

This is what I remember

David Hall

September 2023

Contents

A DEDICATION	2
INTRODUCTION	3
PINEHURST.....	6
SCHOOLDAYS.....	9
CHOOSING A CAREER	22
UNDERGRADUATE DAYS.....	29
POSTGRADUATE DAYS.....	36
FIRST STEPS IN SPACE SCIENCE.....	43
BECOMING A ROCKET SCIENTIST	49
ROCKETS GALORE	58
RAPPSAIVE.....	67
DOING SCIENCE STUDIES.....	79
BECOMING A SATELLITE SCIENTIST	88
GETTING TO KNOW THE EUROPEAN SPACE AGENCY (ESA)	97
BECOMING A PARIAH	105
PLANETARY AND COMETARY LANDERS	113
A DIVERSITY OF TASKS.....	125
POSTSCRIPT	134

A DEDICATION

In case anyone asks, I have set out my recollections of my education and working career (and after). It is almost exclusively about my education and working career, there is very little mention of family matters after my early years because those matters seem much too private for me to write about. But the main support through all of this, from about two months after I first started working in space science, was Margaret. Her support enabled me to withstand the many stresses of working in an area in which absolute reliability was essential though having to use unproven technology and having to work to very strict schedules. And then the walking on eggshells of trying to balance the many conflicting interests between UK funding agencies, funding agencies of other countries, space science communities, the European Space Agency, Industry and Government. Margaret bore the brunt of raising our children, Stephen and Susan, through many periods when I was away from home, always very supportive, for instance, when I arrived home one day to tell her I was going to the USA for three weeks, at three days' notice.

INTRODUCTION

My mother, born in 1918, was from a rural background with her childhood spent living in Oaksey near the Wiltshire/Gloucestershire border. Her father was a farm labourer in his early years and then, from the 1930s until his retirement in the 1960s, an Estate worker for Sir Geoffrey Lawrence. When my mother was 14 she was sent as a housemaid to the Public School, Marlborough College, but homesickness meant her mother had to collect her and take her home after a few days. She then became a housemaid at the Lawrence's house until she moved to be a live-in housemaid at the house of a doctor in Swindon. In Swindon she met my father. He was born in 1913 and lived with his parents in a two up-two down terraced Victorian house close to the Great Western Railway Works which were the reason for 'New' Swindon being there and the main employer in Swindon by far. In 1919, the Garrards company, making early versions of gramophones, transferred from London to Swindon and my father's first job was as a delivery boy for Garrards, using a hand cart. But a car crashed into him and his cart when he was about 16, breaking both his legs and leaving him with a marked stutter. After a long convalescence he became a general labourer in the Railway Works until called up for the army in World War II serving in Italy and Greece.

My parents were married, in October 1939, just after World War II started and had their first child, George, one year later in November 1940. There was a photograph of my father in his army uniform taken whilst he was on leave in June 1942. I assume that I was conceived during that leave, being born 9 months later in March 1943. After returning from the War my father continued as a general labourer at the railway works until the mid-1950s when he transferred back to Garrards working as a machine setter on the production line. In October 1961 (one week before George married and left home) my father deserted us moving away from Swindon with one of the women, Mrs Taylor, who worked on the Garrards production line – a mother of six who deserted her husband and children. She was about 16 years younger than my father. With my father and George both having left home, my Auntie Queen said I should abandon my plans to go to College in Bristol at the start of 1962 and stay at home with my mother but my mother

was adamant that I should go. My father returned after two weeks but (unknown to us) did not end his relationship with Mrs Taylor and they both deserted their families again six months later.



This is the only picture of all four of us together. It was taken at Sand Bay near Weston-Super-Mare, during the only holiday that we had all together other than day trips.

My parents divorced in 1964 and Mrs Taylor died of breast cancer about then. We had no idea at first where they had gone to live but, through the Inland Revenue asking questions, we found their address in Dunstable. I am not sure how we found out that Mrs Taylor had died (I think from a neighbour who worked at Garrards) but my mother started writing to my father, very sympathetically. She showed me his and her letters and eventually she invited him, with my agreement, to move back to Swindon. They remarried with myself and George as witnesses. My

father could not get a job for several months and insisted that because he had voluntarily left his job in Dunstable he did not qualify for unemployment pay, leaving our family income as my apprentice wage and my mother's earnings from being a part-time cleaner at an old peoples' home. Eventually he found work as a labourer for the Swindon Council. His final job was driving the lorry that swept the road gutters and cleared the drains.

On tidying my desk when I was about to retire, I came across a packet of business cards showing my final job:



To me, Director Science, British National Space Centre, sounded a far more impressive job title than I had ever expected at the start of my career. Despite sharing my generation's interest in space through the realisation that 'exploring the final frontier' was becoming a real possibility I had never even contemplated a career in space, how did it happen that eventually I became Director Science at the British National Space Centre? This is what I remember.

PINEHURST

I assume that my education started the day I started at the Pinehurst Infants School in Swindon in March 1948. I do not remember books or numbers at any time before then. The school was newly built in the late 1930's and was custom built for the 20th Century with separate Infant, Junior and Senior Schools on one campus that included a large playing field and also a Clinic at which we were given regular 'inspections' whether or not we were ill. The school was built as part of a major new Council estate, Pinehurst, on the outskirts of Swindon, laid out around a large grassed 'Circle' with avenues radiating off named after trees and many of avenues lined with the appropriate trees.

The Circle included a parade of shops that covered most weekly needs. Pinehurst had no Public Houses but an Off Licence. The whole estate seemed to have been a prime example of town planning that had come to replace the haphazard speculative building of Victorian and Edwardian periods and the 'ribbon development' of the 1920s and 1930s. Even so it was insufficient to meet the needs of the families of soldiers returning from the Second World War and 'temporary' prefabricated bungalows were added to be rented out by the Swindon Council. The 'prefabs' were put up in one half of The Circle.

During the war whilst my father was in the army, my mother, with George and myself, had lived with my father's mother, who was widowed in 1940, in her terraced Victorian house near the Railway Works. From 1943 my father was overseas, first for the invasion of Italy starting in Autumn 1943. During the fighting he travelled from Naples to Florence via Rome including fighting at the battle for Monte Cassino. Then he was in Greece in 1945 helping to prevent a communist takeover (not by himself!). He remained a Private for the whole time in the army. He later told us that at one point he was offered the chance to become a Corporal but refused it because he did not want the responsibility. My father was released from the army early in 1946, that was the first time I was aware of meeting him.



Outside my Grandmother's house where we lived whilst my father was overseas during World War II

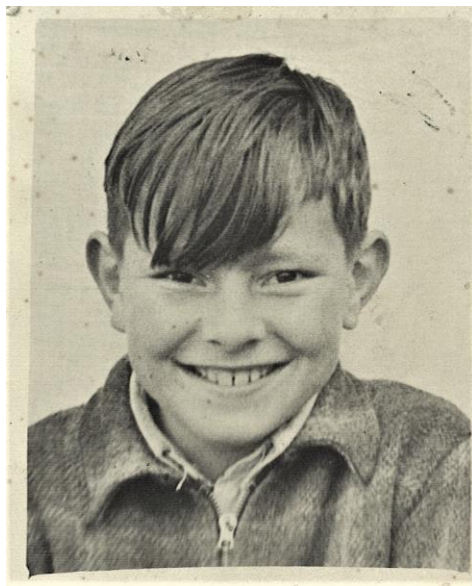
Through my mother's application to the Swindon Council, we moved in January 1947 to Pinehurst, renting one of the prefabricated bungalows in The Circle. Moving there was an unbelievable luxury. Though prefabricated and temporary, the bungalow meant that, for the first time, we had modern conveniences such as an inside toilet, airing cupboard, refrigerator, front and back gardens, a bath and hot water. There were two bedrooms and, for the first time, George and I had a bedroom separate from our parents. Our bungalow looked out onto the half of The Circle that remained grassed and untouched and that was the playground of my early years. At that time, the open countryside started just a ten-minute walk away from The Circle. On present day definitions of income relative to average wage we were living in 'poverty' but it did not seem like it. To us it was idyllic. Fourteen years later I met a girl the same age as me who came from Old Town, the 'posh' part of Swindon. She told me her parents would never drive through Pinehurst, they were frightened their car would be attacked. But the only violence I ever saw

were scuffles between schoolchildren, usually in the school playground. And I definitely did not see any cars being attacked.

Before I started school my mother and I often walked back to visit my aunt and uncle and widowed grandmother who remained living in the terraced houses near the Railway Works. The walk back home took us under the four bridges that carried the railway lines just east of Swindon station. Just past the last bridge was the north-eastern extremity of the Railway Works, at the top of a steep bank. It seemed to be a rubbish dump, and later I learnt that it was where the ashes from the steam trains had been dumped for nearly a hundred years. One day, as we walked past, my father was there at the top of the bank with another man. We paused and waved. 'One day you will be working there' said my mother. And I never doubted that until I was in my teens but, eventually, she proved to be correct.

SCHOOLDAYS

I remember being taken to school by my mother on my first day. There had been no introductory visits, but because George was there, I must have been to the school whilst my mother either took him or met him. But the school was only a 5-minute walk from home so at an early age we made our own way to and from school. I remember passively accepting the need to go to school and not questioning it or making any problems for my mother. The two things that stay in my mind from that first day are that I wore a blue coat which my memory suggests that I kept on all the time and that I sat quietly in a chair at the front of the class not speaking and not being spoken to. But that might be a recollection of only the first minutes. A week later when a neighbour, another David, one week younger than myself started (you started school as close as possible to your fifth birthday whatever time of year that was) I remember being well integrated sitting at a desk with others and feeling a real veteran compared with David when saying hello to him.



At the Infants' School

None of the teachers lived locally and they seemed to be quite distinct from our neighbours living in Pinehurst, far better spoken and dressed. There was no question of anything but utter respect for the teachers. I remember the slates and chalk and the very careful attempts to replicate exactly the letters written on the blackboard by the teacher and eventually the struggle to connect the letters into words whilst trying to maintain the 'correct' shape of the letters. But little

else at the Infants school. At seven I moved to the next building, the Junior school where everything seemed bigger, the classrooms, the desks, the playground. I remember from that school the more formal learning. We were tested often, spelling tests, arithmetic tests, writing tests, 'intelligence' tests and the order of seating in the following school year was based on performance in those tests at the end of the summer term.

My recollection is that I was always in the top five (in a class of about 40) and one year was second. Colin Shinn was always top. He was the only non-Pinehurst boy at the school. His mother was a teacher at the school. They lived on the other side of Swindon and owned their own house. And their own car. It was convenient for her to take him to school with her. Was that a sign the schools were more equal? If he had gone to school in the catchment area of his home he would have gone to a school in which virtually all pupils would be from families that owned their own homes. Those were the parts of Swindon our teachers came from. To choose to place him in a school in the middle of a council estate would seem an unusual move, to say the least, 70 years later. I remember well on one occasion there was an intense debate going on outside the school amongst mothers collecting their children. Some wanted to complain to the headmaster because 'Shinn' always came top of the class.

'It's not fair, his mother teaches him at home, and it shouldn't be allowed.'

It must have been the year after I was second in the class that I sat next to him for a year. I got to know him and his family well. I visited his house; we went to the Cinema together, sometimes during the week but always to the children's show on a Saturday morning. They lived in a 1930's semi-detached house with its own garage. His parents had both been to 'University' though I did not know what that meant except University people took part in a boat race once a year. They took me out for occasional trips in their car; I remember, especially, going to Hayling Island on the south coast. We passed through Winchester and Southampton where we saw the Queen Mary (the next time I saw that ship was about 40 years later at Long Beach near Los Angeles). The Shinns had a bookcase of their own books and Colin could play chess and taught me. And he

had three initials – C. E. G. – the last being Graham, his mother's maiden name. He was my first encounter with the 'middle class', and his family seemed to be like the people that you saw in British films. Their 'living' room, his father with his pipe and his well-spoken mother.



At the Junior School

Of the four years at the Junior School, I remember well the teachers whose class I was in for the second, third and fourth years. For the second and fourth it was Mr Moore, a young teacher who was responsible for the school football team and keen on sports in general. For the third year the teacher was Mr Clark, a much older man – he died about four years later. He was a very traditional teacher who must have started teaching at or just after the First World War. He was a strict disciplinarian who used his steel rule to keep order. He clearly felt it appropriate to punish even minor misdemeanours by hitting the backs of pupils' legs with the ruler, the number of strokes depending on the seriousness of the misdemeanour. But I never remember him punishing a girl in that way, perhaps girls never misbehaved. He insisted frequently that we lived in the 'best and most powerful country in the world' and that if it had 'Made in Britain' stamped on it it was a sign of quality; and he genuinely believed that was the case. We believed it as well. Most of that year seems to have been spent in silence, terrified of anything that might have looked like bad behaviour. But one lesson he mellowed. He had travelled to Switzerland for a holiday and spent one lesson telling us all about it. Travelling abroad seemed a fantastic experience.

In the second year I began to watch Swindon Town football matches with Michael Williams. In January 1952 Swindon Town drew a F.A. Cup game at Cardiff and a replay was needed. That meant a game at Swindon in the middle of a weekday afternoon; there were no floodlights and evening games then. Michael Williams and myself approached Mr Moore and asked if we could have the afternoon off to watch the game. That was a demonstration of how approachable he was. He agreed. We would never have dared approach Mr Clark. In return Mr Moore told us that we would have to give a report on the game to the whole class the day after. That was my first experience of talking at any length to an audience. I remember it being a nerveless and enjoyable occasion.

For the fourth year, we again had Mr Moore as our teacher and he let us listen on the radio to the end of the 1953 Oval test match between England and Australia. Denis Compton hit the four that won the Ashes and we heard Len Hutton making a rather stilted speech. Mr Moore said that the last time England won the Ashes he had been at school – that seemed an awful long time ago (it was 15 years). He also let us listen to the end of the England versus the Rest of the World football match at Wembley when Alf Ramsey scored a late penalty to equalise and the game ended 4 – 4; a relief to us because England had never been beaten at home by a ‘foreign’ (one from outside the British Isles) team. One month later (December 1953) he let us listen to the England versus Hungary game, also at Wembley, and I remember well the shocked silence when he put the radio on and we heard England were 2 – 6 down. Alf Ramsey again scored a late penalty, but it was possibly the first time we had doubt that Britain was the top country in the world. I remember that the best excuse at the time was that the Hungarians cheated because their players were all in the army and did nothing but play football.

During our final year we ‘followed’ the Queen as she made a tour of the Commonwealth and Empire but we thought of it only as the Empire. Usually in each country there was a display of ‘traditional’ indigenous activities which served to confirm to us that ‘white’ colonists seemed still needed to civilize those countries.

In the final year at Pinehurst Junior School I played in goal for the school football team. We travelled across Swindon to play other schools and I remember particularly playing Clarence Street School and talking to one of their players after the game – that was Alan Bushell who remained a friend until he died in 2021. I was also good at sprinting and high jumping and represented the school at the Swindon District Athletics meetings but never came anywhere near winning.

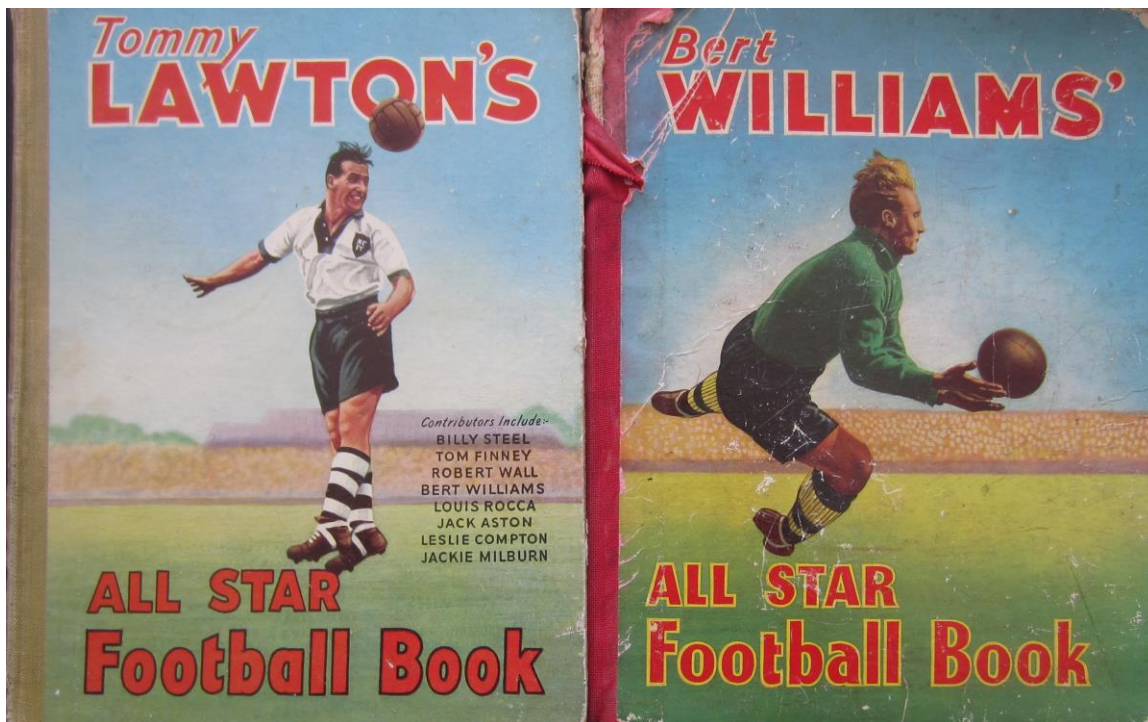
I remember being good at mental arithmetic and during the weekly tests always was one hundred per cent correct, except on one occasion when I put $11 \times 11 = 132$ instead of 121. That really hurt and that I still remember it shows how much that was seared onto my mind. I was also good at writing. With Mr Moore's encouragement, I wrote a book of instructions for goalkeepers. Even outside school on my own initiative I wrote a four-page story on the 'Tudors'. That was heavily based on films that I had seen but it was a good exercise and Mr Moore was happy to 'mark' it and make (favourable) comments. In the year of the Queen's Coronation Mr Moore asked three of us to write out neatly essays that we had written as part of our class work. We did not know but these were submitted for consideration as part of the Mayoress of Swindon's Coronation Year award for work of 'Outstanding Merit'. My essay won a splendid (to me at the time) certificate and was put on public display at the local College. I went to the College to see the display and stood near my essay whilst I saw a lady reading it. I wanted her to know it was mine but did not speak. My parents had the certificate framed.



My Coronation Year Certificate

I have often wondered how I came to be a relatively good writer. I had grown up in an environment without books except for two football albums (Tommy Lawton's and Bert Williams') given to me by my Uncle Sid and Auntie Pat for the 1950 and 1951 Christmases. The only other reading material I remember was the *Daily Herald*, the *Evening Advertiser*, and on Saturdays the *Football Pink* and, Sundays, the *News of the World*. Also, the comics, *Dandy*, *Beano* and *The Eagle*. There was little conversation in our house, and my mother told me later that whilst still living at my grandmother's she was always under orders to keep her children quiet. I grew up not being a good speaker. But I wrote well. I wrote in a different language to my speaking language. My written language was that of BBC Announcers and the better-off people in films and like the Shinns who called bathing trunks 'knickers'. I wrote in the language of Trevor Howard and Celia Johnson in *Brief Encounter*, though I spoke the language of the 'working-class' characters. It seemed obvious to me that the 'middle class' language was the correct one to use when writing at school for teachers who were middle class. I was always far better at writing than speaking. I progressed through my written work not my spoken work. My vocabulary was learned from

books and from BBC radio programmes but the first did not tell you how to pronounce the words (how did you pronounce 'rough', 'through' and 'thorough'?), and the second did not give you the spelling. I tended to mispronounce many words often going for a frenetic (sorry, phonetic) pronunciation (sorry, pronunciation) and in later life did it deliberately. I still find it difficult to believe that Calne should be pronounced 'Carne'. I always envied those who could speak fluently and without reservation in 'proper' language.



