one of its major customers in 2011. A hybrid positioning system involves the use of two or more separate positioning technologies at the same time in order to obtain the fastest and most-accurate position of a mobile device. In this case, the combination was GPS and Matrix (using the GSM telephone signals), the former assisted by eGPS techniques, with measurements from each method combined into a single calculation of position. '*Further work between 2009 and 2011 saw innovation based on both CPS's server technology and CPS's intellectual property to cover further engagement with this leading customer and a network operator. CSR was commissioned to supply the essential components permitting mobile phone location determination in the context of hybrid systems combining GPS, GLONASS, CDMA/A-FLT and LTE/OTDOA. In particular CPS's unique methods of estimation of network synchronization (VLMU) were central to that approach.'*

The relevance and applications of all that CPS has brought to CSR continue to open new avenues: *'Finally, with the increasing availability of bandwidth in communication systems, CPS's synchronization techniques and methods for determining positions using time difference of arrival are continuing to be relevant and applicable.'*

CSR's published accounts for 2012 show a revenue exceeding $1bn and an operating profit of over $100M.

5. Sources to corroborate the impact (indicative maximum of 10 references)

1. Statement from the Chief Technical Officer of Cambridge Silicon Radio about the impact of CPS technology.

2. Public record of CPS in Companies House proves the existence of CPS and its sale to CSR: search on Cambridge Positioning Systems Ltd (now a part of CSR) here: http://wck2.companieshouse.gov.uk

   Patents:

3. USPTO database search (more than 200 hits also show patent citations): http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=0&f=S&l=50&TERM1=Duffett-Smith&FIELD1=&co1=AND&TERM2=&FIELD2=&d=PTXT

   The key patents are:

4. Duffett-Smith, P. J. & Hansen, P. *Positioning system for digital telephone networks (GSM CURSOR 2).* US patent number 7,593,736, granted September 22nd 2009, seen here: http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=%2Fnetahtml%2FPTO%2Fsearch-adv.htm&r=17&f=G&l=50&d=PTXT&p=1&p=1&S1=(Duffett-Smith+AND+Hansen)&OS=Duffett-Smith+AND+Hansen&RS=(Duffett-Smith+AND+Hansen)

5. Duffett-Smith, P. J., Hansen, P. & Brice, J. P. *Improvements in Radio Positioning Systems (Matrix).* US patent number 6,529,165, granted March 4th 2003, seen here: http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=%2Fnetahtml%2FPTO%2Fsearch-adv.htm&r=2&f=G&l=50&d=PTXT&p=1&p=1&S1=((Duffett-Smith+AND+Hansen)+AND+brice)&OS=Duffett-Smith+AND+Hansen+AND+brice&RS=((Duffett-Smith+AND+Hansen)+AND+brice)

6. Duffett-Smith, P. J., Hansen, P. & Brice, J. P. *Improvements in Radio Positioning Systems (Virtual Location Measuring Unit).* US patent number 7,359,719, granted April 15th 2008, seen here: http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=%2Fnetahtml%2FPTO%2Fsearch-adv.htm&r=1&f=G&l=50&d=PTXT&p=1&p=1&S1=((Duffett-Smith+AND+Hansen)+AND+brice)&OS=Duffett-Smith+AND+Hansen+AND+brice&RS=((Duffett-Smith+AND+Hansen)+AND+brice)

7. Duffett-Smith, P. J., Pratt, A. R. & Bartlett, D. W. *Transfer of Calibrated Time Information in a Mobile terminal.* US patent number 7,852,267, granted December 14th 2010, seen here: http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=%2Fnetahtml%2FPTO%2Fsearch-adv.htm&r=8&f=G&l=50&d=PTXT&p=1&p=1&S1=(Duffett-Smith+AND+pratt)&OS=Duffett-Smith+AND+pratt&RS=(Duffett-Smith+AND+pratt)

8. Duffett-Smith, P. J. & Pratt, A. R. *Integrated navigation system.* Patent application PCT/EP2007/059429, publication number WO2008/034728, published March 27, 2008, seen here: http://patentscope.wipo.int/search/en/WO2008034728

9. News release by CSR about the incorporation of CPS's eGPS technology into its Blue Core chips: http://www.csr.com/news/pr/release/73/en