# Martin's life and work

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- **PRELIMINARY:** I am delighted with this opportunity to express our appreciation of Martin for his seminal research and for his valuable contribution to Imperial College. But I have a caveat. I am not a mathematician so some of my comments on his research may be clumsy and insufficiently appreciative of his research. Hopefully my colleagues Mark Davis and Richard Vinter, with whom Martin has extensively collaborated, will correct any infelicities and provide a better account of, at least, some of Martin's seminal contributions.

- **SCHOOL:** Martin had in his various schools two excellent teachers of mathematics; this surely influenced his later choice of career and also helped him win an exhibition scholarship at Cambridge. But before entering Cambridge, he decided to start, in 1956, his two-year military service which was then still compulsory. He served as a radar fitter and acquired considerable practical engineering expertise, for example on the Ward-Leonard system for controlling radar systems tracking enemy aircraft. This background gave Martin the ability to make later surprising interventions (i.e. surprising for a mathematician) to coffee room discussions in the Department of Electrical Engineering. But the experience did not give Martin the desire to study engineering at university; his first love was Mathematics.

- **CAMBRIDGE UNIVERSITY:** At the end of his military service, Martin was admitted to Cambridge University to study mathematics and commenced the Mathematics Tripos. Because of his ability he was allowed to skip the first year giving him the opportunity to complete

the equivalent of a mathematics degree in two years. This gave him freedom to choose what to study in his final year. At Cambridge, Martin typically engaged in extra-curricula activities, the most demanding being the esoteric sport of potholing which gave him many an adventure. He was also, in the Cambridge tradition, a keen rower and cox. Before the end of his Mathematics Tripos he had met an American who was enthusiastic about the theory of control systems which, in the late 1950's, was undergoing a radical revolution sparked mainly by the researchers Richard Bellman, Rudi Kalman and Pontryagin. This encouraged Martin to spend his final year completing the Engineering Tripos which he did successfully. However, he did regret his decision to spend his last year on the Engineering Tripos because he found education in Engineering at Cambridge was, at that time, inferior to that in Mathematics. He applied to pursue research at Cambridge but was told, by his professor, who was well known for requiring most research students in Control to work on very practical topics, to spend first a year in industry.

- **IMPERIAL** So, very luckily for us, Martin decided to apply to Imperial and was accepted in 1961 for research by John Westcott who had just founded a research group on this topic in the Department of Electrical Engineering. The few academics in his group consisted mainly of recent graduates who did not necessarily have a Ph.D; I was one of these, recruited from South Africa in 1959. One of my duties was to give a post-graduate course on discrete-time systems. I have a distinct and deflating memory of Martin falling asleep during my lectures!

  Post graduate research at that time was very different from now. Martin was assigned an advanced research student as his *unofficial* advisor since; his official supervisor, John Westcott was overstretched, getting research grants, designing and constructing laboratories and establishing contact with industry and government research laboratories (which still existed then). On the positive side, Martin's unofficial advisor, John Florentin, was aquainted with the revolutionary developments in control then taking place and introduced Martin to the use of stochastic models for control problems with incomplete state information. However, it was the influence of the books of J.L. Doob and P.A. Meyer on stochastic processes and the papers of Gene Wong and Moshe Zakai on

approximate stochastic integrals that steered Martin towards the topic of his Ph.D. thesis.

Perhaps because his interests were both mathematical and physical, Martin explored in his thesis the subtleties involved in approximating a physical process, described by a system of ordinary differential equations driven by a random disturbance with a short correlation time, by a diffusion process described by an Ito stochastic differential equation. This was at a time when there was considerable argument in engineering circles on the "correct" way to represent white noise in nonlinear systems. In particular, he considered how the idealized nonlinear filtering equations for diffusion processes - the stochastic partial differential equations of Kushner and Stratonovich - related to their physical implementations. For this research he obtained his PhD in 1966.

- **STANFORD UNIVERSITY** After finishing his Ph.D, Martin went to Stanford University at the invitation of Tom Kailath who provided Martin with a post-doctoral fellowship. I think it was during this period that Kailath and Frost proposed the innovations conjecture (one-to-one correspondence between the observation and innovation processes), a conjecture that interested Martin and stimulated considerable activity in the control community for many years.

- **BELL Telephone Research Laboratories:** At the end of his post-doctoral fellowship at Stanford, Martin joined in 1967 the mathematics department of the famous Bell Telephone Research Laboratories. At Bell, there was a group of probabilists doing innovative work in stochastic control, including Vaclav Benes, Larry Shepp and Hans Witsenhausen, the last famous for his much researched counter example in decentralised stochastic control.

  While at Bell Martin wrote the first draft of the widely referenced paper *The representation of functionals of Brownian motion by stochastic integrals* which appeared in The Annals of Mathematical Statistics in 1970. This paper has had, and still has, a significant impact especially in mathematical finance; I have to leave further elaboration to other speakers in this workshop.

- **IMPERIAL (again)**

  In 1968, John Westcott asked my advice about a vacancy in the Control Group. I was delighted when John accepted my suggestion to recruit Martin. Martin accepted and joined the group, cutting short, with some regret I think, his time at the Bell Labs which had, at that time, a very exciting research community. He settled in quickly and in 1969 he presented new results on the innovations problem, on which he continued to work, in a Imperial College technical report *Conditions for the one-to-one correspondence between an observation process and its innovation*; this report was fairly widely referenced which was unusual for a technical report and was followed by a related paper in the IEEE Transactions on Automatic Control in 1970. Extensions to these results were made by several researchers including Martin whose further results with M. Ershov, which were significant, were, unfortunately, not published.

  A number of papers followed fairly quickly: *The consistent selection of parameterizations in system identification*, *The design of robust approximations to the stochastic differential equations of nonlinear filtering* and *The maximum rate of convergence of discrete approximations for stochastic differential equations.*

  In this century, Martin has worked successfully on a variety of applied problems, in which he showed considerable versatility, notably in the problem of estimating the position of a target from noisy data. Confronted with the bearings only problem (estimation of position of a target given only angle-of-sight measurements), approximately dealt with at the time of his investigations by cumbersome, emperical modifications to the extended Kalman filter, Martin noticed that an inconsequential change to the noise model permitted *exact* calculation of the evolving conditional distribution. This enabled Martin, Richard Vinter and their students to develop the very effective *Shifted Raleigh Filter* for bearings only and related problems. Recently Martin has collaborated with Dan Crisan of the Mathematics Department with whom he has a paper *On a robust version of the integral representation formula of nonlinear filtering.* For a sport Martin took up running. He was pretty competitive and holds the over-70's records in his running club for a number of club races.

Finally, let me comment on Martin's willingness, and ability, to help colleagues on a wide variety of applied problems that involve stochastics. Examples include his help on estimation problems arising in devices for energy harvesting, on stochastic control problems arising in renewable energy sources, on the performance of vehicle suspensions in Formula 1 racing, on optimisation of oilfield exploitation under uncertainty and, most unusually, on stably coalescent stochastic froths! As Mark has commented: if you ask Martin a question, he will always give you an answer!

- **APPRECIATION** This brings me to the end of my brief outline of a few of Martin's contributions. Martin, on this occasion, let me convey to you the respect and admiration of your colleagues for your exceptional achievements and their thanks for your valued help and advice. We congratulate you and wish you well!