My first two books

I started using the local library when I was 9 or 10 and made sure I had clean hands because occasionally the librarian asked to see if your hands were clean. It must have been when I was 12 that I first borrowed a book from the grown-up section of library. That was the report of the England Ashes tour of 1954/55 when England retained the Ashes in Australia. It reported games at the WACA, Gabba, Adelaide Oval, the Melbourne Cricket Ground, the Sydney Cricket Ground and, in a short addendum, the peculiarly named 'Basin Reserve' when England made a short visit to New Zealand. Those places seemed so far, far, away and totally out of reach that it never occurred to me that I would be able to visit them, but I did visit the last four 50 or 60 years later. And most Wednesdays I now walk through the Basin Reserve.

Journey into Space

David Hall

Aged 10

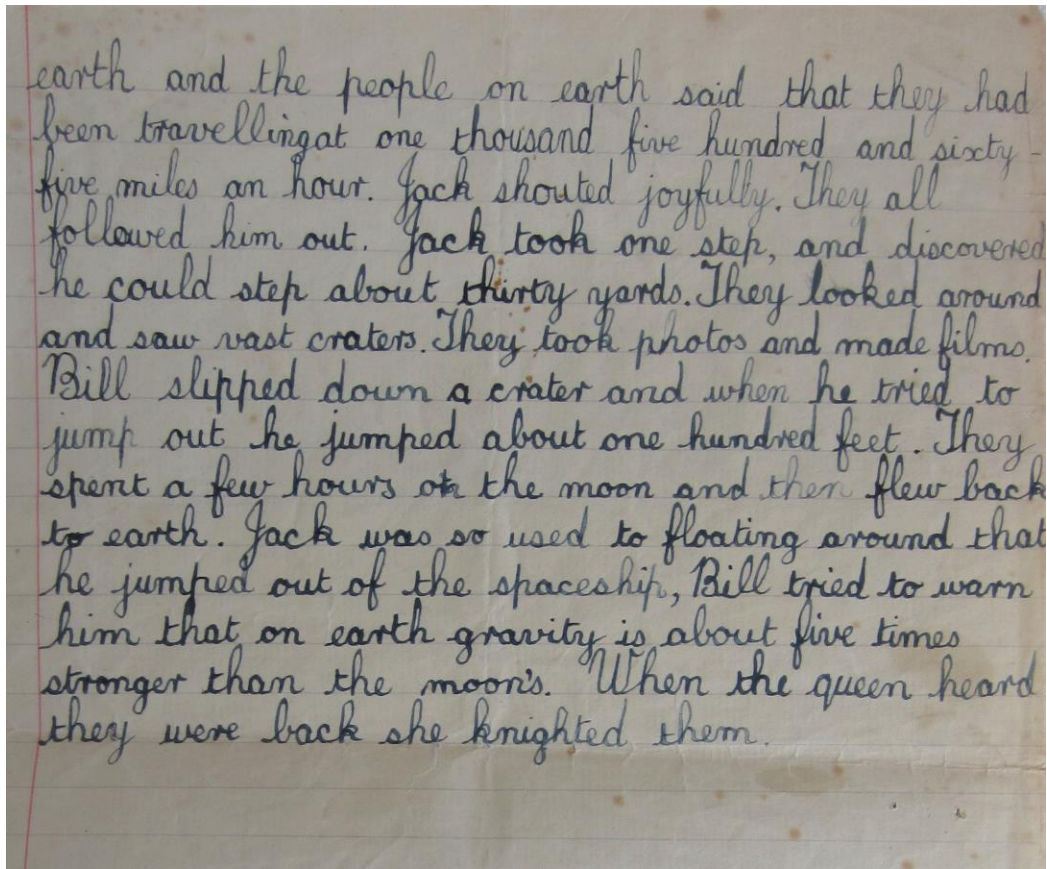
everybody was excited at the atomic camp in the Sahara Desert because that night a spaceship was going to try to get to the moon. In the middle of the camp the spaceship was pointing skywards. At about twelve o'clock the four men who were going to drive it climbed into it. Bill Slack the captain, told crew men Charles, Mick and Jack to lie on their beds and fasten their safety belts, while the people outside went into trenches. "5-4-3-2-1, zero spaceship away!" broke the silence.

There was a hiss it was fire coming out of the bottom of the ship, then a bang, and they had begun their journey!

"Is it all right to get up?" asked Mick.

"I think so," answered Bill.

So Mick undid his safety belt and as soon as it was undone he shot up to the ceiling. Bill said that they would float around until they reached the moon. By this time Mick was getting spacesick. After a few hours flying at over one thousand miles an hour they reached the moon. They agreed that the one who had guessed nearest to the real speed should be the first to step on the moon. Bill said nine hundred miles an hour, Mick said one thousand one hundred miles an hour, Charles said two thousand and Jack said one thousand five hundred miles an hour. They radioed



earth and the people on earth said that they had
 been travelling at one thousand five hundred and sixty-
 five miles an hour. Jack shouted joyfully. They all
 followed him out. Jack took one step, and discovered
 he could step about thirty yards. They looked around
 and saw vast craters. They took photos and made films.
 Bill slipped down a crater and when he tried to
 jump out he jumped about one hundred feet. They
 spent a few hours on the moon and then flew back
 to earth. Jack was so used to floating around that
 he jumped out of the spaceship, Bill tried to warn
 him that on earth gravity is about five times
 stronger than the moon's. When the queen heard
 they were back she knighted them.

Journey into Space – my first document on space activities, I remain impressed that I was using exclamation marks correctly when ten years old.

My essay selected for the Mayoress's award was 'Journey into Space', clearly derived from the Radio programme of that time but actually a very matter-of-fact description of the first visit to the Moon by humans with no fantasies about strange aliens on the Moon. They just went there, took photos and came back. 'They' were, of course, without question in my mind, British. Mr Clark had told us that Britain was the leading nation in the world; the Queen's Empire tour also confirmed that. We had won the war, we had invented radar, and British jet fighters flew over Swindon frequently 'breaking the sound barrier'. We were first to the top of Mount Everest. We weren't the first to the South Pole but that was simply a question of bad luck and the Norwegians, led by Amundsen, cheating. Of course, Britons would be the first men on the moon. More than forty years later, I was responsible for the actual British (lack of) involvement in 'manned spaceflight'.

The fourth year was overshadowed by the Eleven-Plus, due in February 1954 to separate those who would go to Headlands Grammar School from those who would go to Pinehurst Senior (Secondary Modern) School. Every Wednesday with Mr Moore we practised Intelligence tests. During the year with Mr Clark our classroom had been in the Senior School because the Junior School was overloaded. We still went to the Juniors' playground but we had to pass through the Seniors' playground, it seemed awfully rough. And we were told time and time again that when you started at the Senior School you got 'ducked' by having your head put down the toilet. More than anything else at that time, I wanted to pass the Eleven-Plus and go to the Grammar School to avoid going to the Pinehurst Senior School. I imagined the children would be less rough and more respectable at the Grammar School. I had been second in the class at the end of the third year and clearly it would have been a surprise if I had not passed the Eleven Plus (the top eight in the class of forty passed) but it was still a major relief when the headmaster, in Assembly, read out the names of those who had passed. I went home at lunchtime and told my mother, I think I just said 'I passed', she replied 'oh, good' and that was it. I left her to tell my father, I never discussed it with him. I remember them filling in a form for a grant to buy the grammar school uniform.

In my first years at the grammar school I kept my old playmates, the Codlings and the Hardimans who lived in the prefabs at The Circle. But gradually I started mixing more outside school with pupils who lived outside Pinehurst. On reflection the most significant change was when David Cox, in my class at Headlands, whose father was the deputy headmaster at Highworth Secondary School, asked me if I would play for the football team made up of his friends who lived in Headlands Grove, the road that ran alongside the Headlands School playing fields. They were playing a casual game against a team from Meadowcroft, a council estate built on the outskirts of Swindon in the 1950s. I was the goalkeeper and saved a penalty and that made me welcome and from then onwards, for the next three or four years those were my main out-of-school friends often playing football, cricket and tennis together. I played tennis with David Cox's mother's old racquet with broken strings – my power hitting often turned into well-disguised

drop shots if the ball made it over the net. Only David and I went to Headlands, the others went to the Upper Stratton Secondary Modern School, but their parents all owned their own houses; and unlike Pinehurst, few of the fathers had been away during the war, possibly because they had skilled jobs in the local factories such as the shadow Spitfire factory near Swindon at South Marston and the Plessey components factory which supplied components for war engineering.

After I had known David for about a year he said that his family was going to Cornwall during the summer of 1957 and would I like to go with them? My parents could not afford to go on holiday. I spent two weeks at Watergate Bay with the Coxes in a cottage just 50 yards from the clifftops and overlooking the Bay and Newquay. It was a splendid holiday and I have never lost my love for the cliff-paths of South-West England. Watergate Bay was unspoilt and empty, we had it to ourselves. At the time, I had no doubt that it was the best two weeks of my life up to then. I got on easily with Mr and Mrs Cox and they were very relaxed. There was just one 'Joe Gargery' moment when we had breakfast in Newquay just after arriving on the overnight train. At home the yolk of our fried eggs were hard but in the Newquay Café they were soft and the yolk ran all over my plate and I did not know what to do with it. I was embarrassed but tried not to show it.



At the Grammar School

Mr Cox was a keen cricketer who no longer played but was now umpire for the Highworth Cricket Club. We played cricket on the beach, and the moment I remember most was bowling to Mr Cox who played forward, was beaten and the ball knocked his off stump out of the ground. Through Mr Cox, David and I played weekend cricket for Highworth. I thoroughly enjoyed being at the

games and the whole atmosphere of village cricket, visiting villages not too far from Swindon, each with its own distinct pavilion but all with an excellent tea of small triangular sandwiches and small homemade cakes, served at a long table. But because I was only 15 or 16 I got little chance to bowl except for one splendid Saturday at the start of the school holidays when Highworth were short of bowlers; I had an extended spell of bowling and took five wickets, including that of the Headlands School Cricket captain who was playing for the other side.

David and I and our friends in winters went to David's house to gamble for pennies, playing Poker, or Brag, or Newmarket. The others were less law abiding than David and myself; they would break into the Wise's bakery and steal cakes. We all began to go on the train to watch Swindon Town Football Club play away games. When we went to Bournemouth to watch Swindon Town play and we walked along the beachfront, which was empty because it was April, they kicked in the windows of the beach huts. David and I stood aside telling them they were being silly but that just seemed to encourage them. We all stayed friends. Because David and I went to the Grammar school they expected us to behave more respectably. My worst brush with the law was having my name written down by a local policeman for playing football in a street in Pinehurst. Despite being terrified, I heard no more about it. In 1959 we all went to Paignton for a week, staying at a guest house. I don't remember that holiday; we had to go out after breakfast and never really could decide what to do.

The following year we went to Southsea, again in a boarding house. We seemed to have spent the days in the Milk Bar on the seafront listening to the jukebox. The others were drinking alcohol by then – I still abstained until two or three years later – and one night they all got blind drunk. I joined in the loud singing as we made our way home and was surprised how easily the landlady took it all in her stride. We thought we were exceptional, but probably it was just a weekly occurrence for her. We didn't want to admit it, but it was a very disappointing holiday. After that I gradually drifted away from the others becoming friends with other Headland's pupils, including Alan Bushell. The last I heard of the Upper Stratton group was four or five years later when the

Swindon *Evening Advertiser* reported a list of names of those from Swindon fined for causing an affray during a pub-teams' darts match in Portsmouth.

We were well-behaved at the Grammar school; the only time we caused serious problems for a teacher was intended to be a joke not something malicious. Mrs Charlesworth, who taught us German, a subject with no exam and which we did not take too seriously, entered the class one week when we were noisy, but not excessively so. 'You lot sound like a train – settle down' and we did. But the following week we arranged the seating as if it were a train with every second row of desks turned round to face the back of the class. Mrs Charlesworth walked in and said 'turn around this minute' and all the class did, even those who had been facing the front. That was too much for Mrs Charlesworth, she burst into tears and left the class, never to teach us again. We all felt rather guilty.

CHOOSING A CAREER

The real start for me of a career in science was at one of those binary points that everyone has in life that makes you wonder ‘What if the decision had been the opposite?’ I was at school, aged about 15. The form teacher came into the class and said that we had to tell her which group of subjects we would concentrate our efforts for the following year’s General Certificate of Education (GCE) exams. The choice was simple – Arts or Science? There had been no discussion previously. There had been no warning that that afternoon would be when the decision was made. The teacher asked each pupil the question, in alphabetical order:

“Arts or Science”.

I liked arts subjects except that, more frequently, you were asked, in front of the class, for your views on various topics. For science it seemed more a case of a simple answer rather than ‘discuss the answer’ meaning longer answers were needed for Arts subjects. That made me favour doing science. Also, what job did you do if you choose Arts subjects? An ‘office’ job? What did people in offices do? I had no idea. I knew what people in the Swindon Railway Works did, they built the ‘finest steam engines in the world’. Engineering seemed a much more practical and useful career.

The teacher reached me:

“Arts or Science”

“Science”

“But your Arts marks are better”

“No, Science” I repeated hoping to shift the attention on to someone else. The teacher passed to the next pupil. I was committed to concentrate on science. It was true that my arts marks were better; the subject for which I was usually top of the class in our annual examinations was English Language. In the fourth year at the grammar school I wrote a satirical essay on the Swindon local paper, the *Evening Advertiser*, and the English teacher enjoyed it so much he read it out to the

class. That was the only time I recall an essay being read out in that way. In the Sixth Form I wrote a comedy play, '*Sid's Play*' that was the main feature at the Christmas entertainment for the whole school. Of the subjects that I took at GCE, I passed comfortably the Arts subjects, but passed Chemistry only after a resit.

The next step was about a year later when career interviews were being arranged. That was a few months before those that did not wish to stay on past 16 were due to leave school. The question on the form was clear – What career do you wish to follow? That question had been put to me by relatives frequently, I was never able to give a clear answer. My brother (he did not pass the 11-plus) had acquired some status by becoming an apprentice in the Swindon Railway Works to learn to become a Fitter and Turner, the first of the Halls not to be a General Labourer. I could think of no other but 'Radio and Television Engineer'. A repair man had been to our house and repaired our TV a week or two before. It seemed at that time an interesting job and very modern. I told my parents and they thought it appropriate. But I cannot remember showing any aptitude or even an interest in electronics as a hobby. My parents believed that it was up to the school to handle all career matters. To them the Grammar School was rather intimidating; they avoided getting involved in school related matters. They went to the school for an introductory evening a week or two before I started there. But never again. I went to the careers' interview alone. At the interview, the careers master asked:

"What do you mean Radio and TV Engineer? Visiting houses and repairing sets? Or working in the factory that makes radios and TVs?"

SID'S PLAY

PETER GUNN IN BACKGROUND

FADE SLIGHTLY. [OWL NOISES, THUNDER-OPTIONAL]

ANNOUNCER. [OFF STAGE] We bring you an epic of spine-chilling drama and emotion packed suspense..... The time - the present.... The place - anywhere..... only the rift has been ^{changed} to protect the Riftwriter.... once upon a time there were three beatniks - Daddy Beatnik.....

OPEN CURTAIN. SCENE:- DISORDERLY ROOM - MUST INCLUDE TABLE, CUPBOARD, DUSTBIN; JOINT OF MEAT on table together with CARDBOARD RECORDS, WITH BITE-SHAPED HOLES in the

ENTER DADDY BEATNIK - SLOUCHES TO TABLE

ANNOUNCER. mummy Beatnik.....

ENTER MUMMY BEATNIK

ANNOUNCER. and Baby Beatnik.

ENTER BABY BEATNIK

DADDY BEATNIK HOLDS UP BITTEN RECORD.

DADDY BEATNIK who's been eating my ELVIS records?

MUMMY BEATNIK DITTO.

MUMMY BEATNIK who's been eating my Adam records?

BABY BEATNIK DITTO.

BABY BEATNIK. who's been eating my MR. ACKER BINK AND HIS PARAMOUNT JAZZ BAND records?

mummy B. Call the Police.

DADDY B. [SHOUTS] POLICE!

SIREN - SQUEAL OF BRAKES. ENTER POLICEMAN PREFERABLY A WHITE MASKINTOS HED DETECTIVE WITH FELT HAT.

I could not answer. I had expected him to advise me. The easiest option was to stay on at school to do 'Advanced' Levels in the Sixth Form, my GCE marks were expected to be good enough. That is what I chose. My parents did not comment. That postponed the issue for a year or so, but then came the time to start applying for a job or further education. Few of the pupils I had known at Pinehurst remained at school beyond 16. I had grown up in a culture familiar to many at that time - why would you stay on at school beyond 16, you should have learnt enough by then to get a job. Extra years at school seemed to be idling your time away when you should be out contributing to the family income. When, whilst still at school in the Sixth Form, I got a job delivering early-morning newspapers my mother said: 'Your Dad will be pleased, he thinks you should have a job'.



As a teenager with my mother

Most of my class in the final two years at the Grammar School had no doubt what they would do next, University. Many had no doubt about the subject they would study and even their first choice of University. I still felt the need to get a 'job' rather than go to University which in my

culture seemed to mean an extended form of staying on at school. At the time there was an ideal compromise for me.

In one of those bouts in which the Government thinks that something must be done to stop decay in Britain's role as a lead technology nation it had been decided that we needed an alternative to the 'ivory towers' of study of engineering at Universities. The Government set up 'Colleges of Advanced Technology' that would award 'Diplomas in Technology' rather than 'Degrees'. This had been arranged in consultation with industry, asking what education was needed to provide industry with recruits suited for work in the advanced technologies that would maintain Britain's role in the industrial world. How could Britain adapt to the need to prepare itself for the advanced technologies of the future? Colleges of Advanced Technology were one way.

The courses were not organised in the traditional way of a University at which engineering was studied in isolation from industry. Industry would have a much stronger input into the training because the courses would be 'sandwich courses'. Students spent 6 months of the year working in industry and 6 months at College. No long vacation periods. Industry would also be in control because they would pay the students and pay the College fees. Students would be employees sent to College for 6 months of the year but working at their parent organisation for the rest of the year. The periods at College were far more strict and rigid compared to those experienced at Universities. College lectures would start at 9 o'clock and went on until 5 o'clock, with two half hour coffee breaks and an hour for lunch. At the time, it seemed the ideal arrangement for educating a generation of staff trained in advanced technology.

To study for a Diploma in Technology at a College of Advanced Technology was the ideal compromise for me. It meant I would be a salaried employee but would also have the 'graduate' education that was expected following study to Advanced level standard. But first I had to find an engineering company willing to employ me and pay for me. That is where my lack of aptitude for engineering and taciturn nature were barriers. I soon realised I was competing with the people who were already building their own radios and electronics. I applied to companies across

Britain – AEI at Woolwich, Plessey at Ilford, AEI at Loughborough. I was selected for interview at the first two but with never anything but a quick rejection. I returned from Woolwich feeling despondent, the company sent, with the refusal, forms for applying for an accountancy job.

I thought I would have to abandon hope of further study and apply for work locally. I looked in the local paper and was surprised to see that the local Railway Works were offering posts for study for Diplomas of Technology but in mechanical engineering rather than electronics. I was tempted to apply, though knowing that peer pressure for my classmates would be intense, Grammar School pupils who studied to A level were not expected to take employment in the local Railway Works. I decided that I would write to the local electronics company – Plessey to see whether there were opportunities. Plessey had a factory just a 10-minute walk from home. To my surprise I was invited for an interview for an apprenticeship to study for a Diploma in Technology. I had no reason to believe that I would do any better at the interview than elsewhere but found that the interview was conducted alone by the Training Officer, his most difficult question was

“Do you want to study Applied Physics or Electronics?”

I had not considered any subject but electronics since I had entered ‘Radio and TV Engineer’ on my careers form two years earlier. Later I found that the difference was that if I had chosen Applied Physics I would have studied at Brighton, for Electronics, study would be at Bristol. In the later development of my career Applied Physics would have been more appropriate but I could see no reason for changing from Electronics.

“Electronics”

He accepted that and offered me an apprenticeship for study for a Diploma in Technology. I would start even before my GCE Advanced level results were known. I never found out how I had so easily been accepted by Plessey in Swindon after rejection in the rest of the country including

by Plessey at Ilford. Were there behind the scenes contacts between the Training Officer and my school? I often wondered but never wanted to ask, I was relieved to have paid employment for 12 months of the year, not just a grant for the period of attendance at a University.

UNDERGRADUATE DAYS

Walking to work on my first day seemed little different to walking to school except I turned right at the bottom of the road instead of left and did not wear a uniform. I met the Training Officer; he told me that for their first six months, apprentices of all types spent their time in the Apprentice Training School doing basic engineering tasks, working on various machine tools and at a drawing board. The other apprentices had left school at 15; I was the only 18-year-old and the only one working towards a Diploma in Technology. That we were all equal was stamped on us because our first task was to go to the stores and get apprentice overalls, marked simply 'Plessey Apprentice'. I retained the overalls until after I retired but removed the label after I finished working for Plessey. When I saw the overalls hanging in my workshop at home I always felt how incredible that that first day led to the Business Card 'Director Science' at the 'British National Space Centre'.

At the Training School, work was organised around a one-week rota system, in which each apprentice spent one week on a particular skill then moved onto the next, for instance, lathe one week, then a capstan, then engineering drawing, then a week working at a vice with hand tools. And we had films, for instance, meticulously showing us how to use a lathe to make a screw thread. Time in the Apprentice School seemed a waste to me but proved valuable when I later found myself engaged in construction of instruments for space research.

The Bristol College of Advanced Technology was a re-labelling in the late 1950's of a technical college that originated in Victorian times as the Merchant Venturers' Institute and before that had been an orphanage. Changing its name to a College of Advanced Technology was meant to upgrade its status to become quasi-University though it did not award its own degrees, 'Diplomas' were awarded through a National Council for Academic Awards. But, as is often the case, the re-labelling changed the College in the wrong direction. It wanted to be a full University and it was no surprise when, following the Robbins Report into Higher Education in 1963 that called for an expansion of University education, Colleges of Advanced Technology, such as the one in Bristol, were upgraded to Universities that awarded their own degrees eventually breaking

the strong link with industry. The degrees were still meant to be distinguished by being B Sc* to send readers searching in the footnotes for an explanation, but I never saw anyone with B Sc* after their name. The Bristol College became, in 1964, Bath University, having found the space necessary for its expansion at Bath rather than in Bristol. I became a graduate of Bath University never having studied in Bath.



Bristol College of Advanced Technology – originally a Victorian Orphanage

It was not clear where the 'advanced technology' was meant to be covered in our studies at Bristol. The Course covered the transition from the valve to the transistor but not to the next phase of 'silicon microchips' which were the real advanced technologies of the time.

I stayed in lodgings in Bristol. For the first two six-month periods I was in the same lodgings. There were four of us sharing two bedrooms. The landlady cooked our meals. For the third and fourth periods I found lodgings in which I was the only student and much preferred that. The Landlady's son had just left home to get married – I was her first boarder and took over his room.

But for the whole four years I went home at weekends, a one and three-quarter hour journey on the bus. I was never really comfortable in lodgings. But I did make some good friends though they also were students who went home at weekends. Martin Horton was my best friend, we always went out in Bristol on a Wednesday evening sometimes to the theatre, or cinema, or pub. It was with Martin that I first saw *West Side Story* and *The Sound of Music*. We also saw the Rolling Stones, Ella Fitzgerald, George Shearing and Errol Garner. Martin and I went to Lido de Jesolo, including visiting Venice, for one summer holiday, then Lucerne in the following year. After our final year we went to the Costa Brava in Spain with John Beard and three others who had been with John at Taunton School (a private school). They assured Martin and myself that the streets of the Costa Brava were filled with English girls looking for 'it'. But we never found them, perhaps they had gone to Bognor Regis that year.

A main incentive for going home at weekends was that I played football, eventually on both Saturday afternoons and Sunday mornings. On Saturday afternoon for Wesbourne Methodists and Sunday morning for the Old Headlandians, the latter being the team that Alan Bushell, his brother and other friends played for. Alan had given up after one year at Leeds University studying Economics. He was permanently in Swindon working in the Civic Offices and we spent a lot of time together, including drinking (but never excessively) at Swindon pubs. At that time for football, I was a 'left half', a position later renamed as 'midfield'. It was a position where you were always in the game as support either for the attack or defence. The only time I did not like during matches was the final whistle, I always wanted the games to continue whatever the score.

Outside the football season in summer evenings, which coincided with my annual six months working in Swindon with Plessey, there were always casual games at the County Ground extension, a large field next to Swindon Town Football Ground. The games started with a few and built up through the evening. When you arrived, you assessed which team had the least players and joined that side. The teams were distinguished by either keeping their shirts on (the Shirts) or removing them (the Skins). The discarded shirts formed the goalposts. The width of the goal shrunk as the pile of discarded shirts grew. The games went on with people coming and going

until someone shouted 'winning goal' and the next goal ended the game, usually past nine o'clock in the evening.

During my first industrial placement period I found that it was the Wiring and Connectors Division of Plessey that was actually paying my salary and each industrial six months was expected to be in that Division. It seemed a long way from electronics and was more mechanical engineering. The experience in environmental testing and the ensuing development programme gave me valuable experience for later activities but did not prepare me for a career in advanced technology. This was also my first experience of the competing needs of technology development and high reliability. Plessey connectors were used for aircraft and many of the tests that I helped with were simply reliability testing. There was little scope for introducing advanced technology; effort was focussed on improving reliability still further of tried and trusted connectors. When I found myself expected to work in the Wiring and Connectors Division for a second spell after my second year at College, I asked that I be given broader experience, this led to a spell in the 'Resistor and Capacitor Division'. Still experience that did prove useful later in my career but it still seemed a long way from electronics and advanced technologies. Plessey had a subsidiary in Swindon – Plessey Semiconductors – that was the Division that was investigating the potential for silicon chip applications; I asked that I spend my third industrial placement there. I was allowed three months in that Division but that Division did not expect to have apprentices working in it; I was used as an additional hand on the production line rather than in the development laboratory.

The best electronics experience was my final year project in Bristol, modernising a voice synthesizer by replacing valves with transistors. The idea was that speech was broken down into a few selected frequencies for transmission down telephone lines of restricted bandwidth then recombined at the far end to turn back into (rather distorted) speech.

I got my Diploma in Technology with the grade 2.2. By the time I graduated, the 'Diploma' became called a BSc degree from Bath University. After my final year at 'Bath University' as it then was,

I had just four more months before I completed my apprenticeship. The Wiring and Connector Division insisted I spend that time with them although I had asked to be allowed to work in the Semiconductor Division. I felt frustrated that having spent four six-month periods in industry that I had not acquired real experience in electronics. This came to a head one day when I had the task of pressure testing cables in water. This meant packing cables into a container that was eventually filled with water under pressure. The cables were large, it was difficult to pack them into the small diameter cylinder. The lid of the cylinder would not close properly. The cylinder leaked. I decided that Wiring and Connectors was not the area that I wanted to work in, it felt a waste of my degree.



In my early 20s

A young friend in the Wiring and Connectors Division had a father who worked at the Royal Military College of Science (RMCS) at Shrivenham, just 10 miles from Swindon. He worked in the 'Electronics Laboratory' there. The evening after struggling with cables and leaking water tanks I wrote to the College enquiring about work in the Electronics Laboratory. I was invited for an interview with the Head of Department. At first, we were at cross purposes:

“You seem to have appropriate experience for the job, tell us more about your experience”

The College had been advertising for Research Assistants, but I had not seen the advertisement. I soon realised that I was being interviewed as though I had applied for a specific vacancy rather

than had simply written on the off chance that there may be such vacancies. The interview was quite mild. I later realised that my experience would have seemed attractive. The Department had a programme of research into the ionized gases of electrical discharges. It had won a contract from the Admiralty to investigate whether such discharges could be used to generate very short wavelength radio waves with high efficiency. This was seen as possibly the next step after the technology developed for radar about 20 years earlier. It was known that gas discharges generated waves at very short wavelengths of millimetres or less; could those discharges be used to amplify those wavelengths and provide the next generation of radio generators?

The contract had provision for the employment of two research assistants for two years, one to investigate the harmonic behaviour of the discharges, to 'shine' microwaves on the discharges in the hope of stimulating short wavelength harmonics; the other to produce the dense, stable, discharges that would be needed for any practical device. I was chosen for the latter role. For the former, a Physics student from Oxford University, Joe Riley, was chosen. By that mixture of frustration at seeing myself working in what seemed to me the dull field of Wiring and Connectors and sheer luck of timing, I had stumbled across exactly a job in the study of advanced technology that I wanted.

When I had been accepted by RMCS, I telephoned the Training Officer at Plessey to tell him.

"I have been offered a research post at the Royal Military College of Science and have decided to take it."

The Training Officer was a mild man in general but seemed genuinely angry and upset.

"What, no thanks for all the training we have given you? No thanks for paying for your College studies? If you leave now you will never get another job, anywhere."

I did feel guilty. Plessey had invested in me. I realised that the Training Officer would have had to fight hard to win resources for paying for graduate apprentices. But the Wiring and Connector Division wanted its 'payback' on the money spent on me. I had detected reluctance in the Division even for me to have experience in those other Divisions. But the work seemed far removed from electronics. Two days later, I had a call from the Training Officer.

"I have arranged an appointment with the Head of the Semiconductors Division. I think that you should see him."

My first reaction was why they hadn't thought of this earlier. Microelectronics was a fast growing area. At that time, the UK expected to be a major manufacturer of microelectronics, it would have been an ideal time to start a new post in that area. But the thought of the work at Shrivenham seemed more attractive. I did not take into account the permanence of a job at Plessey's compared with the two-year limited contract at Shrivenham. Shrivenham seemed to offer experience that I felt I had not received in working at Plessey's. I replied:

"Thank you. But I am committed to work at Shrivenham now."

POSTGRADUATE DAYS

The Royal Military College of Science was the University of the Military. It provided a university style education for Army Officers at a College controlled fully by the Ministry of Defence. It had a predominantly civilian staff as the lecturers. The campus was large, set in its own grounds with suitable accommodation (Messes) for the officers and ample sports facilities. Research was carried out as at any University. Geoff Bryant in the Electronics Department had built up a research activity in the study of ionized gases - 'plasmas'. The College operated as an academic institution; I never quite adjusted fully to the more relaxed environment, having had the experience of industry, and the 9 to 5 routine at Bristol. I expected to work 9 to 5 every day with strict control over tea and lunch breaks and rigorous control of leave. In my six-month spells at Plessey I had to 'clock in' and 'clock out' every day and pay was deducted even for being one minute late. It took me a while to grasp that at Shrivenham the research staff had a similar freedom as the students at a University, Wednesday afternoons were for sports not for work. Working hours were flexible with no control over time at work except progress in the projects staff were working on.

Soon after starting I was invited for dinner at the Head of Department's house. I did not know what to expect and found there was one other research assistant there and a Professor from the Physics Department and his wife; I sat next to her at dinner. To my horror it was Mrs Charlesworth our former German teacher at Headlands who I had last seen walking out of our class in tears. It was a long evening, I was deliberately vague about my background, desperately hoping my time at Headlands would not be brought up, and it wasn't. I was never invited back to our Head of Department's house.

The environment at Shrivenham meant that time management was entirely up to yourself. Joe and I were employed for two years, but two years seemed a long way away when we started. The first steps for my work was to review what had been done previously. This meant time in the library identifying and reading relevant scientific publications. My first experience of the

'literature' of science. It was a surprise to see that there was an extended international community working on the characteristics of gas discharges, delving deeper and deeper into the behaviour of the discharges and the processes that controlled that behaviour.

The Government had recently set up at Culham, not far from the main Atomic Energy Research Establishment (AERE) at Harwell, a new laboratory especially devoted to the study of the peaceful applications of nuclear fusion for energy generation (at Harwell they studied fission rather than fusion). This had been set up in the first flush of expectation following the ZETA experiment at Harwell in which it was first thought that fusion had been produced and that promised a 'cheap, unlimited, source of power'. But it turned out that what was observed was instabilities in the plasma of the device and AERE, embarrassingly, had to retract their announcement that fusion had been achieved. The task of Culham was to develop an actual fusion reactor. Soon after Culham's opening, an annual series of Summer Schools in plasma physics was started. Joe and I went to the one held in 1966. It was totally incomprehensible to me. My sparse training in physics meant I lacked knowledge even enough to understand the language used – "Maxwellian distributions", "mean free paths", "two-stream instabilities". But within ten years I was using those phrases myself in seminars.

There was a strong research group in Oxford University for gas discharge studies. The Oxford Group and its leader, John Allen was a respected international leader in the field. John's group was part of the Department of Engineering Science, a Department marked by having the most grotesque, seven-storey, 1950's plastic and glass building set amongst the better known and far more attractive old buildings of the University. It was as though Engineering Science felt itself to be the poor relation of the University but set out to demonstrate that it represented the future. But it succeeded only in demonstrating that there was poor lack of judgement and was somehow not part of the 'real' Oxford.

Every Tuesday the Group at Oxford held a seminar in plasma physics, Joe and I tried to attend most of them. But most were well above my head but it did gradually begin to educate me and

tell me where I should put effort in my reading. At Oxford, I noticed how some of the very senior members staff always felt that they had to ask a question but it usually turned out to be the same question each week, whether or not it was relevant to the actual seminar. Twenty years later when working in space plasma physics I gave two seminars to the Group in Oxford and some of the same senior members of staff were still there asking their questions. At that time, after giving each of my seminars, I was taken for dinner at University College Hall sitting at the 'high' table. On one occasion, when I told the lady next to me, who was a Lecturer in English, that I was working in space science you could see the immediate horror that she would have to spend the evening chatting to a space scientist. But by that time I had studied GCE A level English at night school and we ended up comparing the writings of Thomas Hardy and D H Lawrence.

At Shrivenham the Department decided that it would have its own series of internal seminars, each of us had to give a talk on our particular topic. I was still in the early stages of reading background material and my talk was simply a summary of different forms of cathodes that might be used in a gas discharge. It was easy to give but I found it very off-putting when I saw one member of the audience yawning. I learnt that that was common during any seminar by anyone. In an audience of more than 15, in an afternoon seminar, there would usually be one person asleep.

In our first studies of actual gas discharges Joe and I noticed that when we tried to increase the voltage across the gas discharge tube the density of the discharge did not increase immediately as expected but changed more slowly. We found that this could be controlled by heating the walls of the tube and concluded that the effect was due to atoms being adsorbed on the walls and not released instantly when the voltage was increased. We found a published paper that reported the same delay but tried to explain it by some more complicated variation in how the gas was ionized. We thought that it worth inviting external people to a seminar and invited John Allen and his team. For this seminar we had slides produced of the measurements and would use a slide projector for the first time. We decided that we would give the talk jointly and I would start. Unfortunately, I left it to Joe to give the slides to the projectionist. Joe put them in the

wrong order. I did not realise this until I started the talk and the slides came in the wrong order. I became irritated with the projectionist but somehow got through it and Joe admitted it was his mistake. From then onwards I always made sure that I organised the slides for talks that I gave and made sure that I handed them to the projectionist – PowerPoint was a godsend but that was many years away.

At the end of the talk John Allen told us that he had reported the effect some years earlier. This was deflating until soon afterwards we found he had reported the delay but did not have evidence for the effect of the walls. This became another common feature of senior people criticising work of newcomers – ‘I did this many years ago’ – though usually only having scratched the surface rather than providing a detailed insight into the topic. I tried hard not to make that criticism when I was an experienced researcher and asked to review the work of new researchers.

Joe decided to do a Ph D on his studies. I decided to do a M Sc on mine. Geoff Bryant tried to persuade me to do a Ph D. He quoted what he said was Byron – When a man stops striving for the impossible he dies! - I remembered that later when I studied Byron. I never found the actual quote but did find that he was a man of poor judgement and not an ideal source of advice for a young science student. But I felt that my lack of physics training would be a major bar. Geoff and I went to my old Department, now at the University of Bath, and it was agreed that I would register for an external M Sc by thesis. One of my old tutors in the Electronic Engineering Department was appointed as my supervisor for Bath. Geoff was, of course, my supervisor at Shrivenham.

My initial brief had been to study cathodes that could be used to generate high density, stable, discharges in which harmonics at short wavelengths could be generated. I soon stumbled across a phenomenon called ‘hollow cathode’ in which the cathode was an open cylinder rather than the flat sheets usually used for cathodes. The hollow cathode somehow multiplied the density of the plasma; it also seemed to behave in a very stable way. My main research came to be characterising the performance of hollow cathodes and causes of the high densities and stable

behaviour. This meant measuring the plasma characteristics by placing a wire in the plasma and measuring the currents to it. Usually, it was simply a simple strand of metal wire but went by the grand name of a 'Langmuir' probe named after the first person to realise that the characteristics of discharges could be measured in that way.

Before Joe and I had been at RMCS for a year, Geoff walked into our office and leaned against the wall looking rather more sheepish than usual.

"I am leaving. I have been given a job at Plessey Radar on the Isle of Wight"

This was a surprise to both of us.

"I have been given a job in the Space Department. Working on transmission of radar from spacecraft. There is a need to know how it interacts with the ionosphere."

That sounded tremendously exciting to us. The 'space age' was in its infancy. It was no surprise that UK industry was already strongly engaged in space activities. The UK was launching its own satellites at that time. We expected the UK to be in the forefront of a major technology activity – exploring the 'final frontier'. Geoff told us on a later visit about the long hours and enthusiasm of all working on space activities. He said

"The word 'space' has a magic effect on people."

After telling us he was leaving, he said that Joe's main supervision would come from a supervisor at Oxford, a lecturer who had just left Shrivenham for a post at Oxford. The Head of Department would take over supervision of me. But that was almost non-existent; I was left very much on my own. But that was not something I complained about. After one year an external assessor came to review progress on the Admiralty Contract. He was happy with the progress. He saw that the 'hollow cathode' investigations were of interest. It was certainly producing the plasmas of high

enough densities and stability. Joe was becoming an expert on plasma instabilities and measurement of the harmonics at millimetre wavelengths.

I decided to move into accommodation at Shrivenham. This was the accommodation for the military students and was run as any Army Officers' Mess. I had my own room overlooking the Berkshire Downs with the Uffington White Horse as the centrepiece. I shared a 'batman' with five others and he woke you every day with a cup of tea and tidied your room for you. I felt more at home with him than with the Army officers. He had previously been a shepherd working on the Berkshire Downs but had become redundant as the sheep farming declined.



On the left is Roberts Hall, Royal Military College of Science, Shrivenham. My room was on the first floor.

Meals were served in a splendid refectory with wooden panelling and portraits of former, famous (to the Military), soldiers. There was a full waitress service and a bar for before and after dinner drinks. Most of those living in the Mess were from the Public-School stratum of British society that previously I had had no contact with. Even Colin Shinn and his family were a social stratum below those at Shrivenham. It was like being a spectator at a comedy that was parodying the British 'upper class' (this was some years after 'That Was The Week That Was' made poking fun at the upper classes respectable). Needless to say, I never felt comfortable in their company and

usually ate at a table mainly occupied by the civilian staff. My main social life still took place in Swindon, mainly with footballing friends.

With the end of our second year approaching and the end of the Admiralty contract, Joe and I had to write a report on the prospects for generation of millimetre waves using gas discharges. Was this the next generation 'magnetron' whose development had been so vital for radar development? We decided that a practical generator was not feasible. The gas discharges could be made sufficiently dense and stable but the relatively high gas pressure needed to generate the high densities meant that the harmonics were too easily 'damped'. A practical device needed a 'collisionless' plasma, one in which the gases were fully ionized, that needed the type of device that was being investigated at Culham. Even there, collisionless plasmas were generated only for very brief instances; continuous, stable, collisionless plasma was not easily produced in any practical device. Later I realised that we had been too honest. It is far more usual in those circumstances not to reach a definite answer but identify the further work needed to take the activity forward. By reaching a definite, negative, conclusion, we cut ourselves off from potential sources of research funding.

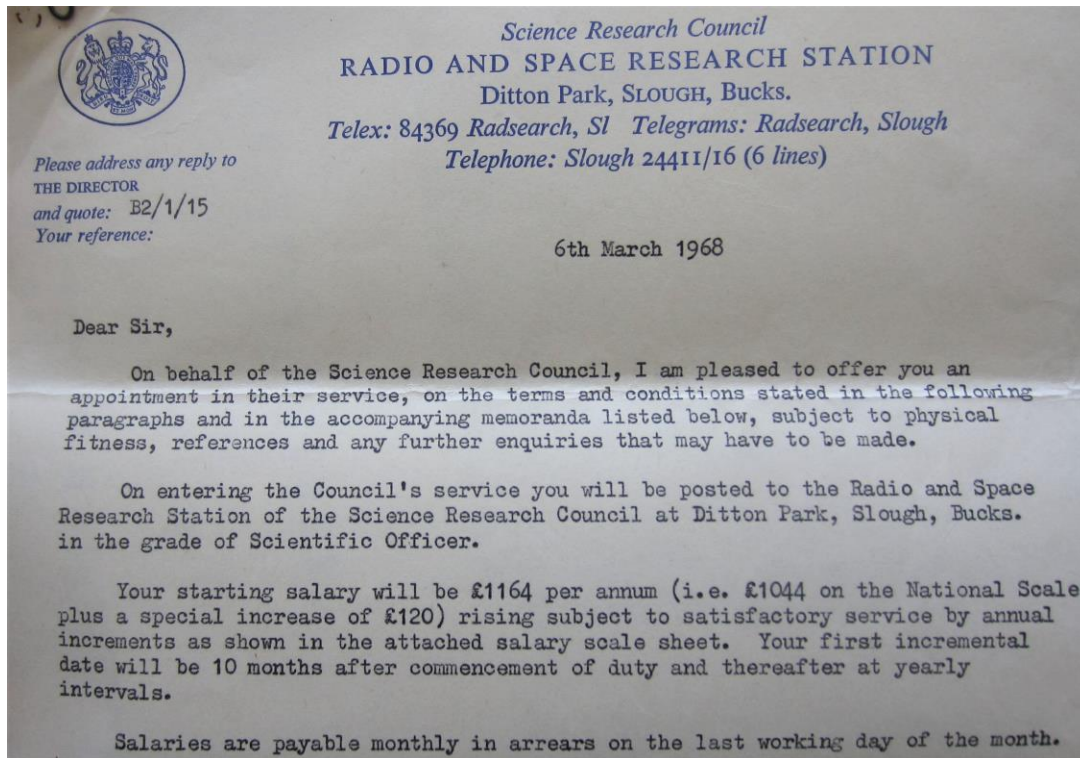
Joe and I both wished to continue our studies as basic research to complete the work for our postgraduate degrees. Following advice from our Head of Department we applied for Research Fellowships in our separate areas of study. We went for the interviews, Joe's was agreed, and mine refused. But I was offered a Scientific Officer commission in the Civil Service. This meant that I had already passed one barrier to obtaining a Government research post, but where? This seemed a consolation prize at the time, but on reflection, I could not have asked for a more positive outcome in view of all the benefits that later flowed from having that commission.

FIRST STEPS IN SPACE SCIENCE

After dinner in the Mess, weekly, I started reading the vacancy section of the *New Scientist* in the Bar. One day, about two months before the end of my contract I saw an advertisement for two Scientific Officers at the 'Radio and Space Research Station'. I had no idea that such a place existed. 'Space Research' jumped out of the page. Was it possible for me to get a job in space research? This was less than a decade after Sputnik 1, less than seven years after the first man in space, Yuri Gagarin, and with the US Apollo programme building to its peak. Apart from putting people into space and planning to send them to the Moon, I did not know what people carrying out 'space research' actually did but it sounded the most glamorous, high-status, job I could think of.

I applied, not believing that it would be easy to get selected for one of the posts. I was invited to visit the Station, which was between Slough and Windsor, for a tour and an interview. I visited a group that was studying the Sun, a group that was studying the ionosphere using rockets, a group studying the ionosphere using satellites, a group studying propagation of radio waves through the atmosphere and how rain interfered with the propagation. The rocket group used Langmuir probes to study the plasma of the ionosphere. I felt at home talking to those groups. I felt far more comfortable with the Station staff than I did with the Officers at Shrivenham; the Station staff were more Colin Shinn than Shrivenham. At the end of my tour, I went for the interview. This was with the Director and Deputy Director of the Station. Although I did not realise it at the time, the Deputy Director was the first man in the UK to realise that radar could be used to detect distant aircraft. When I introduced myself and mentioned my origins in Swindon, he said that he had visited Swindon and told me about it. There seemed little technical content in the interview. It was almost as though he was being interviewed. I was offered a post. It seemed so simple, as though they had already made up their minds and set out to impress me with the tour to persuade me to work at the Station. My earlier experience must have been reasonably impressive. Four six-month periods training in industry to accompany my college studies. I had had two years at Shrivenham carrying out research using Langmuir probes in plasmas. That chance application for a job at Shrivenham had led to a post in space research. Another of those

times that we all have – what if I had not been so frustrated in trying to test unmanageable cables under pressure in water?



The offer for work at the Radio and Space Research Station

I found lodgings in Datchet, just a ten-minute walk from the Radio and Space Research Station, intending to find a flat elsewhere. In going to Datchet I felt for the first time that I was leaving home and had no intention of going home at weekends. I turned up at the Station in early May 1968 and was taken to Bill Harden, one of the Division Heads. After greeting me he said:

“We recruited you to work on TD-2 but that was cancelled last week. You may have read about it in the newspapers”.

No, I had not heard of TD-2, I had no idea what it was. I did not want to show my ignorance within one minute of arriving; it was obviously something that he thought would have been known to most people. This was a case in which people absorbed in their own work felt it to be far more important that it actually was. I eventually realised that TD-2 was a satellite. I knew nothing of

why TD-2 was cancelled or the processes by which it was cancelled. Someone, somewhere, must have decided. Eventually I became one of those 'someone, somewhere' that made decisions to go ahead with or cancel major space missions.

“You will work in the Group that is working on ESRO-1 and 2”

Again, I did not know what ESRO-1 and 2 was. What was ESRO? I was taken to the group leader, he seemed in a hurry, a little like the white rabbit in *Alice in Wonderland*, there never seemed enough time. This was my first experience of people working in the final stages of a project in which they had no control over deadlines imposed from outside. ESRO-1 and 2 were science satellites for study of the ionosphere and magnetosphere and especially the particles that lead to the 'Aurora Borealis'. ESRO was the European Space Research Organization, a body that was 4 years old at the time. ESRO-1 and 2 were its first satellites. The launch of ESRO-1 and 2 was fixed by circumstances outside the Radio and Space Research Station. The group had to complete the instruments before a fixed date.

Because the delivery of instruments and launches of ESRO-1 and 2 were close, it was a nuisance to have someone new in the group; it was too late for me to be trained to support the ESRO 1 and 2 programmes though I did help recording measurements during environmental testing. The Group seemed to be in a high panic solving several last-minute problems with the instruments. I rarely saw my supervisor and was given little supervision. I was given the job of upgrading the calibration system for the space instruments, the task mainly being to upgrade the electron guns of the system. I coped with that well. I had worked with vacuum systems at Shrivenham, I had worked with cathodes, my MSc thesis was “Cathodes for the Production of High Electron Number Densities”. My supervisor also gave me some science papers on measurements of auroral particles to read:

“You ought to know something about the measurements we are making”.

The task kept me quiet for six months until reassignment after ESRO 1 was launched and the instrument for ESRO 2 was delivered. It had been a nuisance having a new member of staff to look after but something had been found that kept me quiet and out of the group leader's hair. I was also writing up my MSc thesis and got the MSc in 1970. I found a flat in Windsor with Danny and John. Danny was a laid-back student from Manchester who was studying plastics and spending his summer working with ICI in Slough. John had mental and physical problems and had been turned out by his parents from their middle-class home. The three of us mixed well. Danny and I found many mutual interests even though he was not into sport. I found talking to Danny far easier than to any other person I had encountered. Danny, John and I went to see the *Wizard of Oz* at the local cinema – I would never have admitted to my Swindon footballing friends that I enjoyed films such as the *Wizard of Oz*. Danny and I were atheists but realised we had both enjoyed singing hymns when we were younger whatever their subject. We put on our best clothes and went to a church in Slough when we found out that many hymns were sung during their services. The vicar tried, unsuccessfully, to convert us.



My first flat in Windsor, on the Ground floor – there was no scaffolding at the time

That was an excellent summer, mooching about Windsor at weekends including walking around the town barefoot. It was the summer I met Margaret when I was on holiday on the River Thames with the Old Headlandian's football team. She came to stay at our flat, I was never sure what she really thought about the flat and my flatmates.

John was a labourer at Windsor Castle and our mooching about included mooching around the Castle which in those days was freely open to the public. We used to spend Sunday afternoons sitting on the landing stage just below the Castle with our feet in the River Thames and that was always an easy introduction to conversation with passers-by. On Saturday afternoons I played football for Stoke Poges Rovers. The football pitch was next to the churchyard where Gray had written his famous *Elegy in a Country Churchyard* (I always, deliberately for fun, called it Gray's *Allergy in a Country Churchyard*). I kept fit by running in the evenings, especially along the Long Walk at Windsor to the statue of George III in Windsor Great Park. The Statue was later renamed the 'Curly-Wurly' statue because my children, Stephen and Susan, frequently found Curly-Wurlys amongst the stones supporting the statue.



The Curly-Wurly Statue

I decided to study A level English at night school. That had been my best subject until I dropped it when I moved to the Science Sixth Form at school. I thoroughly enjoyed the studies which involved one evening a week at Windsor College and writing weekly essays. The course covered both language and literature including *Sons and Lovers*, *Hamlet* and *Uses of Literacy*. At the end of the year I got a B grade, that was my highest A level grade (I had got 2 C's and a D for Pure Maths, Applied Maths and Physics). I was confident it would have been an A if I had not at the same time been working full time and also writing up a MSc thesis.

For six months I worked on development of electron guns for calibrating satellite instruments. It exploited my experience in working with vacuum equipment and I found it interesting and not too demanding, possibly because the supervision was light. But ESRO-2 was launched, the instruments for ESRO-1 were complete, there was no further work for the full group, we were dispersed throughout the laboratory. I found myself in a 'rocket group' – I started work in 'rocket science'.

BECOMING A ROCKET SCIENTIST

The rocket phase of my career began when the Division Head walked into our laboratory with a handwritten sheet of paper. On it was the reassignment to new groups, decisions made amongst the Division Heads.

“Hall to Duncan Bryant’s Group”

I went to meet Duncan Bryant, his office was in one of the wooden huts of a design left over from the Second World War. Duncan’s group used rockets to study the aurora. He kept emphasising that rockets could be just as useful as satellites. I formed the impression that he thought moving from satellites to rockets would be seen as a demotion and a disappointment. Especially because the satellite work took place in the bright new buildings of the Radio and Space Research Station whilst the rocket group was in an outside wooden hut of World War II design left over from the days when the Station was the Radio Research Station.

Duncan had got his PhD at Imperial College in London on cosmic ray measurements and had spent two or three years at the Goddard Spaceflight Centre in Washington studying satellite measurements of cosmic rays. His group at RSRS comprised, in addition to himself, six others, including two PhD’s and the lead engineer of the group, Dick Mason. I worked with Dick to start with, he was very eager to have extra support. Gerry Webb was in the group with the role of making television recordings of the aurora at the time of the rocket flights.

Duncan’s group was called the Auroral Particles Group and used electron and ion sensors to measure the charged particles producing the light of the aurora borealis to better understand the physics that led to the phenomenon. The sensors comprised a channel electron multiplier, which was a small (about the size of a thumbnail), spiral, glass funnel across which 3 kilovolts (kV) was applied. When an electron or ion struck the surface near the entrance electrons were emitted from the inner surface and these were accelerated by the 3 kV down the funnel striking the sides and releasing more electrons until a cloud of electrons sufficient to be measured

electronically was produced. The electronic signal was then amplified and passed to counters. My first task was to improve the performance of the amplifiers.

The 3 kV was generated by a device procured from local industry but this was notoriously unreliable. Two or three months after I joined the group, Dick returned from the launch of a Petrel rocket from the UK MOD site at South Uist in the Outer Hebrides. The RSRS detectors had failed. Dick blamed the high voltage generators:

“From now on we will develop our own, miniaturised, high voltage generators”.

That became my main task, turning Dick’s ideas into practical reality. 3 kV generated ‘in a matchbox’ was his phrase – a small matchbox not the large Swan Vesta box. The generators from industry were about the size of a stack of four Swan Vesta boxes. The generators would have to withstand the considerable g-forces of a rocket launch. Dick described that as:

“We must throw them onto the concrete floor and they still must work.”

That was an interesting challenge that called for us to identify and then bring together advanced technologies that enabled us to miniaturise the generators. Dick had already established contact with a local company, Tectonics, that was experimenting with ‘thick’ and ‘thin’ film techniques for electronics. I eventually formed a close liaison with the company. Both Tectonics and Dick and I found each other’s activities valuable, me and Dick providing new technology targets for the company to achieve. Through Tectonics we also began to change the amplifiers from ‘discrete components’ to ‘thick film’ amplifiers on a ceramic substrate, far smaller than the now old-fashioned discrete component version. Miniaturizing the particle sensor electronics meant more sensors could be accommodated on each rocket.

Duncan’s group was producing instruments for rockets of the ESRO programme. The main vehicle for ESRO was the Skylark. This was a UK developed rocket that was first used for space science in

about 1957 when Skylarks, developed originally for the military, were used for ionospheric studies. The first launches were at Woomera in Australia but ESRO developed a launch site at Kiruna in Northern Sweden. Kiruna was well within the Arctic Circle and the main activity was the iron ore mines. That was a significant enough activity for the town to be quite substantial for its remote location. It was located within the 'northern auroral oval', the region circling the Earth in which auroras mainly appear in the Northern Hemisphere (there is also a southern auroral oval). S29 was the pair of rockets on which Duncan Bryant's group was working when I joined the group, the pair's objective was to observe 'pulsating' aurora, with a more comprehensive suite of instruments than had been used previously, to confirm the location of the pulsations' origin. There had been earlier evidence that suggested the particles were dispersed in energy, that suggested the origin of the pulsations were at some distance from the atmosphere so that the faster moving, higher energy, particles arrived ahead of the slower moving, lower energy, ones.

My first involvement in S29 pair of rockets was after being in the group for about six months when I was asked to support Martin Courtier in seeing the pair through its last stages of testing and its launch. That was of course incredibly exciting. It meant a visit to the European Space Technology Centre (ESTEC) at Noordwijk in the Netherlands, just three years old at the time. This was the main technical centre for ESRO. Also, a visit to the launch site, ESRANGE, in Kiruna in Northern Sweden.

In addition to the particle detectors of RSRS the S29 payloads also included particle detectors provided by a German University group, an instrument from the University of Birmingham to measure ionospheric characteristics and an experiment in which barium was to be released from the rocket and its path traced to understand ionospheric behaviour. The barium cloud ionised immediately and glowed. The cloud's movement depended on the electric fields that were present in the ionosphere. That experiment was provided by the University of Belfast. The various instruments were integrated into the payload structure at ESTEC and tested together.

ESTEC was massively impressive as a place in which the most advanced technology in Europe was under development. ESTEC was also my first encounter with a European Centre; it was unusual to hear so many foreign accents; it was 'accents' rather than 'languages' – English was the common language. The rocket tests were straightforward, just switching on the payload and making sure that everything operated and there was no interference between the instruments. More comprehensive tests including vibration testing had been carried out earlier.

The French/Belgian Company Matra were responsible for providing the engineering support for the science payload – the mechanical structure, the electrical power and the telemetry for transmitting the data during flight. It was soon clear that during the development of the project a very poisonous atmosphere had grown between the instrument teams and the Matra engineers. The engineers seemed to find the instrument teams a nuisance in the tests that they wanted to carry out, the instrument teams seemed to find the industry team obstructive in not allowing all the testing they felt was necessary.

The tests at ESTEC were in August, the launch campaign started in September. I travelled with Martin and Gerry to Kiruna, stopping off at Stockholm. At Kiruna we were met by the ESRO project manager and driven to the rocket range. This was a journey on a narrow 30 km road through woodland. It was still too early in the year for snow. On arrival at the range we were shown around. It all seemed very new and very modern, except that living accommodation was in 'Hotel Albert', a wooden hut, similar to the ones at RSRS. There were small rooms containing two single beds and a small chest of drawers. Washing and toilet facilities were communal, three sinks next to each other but no showers; we had to go into the main building for showers. There was a canteen in the main building that provided reasonable food. It was a 50 metre walk from Hotel Albert to the main building. Because temperatures were usually minus 30 degrees centigrade that meant putting on outdoor clothes but after a week of acclimatisation I found I could do the 50 metre walk in my shirtsleeves as long as you kept moving.



ESRANGE – the main building is in the foreground, the launch area towards the top

The first days were spent going through the same tests as at ESTEC before the payloads were added to the rockets. Also, in helping Gerry to prepare. He was now taking his TV camera to a “downrange” site, about 20 or 30 kms downrange from the actual launch site where there was a collection of ground-based instruments operated permanently for the rocket range and with reasonably comfortable living conditions. That was thought to be a better location than at the rocket launch site for recording the aurora traversed by the rockets. I remember well helping Gerry get the food he would take with him. I drove to the supermarket in Kiruna with a list prepared by him. That was an interesting experience, the supermarket seemed very plush by English standards.

Eventually, the snow came and remained. I found the snow made the range an even more interesting place. We were fully kitted with the appropriate clothing and footwear and walks became far more interesting through the woods with birch trees covered in snow. The river was

beginning to be iced over. Being out in the snow and with temperatures well below freezing I found most enjoyable.

Eventually the rockets were ready for launch. There was usually a two-week launch 'window' in which the rockets could be fired, during the two weeks around no Moon so that the best view of the aurora was obtained. The first night of the launch window was my introduction to the excitement of a real countdown. The range safety man had to plot the wind speed and direction and give his agreement that launch could go ahead. Kiruna was a land-locked range and there were strong weather restrictions on when the rockets could be launched to make sure the rockets did not go outside Sweden into Norway or Finland. Eventually I realised how much of a restriction that was. If you looked out of your bedroom window first thing in the morning and a leaf moved, there would be no launch. It was only on the very still, very clear, windless days that launches were possible.

My task during the countdown was to monitor the output from the RSRS detectors, making sure the correct voltages were operating. At launch the task was to start pen recorders running to obtain data during the flights. This was not essential because the data was of course recorded on video tape but the pen recorders gave a 'quicklook' into whether everything worked and the first indication of how interesting the data was.

Martin's role was to be outside to decide when there was an appropriate aurora at a location to be traversed by the rockets. The first night of the launch window was clear, there was no wind, the countdown continued without disruption and Martin agreed that the rocket should be fired. As the countdown went through zero, I started my recorder and moved to the window to see the rocket, the launcher being about 400 m away. I was very surprised how loud the noise was, a rolling, deep-throated, roar.

Martin came in; he was talking to one of the range staff;

“I am sure there was aurora”.

He seemed to be convincing himself. The recordings showed that the instruments had worked and there were weak streams of particles observed, but not the variations expected for pulsating aurora. The next day I overheard range staff talking;

“They fired the first of the pair last night, but there didn’t seem to be much aurora”

“Next time they will be more careful”.

The period between the two rockets, waiting for good weather conditions and the appropriate aurora, gave me a chance, each night during ‘holds’ in the countdown to observe the aurora. Countdowns were usually ‘held’ at 3 minutes 30 seconds before launch waiting for the right weather or auroral conditions. Once that point for ‘holding’ the countdown had been reached, we could go to the roof of the building and look for aurora, feeling that this was part of the job. All the outside lighting was switched off. Early in the evening, as soon as the sun had set, we scoured the skies looking for what appeared to be clouds but rather more elongated east-west than normal clouds, and, the most telling point, stars could be seen through the ‘clouds’. Those elongated forms were auroral ‘arcs’ sometimes spreading from horizon to horizon. Aurora was seen most nights, and later in the evening the arcs tended to be more southward and brighten and then ‘break-up’ into more chaotic patterns. On evenings of strong aurora the ‘break-up’ could be very dramatic and colourful with bright reds and greens appearing. Following the ‘break-up’ the aurora would become weaker and more diffuse across a large area of sky and that is when patches of ‘pulsating’ aurora appear. Because pulsating aurora appears very late in the sequence, that meant that for S29 we could watch the whole nightly sequence of the aurora without fear of the countdown restarting and forcing us indoors to watch our recorders.

The changes in the aurora were a combination of spatial changes; the aurora on the evening side of the Earth is different to that on the morning side and in between is a region of chaotic

behaviour. Superimposed on that spatial pattern is temporal changes caused by the solar wind variations disturbing the Earth's magnetosphere. Unravelling all that and the physical processes involved was fascinating and was an example of scientists carrying out studies to satisfy their own curiosity. You felt that you were at the end of a long chain of auroral observers, dating back thousands of years to when aurora was thought to be an emanation of the activity of gods in the sky. I loved giving talks in which I could go through the history of explanations leading into my own studies.

The second rocket took rather longer to fire, but when it was fired there clearly was pulsating aurora present and it was obvious in the measurements. Also, the pulsations were clearly separated by a few seconds at different energies – velocity dispersion was proven. Analysis of the data back at RSRS showed that the pulsation was imposed at the equator, with the particles at different energies becoming dispersed in time as they were guided along the Earth's magnetic field to hit the atmosphere at high latitudes. Needless to say, Martin was pleased when he saw the recorder measurements:

“We've got it!” he said pointing to the velocity dispersion. It was partly relief.

The barium releases of S29 worked on both occasions, a ring of bright light could be seen moving slowly across the sky. This was recorded on Gerry's TV and also by still cameras at other locations to determine the position and movement accurately by 'triangulation'. One of the locations was at Abisko, where there was a nature reserve about 100 km from Kiruna. I was given the task on the Sunday after the second launch to go on the train to Abisko to collect the film. This meant a drive to the station in Kiruna, then to catch the train going to Narvik in Norway. Narvik was the main outlet for the iron ore mined in Kiruna, a railway line threading through the mountains connecting Kiruna with the Norwegian coast. I caught the train, it was empty of people. It was a very pleasant journey of about 2 hours to Abisko. I went to the nature reserve, close to the station and met the scientist who handed me the film, we chatted before I went to the station to catch the train back. It was one of those days, spent watching the snow-covered landscape of Lapland

drift by, and feeling – am I really getting paid to do this? It seemed incredible that I had found myself with such an interesting job. What would have been the reaction if I had put on the form whilst fifteen asking me what career I wished to follow “Go to Lapland to fire rockets to study the aurora borealis”? The careers master would have been flummoxed, but perhaps writing at that stage your wildest dreams might be more appropriate for identifying first steps into higher education.



Abisko, it was snow covered when I went there

ROCKETS GALORE

During the next decade, the 1970s, we built about 80 sensors for 15 rockets, all of which were launched successfully and all the sensors worked perfectly. At the start of the decade, soon after my return from the S29 launches, Duncan walked into the office that I shared with Dick and said:

“We need someone to take the lead on C78.”

He turned to me:

“Would you like to take this on?”

I had only heard about C78 vaguely but, of course, I said “yes”.

C78 was another pair of rockets of the ESRO programme, ‘C’ because they were Centaur rockets rather than Skylark. The RSRS role was minor, two electron sensors in support of photometric measurements by a Belgian Group. In terms of developing experience in space experiments, I could not have asked for a better opportunity. The RSRS involvement in C78 was small enough that I could take the lead and carry through all phases of the project by myself, only occasionally having to consult Dick. Through the electronics development work and the S29 experience, I was sufficiently familiar with the whole range of technology needed for C78. It was also the first chance to use our new miniaturised technology. This was also the start of me becoming responsible for the full sensor programme of the group. In addition to the Belgian Group and RSRS, C78 instruments were provided also by ESTEC and a German group. The industrial contractor selected to put together the rocket support services and to integrate these with the science payload was Construcciones Aeronautica S.A. (CASA) from Spain. C78 was also an excellent opportunity to work on an international project.

Until that time, rocket pairs had been simply numbered such as S29-1 and S29-2. The CASA team replaced C78-1 and C78-2 with “La Gitane D’Espana” (The Spanish Gypsy) and “Telesforo” (a

Peasant) my first experience of the extra imagination and romance that is prevalent in the 'Mediterranean' countries of Europe. All the way through the programme it was great fun working with the Spanish team. I wondered why the relationships for S29 had been so sour, was it simply a question of the personalities involved, or the nationalities? Having seen the contrast between the two projects I was always determined to act as a bridge between the industry and instrument teams, and also between national teams, to prevent hostility growing. Eventually those became some of the main themes of my work.

I attended the various meetings with ESRO and the industrial contractors at which we agreed the share of weight, power, volume, telemetry, etc., for the science experiments. This started with meetings at ESTEC and Madrid. The test programme for the rockets in addition to the electrical testing involved vacuum tests and vibration tests. I devised and saw through the tests at RSRS simply deciding what tests needed to be carried out so that I was confident the detectors would work during the tests with the other instruments and the rocket itself, and during the rocket flight. The fear of being embarrassed by a failure and the consequent hold up to the programme of everyone else was the major driver to make sure that the sensors would be reliable in every circumstance. Again, my experience as an apprentice in carrying out several environmental tests on wiring and connectors and analysing the outcome of the tests proved valuable, though it was a shock to see, for the first time, the rocket being vibrated to the levels that would be experienced during launch – it was the equivalent of a 6 magnitude Earthquake.

Every test was very stressful, I never lost that expectation that my part would fail, that was a tremendously strong incentive during the working back at RSRS to do everything to minimise the risk of failure. In some ways that represented my feelings throughout my career whatever activity I was engaged in. I never felt confident and secure, which is not surprising in view of my original background. I over-prepared, trying to eliminate uncertainty, for instance, if travelling alone always arriving at airports unnecessarily well ahead of the departure time. And forcing myself to do things I worried about doing. I always went through the phase in the weeks before I was due to give a talk hoping that the talk would be cancelled. They never were and, once all

the preliminaries were over and I had started a talk, I enjoyed giving talks. But I always made sure I started with a very simple, straightforward, easy to remember, sentence. Especially in mixing with others, there was always a barrier to be overcome – even going to breakfast when away from home, not knowing who I might encounter to eat breakfast with. I always forced myself to join others at breakfast, feeling that was what I was being paid to do, especially when I worked in the diplomacy of space science and informal conversations were as important as formal. No doubt as a result of my first 18 years, I never felt comfortable talking whilst eating a meal - but I forced myself to do it when at work.

Eventually we reached the time for the C78 launch campaign. I would be the only RSRS person attending the launch. Each instrument team sent just one person, except for the Belgium team for which the lead scientist for C78, Marc, had the responsibility for deciding whether the auroral conditions were suitable for launching. Because there was a relatively small group of instrument people we found that we quickly moulded ourselves into a team and I found myself taking part in all the discussions of whether conditions were ideal for launch. As for my earlier experience at Kiruna, the time of the launch would be in the evening; this meant that we were free up to about 16:00 in the afternoon. We made the train journey all the way to Narvik and back. Chatting to the others during the train journey was as interesting as the journey itself. This was my first chance to talk outside RSRS about auroral science and also European matters. We also took the chance to drive to Finland. This was on a Sunday. The Belgians planned it and drove. We were not quite sure how far it was but there was only one road so little chance of getting lost. Also, there were virtually no other cars on the road. We found a small village which had a café for lunch and asked the distance to Finland.

“Two miles”

Of course, we realised later that the “miles” were Swedish country miles and those two miles took us another hour or more to cover. We reached the Finnish border, took photographs and then drove back arriving late at the range, after the time when the countdown was due to start.

The launch controller who made the various announcements during countdown started by saying:

“Start of launch on day 31 January 1971, the start of the countdown is late because of the late arrival of the scientists.”

We felt censured, we knew that the countdown announcements were recorded but we did not know who listened to them. We feared that this might be sent to the senior managers in ESRO but we heard nothing more. It reminded me of the policeman in Pinehurst taking our names for playing football in the street.

The Spanish Gypsy rocket was fired in January 1971, crossing a medium brightness auroral arc. Nothing spectacular about the measurements. As with S29, the project scientist was determined that the conditions for the second rocket, the Peasant, would be exactly right, though it seemed to need the brightest aurora of the decade to give the Belgium instrument meaningful results.

The other significant event I remember about that first launch was that because the RSRS detectors could operate only in vacuum, there was a 90 second delay after launch before the detectors were switched on clear of the atmosphere. This meant that for the first 90 seconds after launch there were no measurements, at 90 seconds the recorders were meant to spring into life. At the moment of launch I started my recorder but then went to the window to see the rocket taking off, going back to my recorder, I thought, in time to see the measurements begin to start at 90 seconds. I looked at the countdown clock – ‘102, 103, 104’ it showed, I felt utter devastation, no measurements, and something has failed all that effort for nothing. But at ‘130’ the measurements started, I had forgotten that the clock counted in minutes and seconds not just in seconds. I remember the relief that my detectors had worked, at the time that was more important to me than the science measurements. From then onwards, I was always reluctant to celebrate a launch, celebration should start when the first science measurements are too hand,

for satellite projects that could be some days; or for a mission to Mars, six months, or to a comet, 11 years.

The weather became cloudy; we could not see the aurora. Soon the no-Moon period was over and we had to go home for two weeks until the February no-Moon period. That also was fruitless because of a combination of bad weather and no aurora. We would spend our evenings going in and out of the control centre hoping to see the clouds break up, it reminded me of wet days when I used to play cricket, staring at the skies for any slightest hint of better weather. One evening, Jean, the Belgium engineer rushed in from outside in great excitement:

“Une etoile! Une etoile!”

From then onwards ‘Une Etoile’ for me became the equivalent of the ‘light at the end of the tunnel’, the ‘silver lining’ on storm clouds, the first glimmer of hope.

But it was never more than two or three ‘etoiles’ and we went home without firing the second rocket. We went back in October and I showed the ESRO payload engineer how to check the RSRS sensors and went home after a week, pressure was building up at home to prepare for a UK national rocket campaign. ESRO senior management was also getting sick of C78 blocking everything. Towards the end of the November launch window, the ESRO Project Scientist was encouraged to overrule Marc and fire the rocket. That happened on November 22nd, and immediately after the rocket was launched the brightest aurora of the decade appeared and the rocket flew through it giving excellent measurements.

After the C78 launches I became involved more in planning the future programme of Duncan’s Group. The next major rocket programme was intended to be a UK National activity. C78-2 was the last rocket of the ESRO programme. There was sufficient interest in UK Universities that a ‘high-latitude’ rocket programme became a strong element of the UK Research Council programme. Duncan took me to the University of Southampton to meet Michael Ryecroft and

Pamela Rothwell to put together a programme of four or five rocket launches combined with ground-based observations. This also meant working with the University of Sheffield and with the Mullard Space Science Laboratory (MSSL), which was at Holmbury St Mary in Surrey but part of University College, London. I helped draft the proposal for the programme that envisaged a sequence of rockets launched at different phases of the Aurora – study of early evening arcs, ‘break-up’ and the diffuse, pulsating aurora, the idea being to understand the physical processes that controlled the overall sequence. Over the next few years there was a series of UK launches, in 1973, 1974 and 1976, mainly Skylarks. Each rocket contained instruments from three or four UK groups, with detectors from RSRS on all. Duncan and I found ourselves more and more playing a mediation role in disputes about how payload resources were assigned to each group, and in disputes between the experiment teams and the industry team.

It was at this time, when I was hoping for promotion to Senior Scientific Officer, that I came nearest to leaving space work and applied for other jobs that would have been equivalent to promotion. One application was to the British Steel Research Centre on Teesside. That was driven by having Margaret’s family living in Teesside and realising for the cost of our house in the south of England we could afford a much grander house in Teesside. I applied for a group leader job at the research centre but was offered only a research assistant post. My work in space science was far more interesting and without the promotion moving to Teesside seemed far less attractive. I also applied to Freedom Fields Hospital in Plymouth for the post of looking after the physics instrumentation with scanners of various types becoming more important. There were only two people interviewed and the other one, who was already working in a hospital, got the job. I never applied anywhere else. I was promoted in 1974 and that took away the incentive to look elsewhere. And the work every year increased in interest and my job became more and more identifying the projects that we should seek resources for and then getting the resources and seeing those projects through to measurements in space.



Andenes Rocket Range

The 1973 rocket campaign was planned for the Norwegian rocket range at Andenes. This had the advantage that the rockets were fired out to sea and there were far less restrictions on wind strength necessary for launch but had the disadvantage that the weather was cloudier than at Kiruna. The other major advantage was that higher performance rockets could be used. One constant drive was to achieve a higher altitude for the measurements and also a longer range and a longer flight time which meant far more scope for the location of the aurora we wanted the rockets to traverse.

For 1976, the Skylarks were Skylark 12's, a three-stage rocket capable of reaching 1000 km altitude and 1000 km range. These were developed in response to our requests for higher altitude and longer range. All the Skylarks performed perfectly and in every case a full set of measurements was obtained. Skylarks were still in use 30 years later, having first been used in 1957. I still have the tie given out to celebrate the launch of the four-hundredth Skylark. The name Skylark was given to the full rocket assembly which for the bigger rockets included three stages. Each of those stages was also named after birds – cuckoo, raven, goldfinch. Many years later I enjoyed telling people that I fired skylarks and cuckoos and ravens and goldfinches into space.



Skylark 12 – about 30 metres from top to bottom

In addition to the UK National Programme, I led the RSRS effort for two rockets of the Norwegian programme, F38 and F39. These were in collaboration with the US and were American rockets, a Malemute (named after an Alaskan dog breed) and a Tomahawk. The project scientist was Nelson Maynard of the Goddard Spaceflight Centre at Washington. This was my first experience in working with the US. I always found it extremely fruitful scientifically, technically and personally. The US scientists always seemed extremely polite and easy-going and with none of the arrogance I had expected from UK newspaper reports at the time of the behaviour of Americans abroad.

I was also fortunate to have the opportunity to work with Canadian scientists. Don McEwan of the University of Saskatoon spent a sabbatical year with our group. One outcome was that we were invited to put instruments on two Canadian rockets that were planned for study of the magnetosphere 'cusp'. That was the region of the magnetosphere facing the sun and the magnetic field configuration was thought to allow direct entry of solar wind particles into the

atmosphere. There was aurora on the day side of the Earth but rather weaker and more tenuous than on the nightside suggesting much lower energies of the particles reaching the atmosphere.

I was the most appropriate person to go to the launch campaign in Canada and also arranged to give a talk on pulsating aurora at Don's University in Saskatoon and a talk on auroral acceleration to a group in Ottawa. In addition, I visited Hudson's Bay where we collected clothing and Yellowknife, where we had to change planes. The rockets were launched from Cape Parry where there was an American Early Warning Radar site looking for Russian missiles coming over the North pole. Cape Parry was on the very northern tip of Canada well inside the Arctic circle, that is why it was ideally placed for study of the magnetosphere cusp. It was well equipped and the food was excellent but too much, most of the Americans were overweight. The temperature outside was rarely more than minus 55 degrees. I went for walks for the sheer experience of being outside at those temperatures. It was mid-winter so the daylight was very limited. After the rockets were fired I went to Ottawa for my talk on acceleration of auroral particles, staying at Winnipeg before travelling on to Ottawa.

RAPPSAIVE

About 60 km to the north of the rocket launch site at Kiruna is 'Rappsaive', which is a mountain that stands out from an area of relatively flat plain and it very much the classic shape of an old volcano. It is the actual point at which the rockets are 'aimed' when they are fired from Kiruna. When the weatherman at the range plots his wind direction and speed, the elevation and direction of the rocket is changed so that it is always intended to hit Rappsaive. But the 'dispersion' of the unguided rockets, the inaccuracy of their trajectories, means that they can land anywhere within about 10 km of Rappsaive. At the Kiruna range I had seen the records of where various rockets had landed, none had actually landed on Rappsaive although this was shown as the 'target', indicated by a circled dot on the maps.

In order to assist the recovery of rockets, which took place mainly to prevent the build up of waste rather than find re-usable pieces of rocket, a Lapp-style hut was placed on the top of Rappsaive with microphones attached to each corner. The recordings from the microphones gave some indication of the direction in which a rocket had landed. The hut was triangular about 10 feet high, 8 feet wide at the bottom, and 14 feet long, made of wood as were most of the houses in Kiruna itself.

After the 1976 campaign of rocket launches I was preparing the case for launches due in 1979. Our improvements in instrumentation had advanced to the point where a case could be made for another set of launches to study in more detail the aurora and the processes that caused it. For earlier launches at Kiruna, Gerry had been at the 'downrange' site, about 30 kms north of the launch site, halfway to Rappsaive, for the low-light television observations. However, it was clear that this was not the ideal location. The electrons striking the atmosphere to produce the auroral light travel in the direction of the Earth's magnetic field. This meant that at the 'downrange' site that Gerry used the best observations were achieved only whilst the rocket was ascending and only for a short time. The direction of the Earth's magnetic field meant that far better observations would be obtained by ground-based instruments located close to the impact point. The rockets more or less followed the direction of the Earth's magnetic field for nearly all their

downward leg and the best observations could be made for a far longer period. Gerry was on the point of leaving the Group. As I made the case for observations close to the impact point, I decided it was a task that I wanted to take on, spending time at a remote location well inside Arctic Circle in the middle of winter making television recordings of the aurora.

We found that Swedish scientists had also realised where the best ground-based observations should be made during rocket flights and the hut at Rappsaive was being prepared for use as an observatory. Sweden attempted this for the first time in the winter 1977/8 but that was truncated early when one of the scientists became ill and had to return to the launch site. Our proposal to make the observations close to the impact point proved perfectly feasible. The proposal was accepted, I was selected for the task, no one else in the group seemed keen. We saw pictures of the hut and its interior;

“There’s no toilet”

was the first remark I heard. We discussed the availability of resources to run the instrumentation and decided on the collection of instruments – a low light television camera, an automatic camera that took a sequence of photographs in case there were problems with the television, and photometers to measure the spectral characteristics of the aurora to complement the black and white television images. We tested the instrumentation using the battery of a forklift truck at RSRS; this had the same characteristics as the power available at Rappsaive. We designed good thermal insulation for enclosing the instruments.

I left for Kiruna at the end of December 1978 and there I met, for the first time, Lars Andersson, the Swedish scientist who would accompany me to Rappsaive. He would also carry out ground-based observations because at the same time as the UK campaign there was also a Swedish campaign. One rocket of the Swedish campaign was a Black Brant, a Canadian version of the Skylark but a version larger than the Skylarks usually used at Kiruna. The Black Brant carried a

guidance system to overcome the restricted scope of the Kiruna range. It also had a destruct system in case the guidance did not work and the rocket veered towards Norway or Finland.



Lars Andersson at the Rappsaive hut

Lars had had considerable hunting experience and his other main task was to act as my minder and make sure that I was safe. One important message he gave me was that I must take two blocks of polystyrene, each about 18 inches long, about 2 inches square. It was not clear why this was needed but he was very insistent that this should not be forgotten. There were three or four days going through what was now, to me, the very familiar routine of the final tests of the rockets. In addition, I had the task of stocking up on food for my time at Rappsaive. I bought the usual collection of food – meat, potatoes, vegetables, cereal, bread, and fruit juice – with the restriction that it all had to fit within a small packing case. The only way to get to Rappsaive at that time of year was by helicopter that had a limited carrying capacity; also, of course, there was restricted storage space at the hut. When hunting Lars had to live in the wild off the land. He was taking with him a cured reindeer shoulder that seemed to be all that he ate, peeling off a slice off with

his knife. "It is good training for when I go hunting" he said, when he saw that I had tried to bring a collection of food that I would normally expect when living at home.

I never remember feeling particularly apprehensive about the task. I remember wanting to travel to Rappsaive as soon as possible. Swedish health regulations meant that Lars could spend no more than two weeks in the isolation of Rappsaive; we could not leave too long before the start of the rocket launch window. This was at a time when Health and Safety at work in the UK was not a major issue. Later, every time a Health and Safety issue placed restrictions on what you were allowed to do, I always wondered what the response would have been if I had reported that I would be going to Sweden to spend two or three weeks at the target point whilst the UK and Sweden fired rockets at me.

I went to the helicopter pad at the range and the helicopter soon arrived from Kiruna town scattering snow all around. It was quickly loaded and I sat beside the pilot. We took off scattering snow again over those who had come to see me off. We flew north over the hills that were the horizon that I had got used to from my many visits to the rocket range. We flew mainly over wooded land, with many reindeer stampeded by the noise of the helicopter. We passed over the downrange station where Gerry had been located, that seemed quite large and comfortable compared with the pictures I had seen of the hut at Rappsaive. The pilot tapped me on the arm soon after we passed the downrange station and pointed ahead to Rappsaive. It rose out of a plain and was very symmetrical. Lars was waiting as we flew in; the top of the mountain was relatively flat for about a 50m diameter, it was easy for the helicopter to land. We quickly unloaded and then the helicopter left, leaving Lars and myself alone.

Lars took me on a 'tour'. The hut looked taller but narrower than in the photographs. Lars pointed out our link with the outside world - the radio aerial attached to the top of the hut. In an emergency we could call the helicopter immediately; it was kept on standby for our period at the hut. At each corner of the hut there were strong wire straps securely fixed into the rock. Lars said that occasionally there were strong winds at the mountain top, the straps held the hut in place.

The hut was divided into two parts, a 'porch' area which was used for storage and shielded us from the door. Then the main area with two beds, foot to foot, a sink with a small water storage tank with a tap. The living area also had a small two-ring gas cooker and a table with a single chair next to Lars's bed. We used the area under the beds for storing the equipment for operating our instruments and put the equipment on our beds during rocket countdowns. There was also a small gas heater. On the wall was a map of the entire area with Rappsaive marked.



Setting up for countdown in the Rappsaive hut.
My bed in the foreground, with equipment on it.
Lars's bed is behind mine.

"This was a job I really liked" said Lars "making the hut at Rappsaive habitable. We use snow for our water supply. But be careful not to fill it with yellow snow"

"Yellow snow?" I was puzzled.

“I will show you outside” he said.

Outside there was a magnificent view, especially to the west where there were high mountains separating Norway from Sweden. It was early in January and the Sun was below the horizon throughout the day but it was still daylight for 5 or 6 hours.

“Go for walks, but never out of sight of the hut” Lars said. This meant that walks were down the mountain until just before the hut disappeared from view and then around the mountain.



The two huts at the summit of Rappsaive.

He took me to a second hut, about 30m from the main hut. The second hut was no more than the size of the temporary toilets that are nowadays very common at building sites. This was also strapped into the mountaintop. Inside was a wooden plank with a hole over a bucket.

“There is no heating” he said. “That is why the two blocks of polystyrene are important. Otherwise your skin will stick to the seat at these temperatures (never more than minus 30 degrees). Only use the toilet for solid matter. For passing urine just use the snow at the east of the hut. You will find the snow turning yellow. Remember not to take the snow for our water

supply from there. Piss across the wind. That is the best way of keeping it off you. Most inexperienced people piss with their backs to the wind but that causes it to eddy and blow back towards you.”

Next to the toilet hut was our petrol-driven generator for the electricity supply. This was placed away from the main hut so that we would be less disturbed by the noise when in the main hut. Lars had found that the generator ran most stably when fully loaded, if not, it would produce interference on our low-light television pictures. We found ourselves using a small electric fan heater to add additional load on the generator, but this made the inside of the hut unbearably hot. We put the fan heater outside when it was operating, heating the Arctic night. We joked about warming the atmosphere but not anticipating the later interest in Global Warming.

The tour ended, we spent the afternoon assembling our observing instruments, the low-light televisions, photometers and cameras. These were insulated to keep the temperatures high. We had to feed cables from the interior of the hut to the instruments. This was rather more difficult than I had expected because the temperature was minus 30 degrees and the cables were difficult to bend. It was as much a struggle as fitting cables into the pressure cylinder at Plessey that had made me leave that Company but this was enjoyment; it was all part of the excitement of space research. We also had to tie large stones to the boxes to secure them in case of high winds. When all was set up, I cooked myself a dinner, feeling very inexperienced at living in such a remote location, cooking meat and two veg whilst Lars simply had his reindeer shoulder. After ‘dinner’ Lars suggested that we play chess and he also produced a bottle of lingonberry wine that we shared. We finished every day in that way. He usually beat me, but not always. It occupied us for a couple of hours; we did not want to go to bed too early. Countdowns to the rocket launches did not start until about 3 in the afternoon, we rose late so that there would not be too much of the day to fill in.



Setting up the low-light TV camera

Lars was usually first to rise. He ablated, had a very simple breakfast and then busied himself checking the basics that supported us – the generator, the heater, the radio. After my breakfast, I usually went for a walk, down the mountain and then around, keeping the hut in sight. The mountain top was snow covered but not very deeply, it was, of course, usually windy at the mountain top, that seemed to prevent the snow from building up too deeply. We both seemed to have temperaments that suited us for the task. The other time filler was reading. At about three in the afternoon we would pull our equipment out from underneath our beds, and place it on our beds, connecting it to the instruments outside the hut and then checking in turn that all were operating satisfactory. One point in the countdown was for those at launch site to check;

“Are you ready for launch at Rappsaive?” We always were.

That happened at about 17:00 in the afternoon, and then we had to wait, for the weather and aurora. Our low-light televisions were always on looking at the stars. In particular, every night I remember the star Capella drifting across the screen reminding me of the boat Capella Star on which I drifted down the Thames to meet Margaret eleven years earlier. For the first five or six nights either the weather or the aurora was unsuitable. On the sixth night the wind was very strong at the top of Rappsaive. We first noticed it when Capella started rocking back and forth on our monitors as the wind blew our cameras outside the hut. It was unpleasant going outside to try to make them more secure because of the danger of being blown off our feet. That problem was eventually solved because we found that the strength of the wind and the wind direction meant that we could no longer open the door, the wind was too strong. This also meant that there would be no chance of the helicopter coming to us. Lars contacted the Swedish scientist in charge of the countdown, normally the communication was in English because of the presence of the strong British contingent but this time Lars spoke emotionally and very emphatically in Swedish. Soon we heard:

“The countdown is cancelled for this evening.”

We played our chess and drank our wine and I went to bed hoping that I would sleep until the wind dropped. It was a very restless sleep, I was not sure whether listening to the wind was waking me up or lulling me to sleep. Eventually, it was morning. I noticed the Lars was already up.

“How did you sleep?” I said.

He told me that he had stayed up all night, fearing that the gas heater might blow out. Apart from worry about the cold, he had been worried that carbon monoxide might fill the hut; that had been a problem in the previous year when Rappsaive had been abandoned.

I went outside with Lars to see if there was any damage to our instruments. They had survived the winds. The mountaintop was bare; all the snow had blown away. The toilet hut was still in place, we looked inside, it was as if all the snow from the mountaintop had blown inside, snow was piled almost to the ceiling. We set about removing it, feeling relaxed for the first time since we had seen Capella “rocking” on our television monitors.

After one week at the Hut the Sun was due to appear above the horizon briefly for the first time that winter. By that time our activities had become routine and it began to seem more of a holiday than working. At the weekend, one of the range staff flew to us in his own small plane and dropped a canister of mail to us on a small parachute. In the second week, the first rockets were fired. After checking that all equipment was operating satisfactorily, we went outside to look for the rockets coming down. We had never discussed what we should do at the time the rockets were fired. Health and Safety would have said remain in the hut. Huts such as ours were scattered across the countryside for the Laplanders to use during rocket firings when sirens were sounded. We heard bangs and saw flashes as the rockets landed but none within about a kilometre of us. The next day the helicopter came to search for the remains of the rockets. The helicopter landed on Rappsaive and we handed over letters to be sent to our families. We gave the pilot and co-pilot our impressions of where the rockets had landed.

Not all rockets had been fired by the end of the two weeks that Lars was allowed to stay at the hut. It was very disappointing that he could not stay until the final rocket was fired. We had decided that it was a Swedish law that did not apply to foreigners; I could stay until all rockets were fired. Another Swede, Jan Egeland came to join me. It was strange for me to feel that I was the person most familiar with the observatory and I showed him round but did not feel it appropriate for an Englishman to tell a Swede which direction to ‘piss’. He had though been there before and helped to prepare the site. Within two or three days the remaining rockets were fired, the last being the Black Brant with the guidance and destruct system. Unknown to us, it had been decided that even if the guidance system worked the destruct system would be tested at the end of the flight and this was immediately obvious because a bright light appeared above Rappsaive

as the rocket descended. Jan had stayed in the hut and was watching the television monitors, he came running out,

“Where is it?”

Feeling a veteran, used to rockets coming down near Rappsaive, I pointed to it:

“There it is”

It was descending close to us, but clearly not going to hit us. It landed a few hundred metres away on the lower slopes of Rappsaive. Later when we reran the television recordings the bright light appeared in the very middle of the screens and appeared to be heading directly for the camera, drifting out of view at the last moment. Jan had run out when it appeared that it was heading directly for us.

The next morning we disassembled our instruments and packed. I was asked to return on the first helicopter flight to attend a campaign ‘debriefing’. I was reluctant, I wanted to stay and help complete all the tidying up and shutting down for Rappsaive to be left vacant. I suspect that it was also a reluctance to see an end to the experience. It was two weeks that would never be bettered in my working career. I saw the helicopter making two or three more journeys, and on its final flight from Rappsaive it arrived with the bucket from our toilet carried beneath it on a long cable. It placed it in an open space just outside the main building. When I finally left to return home, it was still there. I never saw Lars again. Later I found that he was regarded as a ‘loner’ who did not form working relationships easily. Some months after I was back in England, I received a letter from him with photographs he had taken at Rappsaive. The letter concluded:

“I hope to see you again, especially on the summit of the Rappsaive Mountain.”

But the opportunity never arose, that campaign was more or less the end of the rocket phase of my career. Opportunities for the Group to work on satellite experiments rapidly evolved. That was at the expense of the UK rocket programme.

DOING SCIENCE STUDIES

After the second C78 was fired, I said to Duncan;

“They fired the second C78 last night. It sounds as though there was a good aurora.”

“Good. We should have some good measurements.”

Then, almost, as an afterthought, he said:

“Would you like to work on the data?”

Previously, I had been involved mainly in detector/electronics development working with Dick. But my experiences at Kiruna had of course stimulated my interest in the science of the aurora.

“Yes.” I replied.

When the C78 data tapes arrived the most obvious feature was that the electron intensity measured in the brightest parts of the aurora was highest in the energy range 1 – 10 keV. This was no surprise, there had been earlier measurements in the US that demonstrated clearly that that was the energy range of the electrons that produced the aurora, and that the main carriers of the energy were electrons rather than ions. At that time demonstrating that point was a sufficiently strong reason for publishing a paper. Although, it had been accepted for several tens of years that aurora was the result of electric currents flowing to the atmosphere, the energies and natures of the particles had been unknown. The next step was to identify the physical processes that led to the energy being deposited in the atmosphere at those specific energies which were far higher than those of the ionosphere or the solar wind, the two main possibilities for where the electrons started from – how did the electrons gain that additional energy to produce the light of the aurora when they hit the atmosphere? Just before the C78 measurements, Dave Evans of NOAA at Boulder in the US had proposed that a static potential

difference developed along the magnetic field lines. That gave a very straightforward prediction, electrons would gain the energy of the potential difference; their distribution in energy and their direction of travel ('pitch angle') was easily predicted. The most obvious use of the C78 measurements was to see how well the explanation of Dave Evans could be confirmed, and to estimate the potential difference traversed by the electrons.

I measured the energy of the maximum intensity for every energy scan (about 4 times a second); that should be a measure of the potential difference. One immediate problem was that it changed quite significantly from energy scan to energy scan. Also there were still high intensities of electrons at energies below the energy of the maximum intensity. For a potential difference there should be none. There were similar complications when the pitch angles were studied. At first I was keen to ignore those complications and to publish a simple paper reporting confirmation of the Dave Evans results, but Duncan was wary. This was a real strength of Duncan in ensuring that the scientific output of the group was of a high standard, he always took the most critical line and wanted all to be explained.

At that time, 'Chunkie' Lepine had joined the group; he was an expert in computing and mathematics. I was casually talking to him about how I was having difficulty making the C78 measurements fit with the Dave Evans explanation.

"The electrons are thought to be accelerated by the static electric field of a magnetic-field aligned potential difference."

Chunkie replied, not totally seriously:

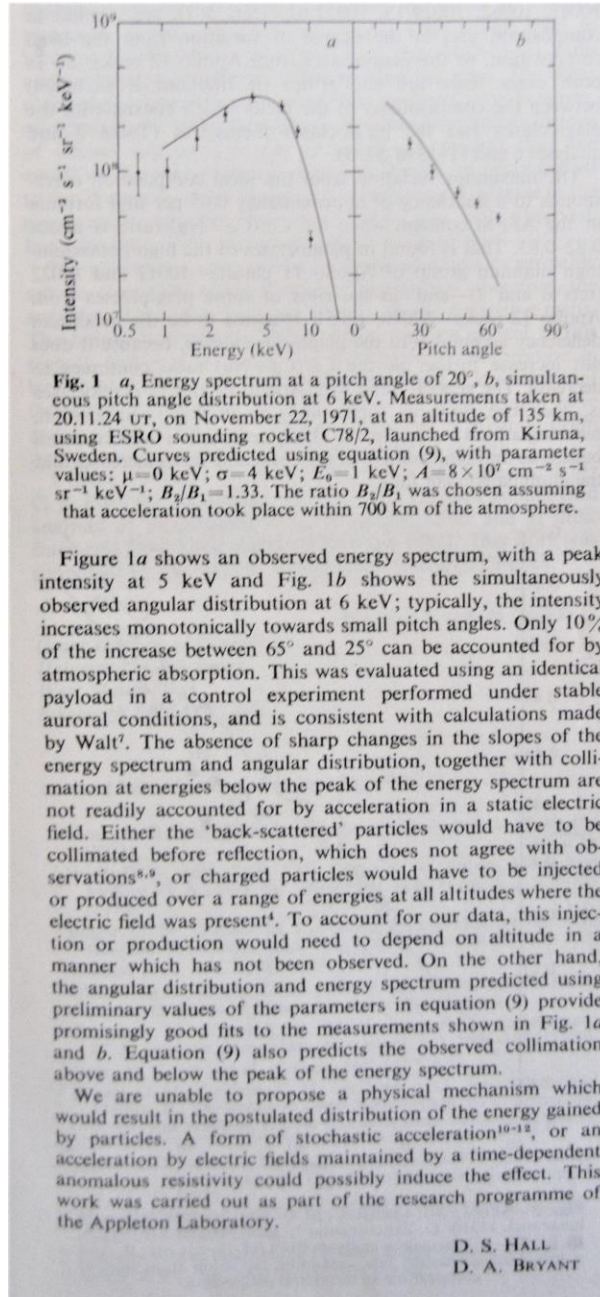
"Well, perhaps it's dynamic and not static"

Immediately I recognised that that may well be the obvious explanation. Perhaps the hypothesized potential difference was varying rapidly so that our measurements were only a

crude average. I went to Duncan with that suggestion; he immediately saw that if we assumed there was a rapidly varying potential difference that would give a far more believable description of the measurements. That was the start of the topic, acceleration of auroral electrons, that pre-occupied the group for several years. Duncan was still writing about it twenty-two years later.

During the next months I developed the idea that the measurements demonstrated a rapidly-varying potential difference, using the C78 measurements to derive the average potential difference and the spread of the variations. We wondered if the variations were so rapid and so marked that perhaps we should call the dynamic electric fields associated with the varying potential difference 'waves' but hesitated to do that, introducing the idea of time-varying potential differences seemed a sufficient step. We wrestled with whether to include the word 'stochastic', meaning the electrons were accelerated in a series of small steps rather than the one big step of a static potential difference. Eventually, I wrote a paper with Duncan, 'Time-varying acceleration of auroral particles' that was published in *Nature*.

My first science talk on auroral particles was at a 'European Rocket and Balloon Symposium' in Sweden. My paper on time-varying acceleration was controversial. Swedish Groups at Kiruna, Uppsala and Stockholm were publishing papers in support of the static potential difference model. The evening before my talk was the conference dinner. That was my first experience of dinners at which the alcohol flowed far too freely. I sat across the table from Rolf Bostrom of Uppsala. We seemed to spend the whole evening discussing static or dynamic electric fields, without noticing just how much wine was poured into our glasses. It was a friendly discussion, I remember us parting at the end of the evening of friendly terms but agreeing to disagree.



Extract from my first publication

The following morning I had to give my talk, I felt dreadful and remember talking through an intense headache. Bengt Hultquist, head of the Kiruna Geophysical Institute, made some criticisms. My talk was followed by one from his deputy, Rickard Lundin. Rickard's measurements seemed to support my ideas but he kept to the static potential difference explanation (in my view ignoring the many features that did not fit that explanation). That rivalry between RSRS and the

Swedish Groups continued for several years but always as a friendly rivalry, held together by the feeling that we were all trying to achieve the same objective, understanding fully the nature and causes of aurora. I found it fascinating how that early and continuing rivalry meant that I always had very close relationships with Scandinavians and worked well with them on many later occasions. After I retired I was invited to join the Swedish Space Science Advisory Committee that reviewed Swedish grant proposals and recommended which should be supported. I spent two three-year terms on that committee and thoroughly enjoyed working with Swedish colleagues who I had known for thirty years.

In the early 1990s the post of Professor of Space Physics was advertised to be located at Kiruna when Rickard Lundin, who had taken over from Bengt Hultquist, decided to go into semi-retirement and move to Umea. I applied but Herman Oopgenorth got the post. Risto Pellinen from Finland was on the selection committee and told me the choice had come down to me or Hermann. Risto said because of Kiruna's key location in the auroral region it was felt more appropriate to have a professor who specialised in ground-based studies as Hermann did. Quite rightly, Risto pointed out space instruments could be constructed anywhere.

Hermann gave up the post after one year. He apologised to me for giving up so quickly and told me that his life had been made hell because two of the Kiruna women scientists thought one of them should have got the post. When Herman left, Sweden had just introduced a rule on gender equality, one of women got the post and it was not advertised.

Together with Duncan, I developed further our thoughts on 'stochastic' acceleration of electrons, identifying more and more features that simply could not be accounted for by the static potential difference theory. There seemed to be a population of low energy particles that traversed the acceleration region but without changing energy, that to me suggested a 'resonant' effect, only particles of a certain speed were accelerated which would be expected for wave-particle interactions – think of surfers, it's only when they get themselves to a certain speed relative to the wave they are picked up and accelerated.

I remember well my first major public presentation on that at a conference at the University of Alaska in 1980. That was my first experience of a conference in the US and first contact with the lead American proponents who favoured the idea of static acceleration, for instance, I met Dave Evans for the first time. My paper was scheduled to follow an afternoon coffee break. For the first few days the weather was magnificent – it was June – but following lunch on the day of my paper large black clouds gathered and during the coffee break a massive thunderstorm started. The auditorium was sparsely filled when I had to start my paper, most were outside watching the storm. I was politely listened to and did not have the intensive grilling that I expected and was disappointed. Perhaps we were considered an eccentric sideshow. Scientist tended to listen politely but then ignore the work. We were never viciously attacked, suggesting that we were not seen as a real threat.

A couple of years later Bob Bingham joined our group. He was a ‘theorist’ rather than an experimentalist and he was able to translate our ideas on resonant acceleration by waves into a more rigorous mathematical model and also identify possible candidate waves, lower hybrid waves.

During my years of studying auroral physics and interacting with the international community I was fortunate to be able to justify attending many international workshops/conferences many of which dovetailed with the work of planning and implementing new projects. Most were in Europe but, what became my main annual conference was the American Geophysical Union conference in San Francisco every December. That was the top conference for auroral physicists, attended by most of the leading scientists in that area of study. Every year I gave a paper at that conference.

My last significant contribution to studies of auroral acceleration was a paper on auroral ‘rays’. Auroral rays are the fast-moving striations that make aurora look like curtains. Most of the dramatic pictures of aurora feature those striations. By chance, F39 had traversed aurora as it

‘broke up’ into a series of fast-moving striations. Those could be identified clearly in the rocket measurements. In addition to our particle measurements, Karl Maseide from Norway had photometers on the rocket and Nelson Maynard from the US had electric field measurements. I brought those measurements together, the photometers confirmed that we had encountered the ‘rays’ recorded by the ground-based television at the launch site. I demonstrated that the electric field changes measured at the rocket were most likely a consequence rather than a cause of the variations in the particles. The particles were measured with sufficient resolution that we could distinguish the rapid changes within the particle streams that caused the variations in the auroral light to give the fast-moving rippling-curtain effect. It was clearly the level of acceleration that was changing to give the striations, as would be the case for wave acceleration. The static potential difference model predicted changes in density but not acceleration. The patterns that are taken up by rays made nonsense of the idea that there were well-ordered, large-scale, patterns of static electric fields within the magnetosphere. Bob Bingham pointed out that what happened when areas of dense waves built up it was known that striations would appear – his term was ‘filamentation’; that was the title of the paper.



Auroral Rays – Filamentation in the Auroral Accelerator

We were treated as eccentrics because of our continual raising of doubt about the static potential model that had become the standard within the community. I remember giving a talk to the general public on the aurora and saying that:

“We think that auroral electrons are accelerated by waves. We had not managed to persuade the rest of the world; or the rest of Europe; or the rest of the United Kingdom; or even the rest of our Laboratory; but we remained convinced.”

It seemed a nice summary of how the science mavericks that are present in all fields feel about their ideas. But both Duncan and I never lost our belief that there were simply too many features arguing against the static potential difference model. We were best placed to realise that because we had the best series of measurements of auroral electrons through our rocket studies. In some ways our arguments against the model strengthened it, our attacks forced people to work even harder at justifying the model and closing minds to alternatives. Most of the work by others became concentrated on explaining electric field measurements rather than detailed studies of the electron energy distributions. Even if the static potential model is justified there is still a need to account for the many details of the electron energy distributions that cannot be explained by that model. I always felt that it needed the passing of our generation for newcomers to contest the standard interpretation, as newcomers do. Our work will have been forgotten; perhaps we will be the old fogeys who, when a controversial newcomer proposes a wave theory of the aurora, will say ‘We did this many years ago’. One day, the penny, or the kroner, or the dollar, or the euro, will drop.

For instance, 48 years after my first paper, this appeared:

The Source of the Aurora Borealis: Electrons Surfing on Alfven Waves

Professor G. G. Howes, University of Iowa; Professor J. W. R. Schroeder, Wheaton
College, Illinois April 29 2022

New experiments have shown the source of the aurora borealis. Researchers have demonstrated waves accelerating electrons under conditions that correspond to Earth's magnetosphere. The new experiments show that electrons "surf" on the wave. This means the energy of the wave is transferred to the accelerated electrons, like a surfer catching a wave and being continually accelerated as the surfer moves along with the wave. These electrons are the ultimate source of the light we call the aurora borealis.

My final science effort was a paper on the 'boundary layers' of the Earth's magnetosphere; those are the regions of the magnetosphere that map to the regions of auroral displays. The study was a consequence of my role as Principal Investigator for the electron measurements of the UK satellite of the AMPTE mission (see below). It seemed to be the standard paper that is cited whenever electrons in the boundary layers are mentioned in papers. Twenty years after its publication it had been cited more than a hundred and thirty times whilst twenty times is the average for a space science paper. A Greek scientist had worked with me on the boundary layer paper, I was astonished, 30 years later, to find, through working with him, I had become an Affiliate of the Academy of Athens.

BECOMING A SATELLITE SCIENTIST

Within Europe, through a combination of the European Space Agency and the French national space agency, Centre National Etudes Spatiale (CNES), an independent European satellite launcher was under development, Ariane. A second test launch was due in 1980, Ariane offered to carry a payload at no cost on the test flight. Gerhard Haerendel, Director at the Max Planck Institute for Extraterrestrial Physik at Munich, proposed that this opportunity be used for an experiment, “Firewheel”, in which chemicals were released to ionise and disturb actively the Earth’s magnetosphere and the consequent local physical processes would be observed. Gerhard was one of the most influential space scientists in Europe and remained so for more than 30 years. He was an imaginative, dynamic, scientist that was always a pleasure to work with. Duncan knew Gerhard from contacts between the UK and German rocket programmes. Gerhard proposed that Germany build a satellite that carried out the chemical releases and a second satellite to observe the consequences and that three other satellites be provided by others to observe the consequences. He approached Duncan for him to argue that the UK would provide one, others would be from the US and Canada.

The satellites would be battery powered and last only for the few hours needed for the measurements at the time of the chemical release, in other words, they would be similar to rockets. RSRS was designing and constructing complete rockets by that time, the mechanical structure, the power system, the telemetry in addition to the instruments. It was perfectly feasible to build in the UK one of the satellites proposed by Gerhard. A team from RSRS and MSSL was set up to do this. The schedule from the start of the project to launch was 18 months. That did not seem too bad for teams that had been used to a two-year schedule for rockets but now seems an incredibly short time for a satellite project. I was keen at the time to spend more time carrying out studies using our data from rockets. I was regularly giving papers at conferences and writing joint papers with Duncan; we were developing our ideas about the roles of waves in the acceleration of auroral particles, I wanted to concentrate my efforts on this instead of taking the

lead on development and construction of Firewheel sensors. Mike Smith had joined the Group to eventually take over the sensor production from me, but the time pressures were too much for him – he frequently had epileptic fits when under pressure - and I had to step in to use my experience allowed to construct suitable detectors in the time available.

After delivering the sensors, I again hoped to be able to concentrate on science analysis and interpretation, but, no, another crisis arose. To reduce the satellite battery weight to a minimum the batteries had to be lithium. These were batteries in an early stage of development. A very efficient battery in terms of energy per kilogram but still with uncertainties to be resolved before they could become standard. There were stories about lithium batteries bursting into flames even when left dormant. This meant that there were difficulties in transporting the batteries. No airline would carry them until further proving of their safety had been made. The batteries chosen for the UK Satellite were manufactured by Honeywell in Philadelphia. It was not possible to transport them to the UK without several phases of bureaucracy and cost. The decision was made that the battery box would be assembled at the Honeywell factory in Philadelphia. This would be the task of an MSSL 'wireman' but at a late stage there were difficulties that prevented the MSSL wireman from going to Philadelphia.

Dick walked into my office.

'Can you spend the next three weeks in Philadelphia assembling Firewheel battery boxes?'

I was an obvious choice, I had finished my main tasks for Firewheel, what would be lost would be a delay in the science analysis work of the group. The only other possibilities were Dick and Trefor Edwards but they were preoccupied in the assembly of the satellite itself. The battery box task was not particularly demanding in terms of technical ability but needed a cautious, careful, approach. Piers Eggett, who was a skilled technician at RSRS, would accompany me. I knew I could do the task especially with the support of a skilled technician. There was the additional concern about the safety of the lithium batteries but I felt confident that working at the American factory

would educate us in the precautions to be taken. Three days later, Piers and I were on the plane for my first visit to the US.

We turned up at the factory, we were relieved to find we were expected, everything had been arranged in a rush and our travel section had forgot to hire a car for us and we had to spend our first morning in central Philadelphia sorting out a hire car. The first days seemed to be spent on the phone back to the UK asking about the materials to be used, the methods to be followed. There were no written 'procedures', no documents showing the battery box layout, the steps to be taken, the test programme. That was left for Piers and myself to work out on the spot. We had to establish the facilities that would be available to us. For instance, vibration and vacuum test facilities would be needed. The main technical challenges was the welding of connections to the batteries and the encapsulation of the batteries to allow for security against vibration. The Honeywell people were very helpful throughout and that made our task easier.

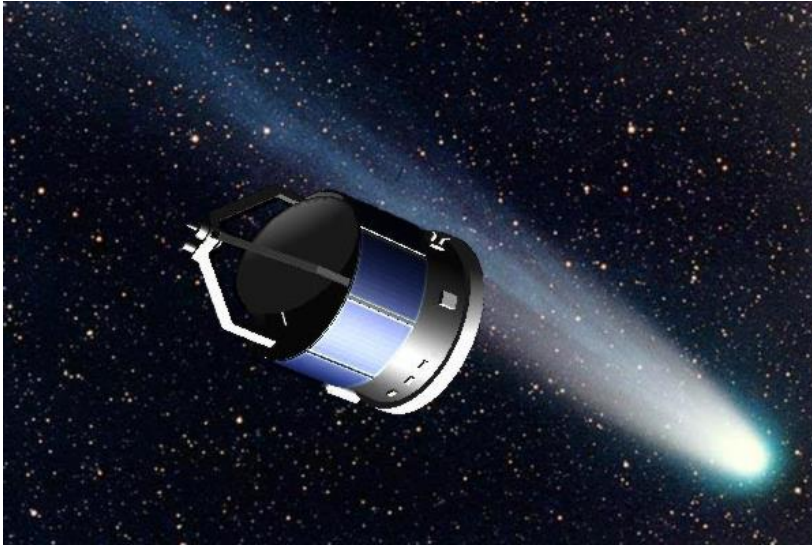
The factory was closed at weekends and that allowed us to travel around and see more of the countryside. The first weekend we drove inland, simply happy to see the sights and sounds of the USA. I did all the driving because Piers had never learned to drive. The second weekend we decided that we would visit New York on the Sunday. We did not quite know what to expect in New York but when we arrived we found that the traffic was very light, we drove straight into Manhattan and parked on Wall Street. There were very few other cars to be seen. We were nervous about leaving the car, we had the image of New York being full of car thieves that made me remember arriving in London for the first time as a teenager and thinking that all were gangsters. We walked around, it was all very quiet. We went to the top of the Empire State Building, that was something I really enjoyed, I was familiar with the images from 'King Kong' and bought a pennant showing the building with King Kong on it. We also had breaks in our work to drive around Philadelphia. We saw the Liberty Bell and the historic part of town, also we enjoyed driving round the suburbs, all was new to us.

The actual tasks in Philadelphia were to obtain working and checked batteries from the production line and then insert them into cells of the battery box after first filling the cells partly with epoxy to hold them in place. Choosing the correct amount of epoxy and the right pressure to try to ensure that the epoxy filled around the edges of the batteries was where a degree of dexterity was needed. The work was mainly straightforward but a high degree of care was needed. The reliability depended on the skill and integrity of Piers and myself. It took two weeks to complete a battery box and a spare and fully test them under vibration and under vacuum.

The next step was to deliver the battery boxes to the launch site in French Guiana. This illustrated another degree of informality in the whole Firewheel project. Because of the uncertainties in the behaviour of the batteries special arrangements had to be made to transport them from the USA to French Guiana. An arrangement was made with the Argentinian air force. One of the scientists working in Germany on Firewheel was a Colonel in that air force. But the battery boxes first had to be delivered to Florida. We arranged to meet Dick and Trefor at NASA's Goddard Spaceflight Centre in Washington where they were at a final meeting of the full Firewheel teams before going to the launch site. But NASA would not allow the batteries on their premises. I drove to Washington with Piers and we handed them over outside the fence of the Spaceflight Centre for Dick and Trefor to carry them to Florida for onward transfer by the Argentinian air force.

Eventually, the satellites were completed, the Ariane rocket was ready, it was launched, went off course and was destroyed. There was no return from Firewheel for us, except the extra experience that we had gained in moving to a satellite project. That explosion seemed to be accompanied by an explosion of opportunities for satellite experiments. That was also the time RSRS was moved to the Rutherford Appleton Laboratory (RAL) in Oxfordshire. Gerhard Haerendel was determined that those who had contributed to Firewheel should not be left empty-handed; he secured a role for us in a German-US space mission Active Magnetospheric Particle Tracer Explorers (AMPTE). This was a mission of NASA. There were two main satellites provided by Germany and the US; they were connected during launch by a metal cylinder; it was agreed that the UK could use the cylinder as the basis for a third satellite. The Firewheel

experience meant that taking the additional step of upgrading the power system was a relatively minor development.

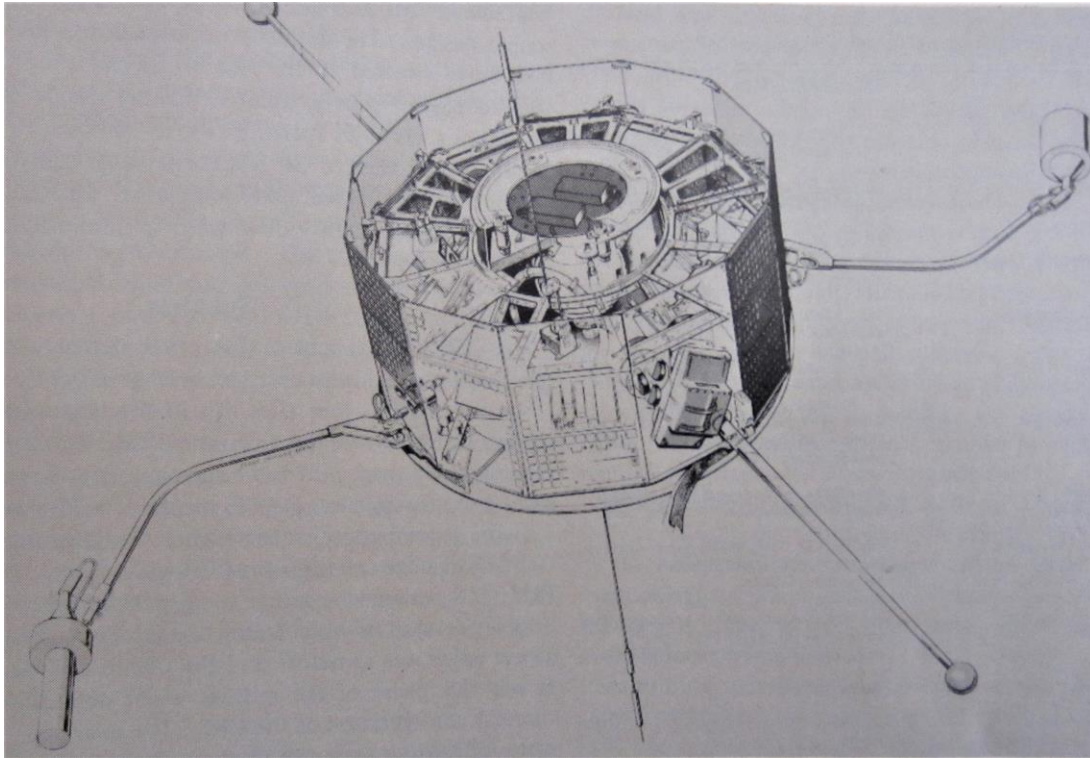


The Giotto mission to Comet Halley

Alan Johnstone had been an original member of Duncan's group but had spent four years in the USA carrying out auroral research before returning to work at the Mullard Space Science Laboratory. We worked with Alan on several projects. First we became involved in the ESA Giotto mission to Comet Halley. Alan had proposed to provide the both the electron and ion sensors and was selected to provide the ion sensors. A separate group led by Henri Reme in Toulouse would provide the electron sensors. I provided the high voltage generators for Alan's instruments. The sensors were flown to Comet Halley on the Giotto spacecraft in 1986 and worked perfectly.

For AMPTE, again I had to take responsibility for providing the electron sensors and was now formally called a Principal Investigator (PI); a status in space science that was always eagerly sought. That satellite, called AMPTE-UKS, was operated in 'real time' from a control centre at RAL. There were insufficient resources to operate the satellite continuously and also the on-board batteries were limited to a few hours operation and then needed recharging. The satellite was operated for only a few hours each day. But we could choose what time of day and that

meant we could choose which region of the magnetosphere to study, daily the satellite travelled from the solar wind into and out of the magnetosphere crossing all its different regions. Real time operation meant we could check using just one instrument which region the spacecraft was traversing and then switch on all instruments when we were in the region chosen for study on that day. That also meant we could watch the science measurements as they were received.



The AMPTE-UKS Satellite – about 1 metre diameter

Operations in that way needed a scientist-in-charge and on most occasions that task was mine. I enjoyed that task thoroughly although it did mean occasional anti-social hours and working during the Christmas break. It was rare that there was any problem until early one January morning five months after launch, John Wright who was responsible for the main reception and transmission of information to and from the satellite was going through the usual routine of establishing contact for me to look at the science data but received nothing. I felt immediately that that was the end of operations; not feeling disappointment just an acceptance that all good things must come to an end and we could now concentrate on interpreting the data already

available. I went back to my office to work on other things. There were meetings, there were attempts to re-establish contact but we never knew what had gone wrong.

At the same time that we were becoming involved in AMPTE and Giotto another key strand in our work started. Duncan had been invited by Ian Axford, head of the Max Planck Institute for Aeronomy in Katlenburg-Lindau, about an hour's drive from Hanover, to explore possibilities for collaboration. Ian was born in Dannevirke, New Zealand, but spent most of his working life either in the USA or Germany. Two German scientists, Bernd Wilken and Wolfgang Studemann came to visit us and that was the start for me of a long and fruitful period working with Germany. Collaboration in four space missions evolved from that visit – a NASA satellite, Polar; a NASA/Department of Defense satellite, Chemical Release and Radiation Effects Satellite (CRRES); a Swedish satellite, Viking; and, finally the ESA Cluster mission (and almost the ESA SOHO mission). I took the lead within RAL on all those activities with Duncan being preoccupied with AMPTE. During that period in the early 1980s I was working on instruments for AMPTE, Giotto, Polar, CRRES and Viking.

It was during that time that I had a major collapse and was half paralysed for about 6 – 10 hours. A diagnosis of epilepsy was eventually confirmed, but it never interfered with my working life. When back at work on the Monday morning after the major collapse, which was on the preceding Friday evening, at first, I wondered what extra precautions I should take, for instance, using the lift instead of the two flights of stairs between my office and our laboratory, but decided to ignore the collapse and carry on as though it hadn't happened except I had to give up driving for two years.

Giotto and Viking were launched within a 18 month-period between August 1984 and February 1986, Polar and CRRES had also been expected to be launched in the late 1980's but in the end slipped into the 1990s. In the early 1980s the instrument programmes for all overlapped and meant working with Germany and the US in addition to activities in the UK. In the words of Geoff Bryant at RMCS Shrivenham quoting Byron to me years earlier, I strove for the impossible and

had started work on a PhD based on our studies of auroral acceleration but the demands of the instrument programme were too much. Also, from a career point of view, a successful instrument programme would be a far better career move than acquiring a PhD in my early forties. I dropped the PhD and forever had to stop people adding Dr to my name; it was extremely rare that someone in my position did not have a PhD.

Bernd and Wolfgang were experts on instruments that determined the weight of ions, and hence the type of ion (Hydrogen? Helium? Carbon? or whatever), through measuring their 'time-of-flight' - the time taken for the ions to pass a 'start' target and then be detected by a 'stop' target. We were experts on the 'front-end' that analysed the ions by energy; that meant that our role was to design and construct an electrostatic analyser and the high voltage generator that went with it (20 kV this time, far higher than our previous generators). Another challenge was manufacturing the electrostatic analyser from beryllium a material for which there were health dangers if it were not handled properly. But it had excellent lightweight and particle scattering characteristics. We needed to find a manufacturer who could produce 'ogive' shaped products with the special handling equipment that was necessary for working in beryllium. Fortunately, Tony Jones, our mechanical design engineer knew of just the place; a Royal Ordnance factory at Cardiff which had become part of the Atomic Weapons Research Establishment. We visited the plant and were shown the facilities. There were several ogive-shaped pieces in the factory, we could not be told what they were for but from my rocket-experience they were rocket (missile) nose-cones.

Eventually all the instruments were delivered successfully and worked in space. That period through the early 1980s expanded my international networking considerably. For the first time I had exposure to an ESA programme through Giotto. I expanded my experience to working with Germany and the US, and Viking meant re-establishing links with Scandinavians. I remember waiting to meet someone to discuss a future project at the entrance to the auditorium where a major international conference was being held at the end of the 1980s; more than twenty people recognised me and stopped to say hello.

Viking, the Swedish satellite, was operated in a similar way to AMPTE with a national control centre that displayed data in real-time and allowed scientists to operate their instruments in real-time. I spent two periods at the control centre which was at the Kiruna rocket range and became sufficiently familiar with the instruments and, having now had considerable expertise from those many days of AMPTE operations as scientist-in-charge, the Swedish team, many of whom I knew from my auroral science studies, invited me to take on the role of scientist-in-charge for Viking for a few days. I felt immensely proud of being asked to take on such a role for a foreign national satellite.

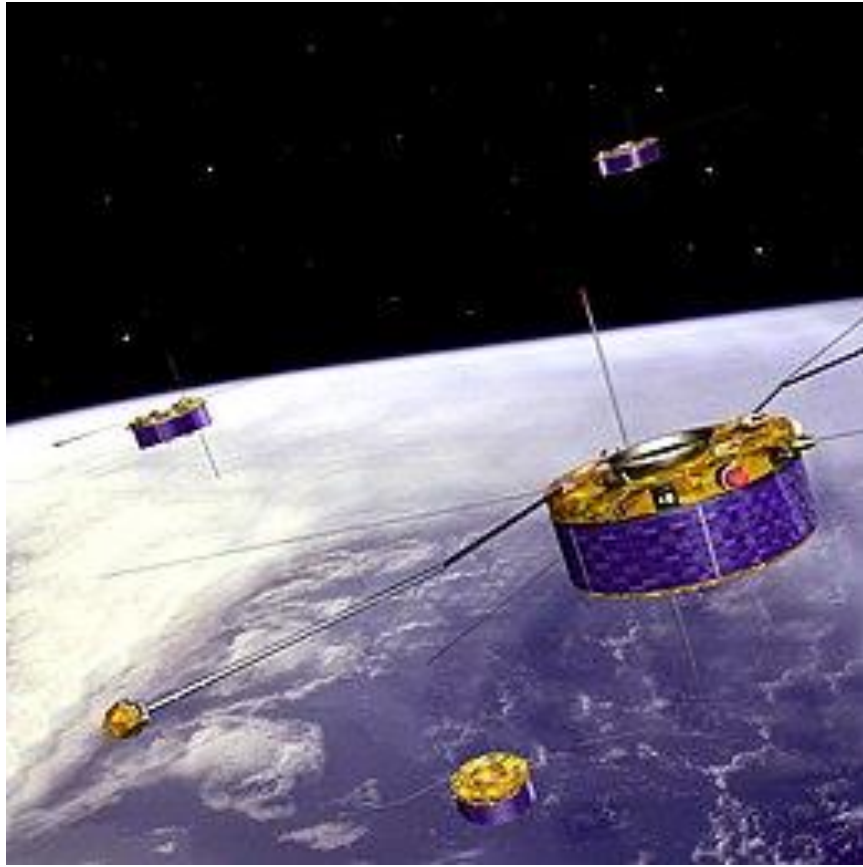
Another relationship that I built through the AMPTE programme was with David Southwood of Imperial College who was the principal investigator for the AMPTE magnetometer experiment. At that time David was extremely influential in the UK programme, he seemed to be the chair of just about all the key committees. I got on very well with David. He reminded me of Harold Macmillan because he had an impressive moustache and a very English sense of humour. Also, we were both west-countrymen and shared a nostalgia for the Great Western Railway.

GETTING TO KNOW THE EUROPEAN SPACE AGENCY (ESA)

The European Space Research Organisation (ESRO) had by the 1980s become the European Space Agency (ESA) which covered a broader range of space activities. Another flight opportunity for our particle detectors became possible when in 1984 President Reagan decided that the USA should have a permanent orbiting facility in space – a Space Station. Because the Space Station seemed to be the major activity that would dominate space activities in the late 1980s all sections of ESA wanted to be involved, including the Science programme. For the ESA Science programme all 13 ESA member states had to make a mandatory contribution based on their GDP, thereby making Britain an integral part of the programme. The Science Directorate issued a call for ideas for using the Space Station. We were part of the proposal, Auroral Imaging Observatory (AURIO), that won the competition. AURIO was proposed by Johan Stadsnes from the University of Bergen and our role at RAL was to provide detectors to measure the auroral particles whilst Bergen and a Canadian group provided instruments for imaging the aurora from space. We had many, many meetings with ESA planning the experiment needs and modifying those as the Space Station programme evolved and the accommodation for the instruments evolved. The main value for me was the experience I gained in working with the ESA Science Directorate, the Space Station programme and at ESTEC. That experience became valuable when I later became a delegate to the ESA Science Programme Committee (SPC). And when I found myself as Britain's first point of contact on Space Station matters, trying to keep opportunities alive for British scientists whose studies needed microgravity conditions.

By the middle 1980's the ESA Science programme had become far more structured through the programme 'Horizon 2000' led by Roger Bonnet, the ESA Director of Science. This envisaged a series of 'Medium' (each at a cost of about 400 MEuro) and 'Cornerstone' projects (each at a cost of about 1000 MEuro), the Giotto mission to Comet Halley being one of the first of the Medium missions. The first Cornerstone was to be a combination of two missions, a solar mission SOHO and a magnetosphere mission, Cluster, a 'cluster' of four spacecraft flying in formation. The justification for the joint programme was the strong link between the Sun and its impact on the Earth's magnetosphere. Horizon 2000 also envisaged increased resources paid by the member

states; that killed any possibility of any more national satellite programmes in the UK; the 'only show in town' for British space scientists became involvement in ESA missions.



The ESA Cluster mission – a cluster of four satellites studying the Earth's magnetosphere

The arrangement within the ESA Science programme was that ESA through industry provided the spacecraft, the launch and operations; the national agencies provided the science instruments through their national research teams. The selection of who should provide those instruments was through international competition organised by ESA. Duncan had been on the team that had planned the Cluster mission; it was natural for us to take part in the competition for providing the science instruments. It was agreed that Alan Johnstone would lead a team proposing instruments to measure ions and electrons and that we would be part of his team. Through our contacts with Bernd Wilken at Lindau we also took part in his team that would propose measurements of 'energetic' particles, particles at energies higher than those covered by Alan's

instruments. Joe Fennell of the Aerospace Corporation in Los Angeles and Ted Fritz of the Los Alamos National Laboratory also worked with the Lindau team and that meant we eventually had team meetings in Los Angeles and Los Alamos. Also, through my many visits to Lindau I had got to know Helmut Rosenbauer and he invited me to take part in a team proposing ion and electron measurements for the SOHO spacecraft. That began an intense period of planning new instruments and writing proposals; for ESA those had to cover all aspects of instruments including topics such as 'Product Assurance' meaning the procedures that would be in place to guarantee successful reliability of the instruments.

Working on the Cluster and SOHO proposals gave me considerable experience in working with ESA, especially the ESA Science Directorate. I found myself leading the instrument planning and proposal writing for the RAL involvement in both the Cluster electron and ion instruments proposed by Alan Johnstone; in the Cluster energetic particle instruments led by Bernd Wilken, and in the SOHO electron and ion instruments led by Helmut Rosenbauer. Because SOHO/Cluster was the only opportunity in the ESA Science programme for solar-terrestrial physics for perhaps a generation, all European teams in particles and fields studies wanted their instruments selected. The competition became intense. For the low-energy ion and electron instruments the two Giotto PI's, Henri Reme, from the University of Toulouse, and Alan Johnstone were again leading separate proposals both proposing a combination of ion and electron sensors. The electron sensors were the more straightforward without the complication of determining the particle composition as was the case for the ion sensors. Planning the electron sensors of Alan's proposal was delegated to me following my experience as PI for the AMPTE electron sensors.

For Giotto, Alan and Henri had led separate proposals each proposing both electron and ion sensors and, though the selection was meant to be on the science performance of the instruments, a compromise was reached by ESA that Alan would provide the ion sensors and Henri the electron sensors. I eventually found that that was a typical political compromise during the competition and ESA selection. The instruments were nationally funded and finding roles for both Alan and Henri spread the funding load between the UK and France. It also spread

involvement in the mission across a broader group of scientists. Eventually helping to engineer those compromises became part of my responsibilities.

Whilst at ESTEC with Alan and his team waiting for one of the ESA Cluster reviews we were left in a room that contained piles of documents, it was still a world of paper rather than electronic documents. On casually looking through the documents we realised that they were ESA comments on the product assurance sections of the Cluster proposals – nothing particularly revealing. That episode became common knowledge but, as always, became distorted in the retelling – it seems to have reached Henri Reme's ears that Alan's team had seen his full proposal and that would have given Alan a considerable advantage in the competition for selection. Relations between the two groups became exceedingly frosty and, though Henri and Alan had worked together well on Giotto, communication stopped and suspicions grew.

I had met at a science conference, Claude D'Uston who worked at Toulouse with Henri and we had established a good relationship through our common interests in electron measurements. Despite the frosty relationships between the French and UK groups Claude and I got on extremely well to the extent that I arranged to visit him with my family for lunch whilst holidaying near Toulouse. He gave us lunch and then took me to the University to meet Henri. That was the first time I had met Henri and was not quite sure what to expect. One of his first questions was whether we had seen their proposal but I could assure him we had only seen ESA's brief comments on product assurance aspects. He was reassured and we spent the afternoon chatting pleasantly about our common interest in electron and ion measurements. I realised the importance of such face-to-face meetings with those who disagreed or were suspicious of your motives. That stood me in good stead when later I became involved in the diplomacy of space science. The outcome of the competition for Cluster involvement was the reverse of Giotto – Henri was selected to provide the ion sensors; Alan to provide the electron sensors, the sensors that I had led the planning for. Our team led by Bernd Wilken was chosen to provide the energetic particle sensors.

For the SOHO proposal, Helmut Rosenbauer differed from Alan and Bernd in that he was more passionate (yes, some Germans are passionate) and hence less efficient. He had gained a reputation for interfering in instrument development programmes on his own initiative and without consulting others. I was warned that he was a difficult person to work with, but we worked together well in preparing the proposal and were selected to provide the instruments for SOHO. For a while, I was the only scientist in Europe working on the instruments for both SOHO and Cluster. But, during the Giotto programme, the Max Planck Institute at Lindau had over-committed itself in providing the spacecraft camera and that was a major concern. It was the key instrument as far as publicity went and there were fears that it would not be ready. It was ready but at considerable expense to Lindau. Ian Axford, in his role as head of Lindau, decided that Lindau should not over-commit itself on SOHO/Cluster and Helmut's instrument was withdrawn, leaving SOHO without plasma measurements. That was a great disappointment to me. I had already, through the AMPTE studies, developed a keen interest in relating solar wind measurements to features on the Sun and the joint SOHO/Cluster studies would have been the ideal follow-up.

So, I had a significant role in three SOHO/Cluster proposals and all were selected against the European-wide competition. That meant a valuable addition to the RAL Programme – involvement in an ESA Cornerstone mission meant a guarantee of support from the Research Council. But we had to go through a formal application process for the actual level of resources needed to carry out the work. That meant going for the first time to the Research Councils' new custom-built facility, Polaris House in Swindon; the Councils had been moved out of London. The construction of Polaris House foundations met some difficulty because they were built on land previously occupied by Swindon Railway Works; in fact, on the ashpits on which ashes from a century of steam trains had been dumped. It was where my mother and I, forty years earlier, had seen my father and she had told me I would be working there one day!! It felt really special going to Polaris House for the first time. After that first visit I visited Polaris House many, many, times; even now my pension is sent out from there.

The application process for funding for Cluster involved going through the mill of scrutiny of costs by Alan Wells of Leicester University. Alan was the lead manager for the Leicester X-ray astronomy group and had established himself as an authority on managing space instrument programmes. Leicester was a main rival to RAL and Alan was seen as an ogre who would go out of his way to make life difficult for RAL. Eventually Alan and I worked together well, for instance, I contributed to planning for the National Space Centre at Leicester that had started on Alan's initiative. I learnt that he was a very fair and level-headed person. After I retired, he invited me to join him in reviewing management proposals for NASA projects but I was committed to spending time in New Zealand and could not make the commitment to work with Alan .



A rare picture of some the Space Plasma Group members together, a year of two before I became leader. Chris Chaloner and Chunkie Lepine are to my right; Trefor Edwards directly behind me with Duncan Bryant on his right.

Partly as a result of my successful contribution to securing key RAL roles in SOHO/Cluster instruments I was promoted and became leader of the RAL Space Plasmas group with Duncan made an 'individual merit' Senior Principal Scientific Officer which freed him to concentrate on science rather than project activities.

Over the next decade, I got to know well Marcello Coradini, Head of Solar System Science at ESA, and thoroughly enjoyed his company. But there was an early hiccup in our relationship. I had decided to propose to ESA a Programme Of Many Innovative Space Experiments (PROMISE) which called for the next 'Medium' mission to be a series of smaller missions rather than a single mission. The ESA Science Directorate were adamantly against 'small missions'. In their view, those were for national agencies to carry out, not ESA.

My concept was that there were significant science missions that were far less expensive than an ESA Medium mission but still could not be afforded in national programmes. Opportunities were becoming sparse and after a Cornerstone mission it would be a generation before another mission in that particular field of study would be possible in the ESA Programme. I spoke to scientists across Europe who I knew had ideas for space missions but with little prospect of them being carried out because they were too small for ESA but too expensive nationally. I wrote the preamble to the PROMISE proposal and tried to take into account possible objections. Our objective was to be selected for ESA to, at least, study the concept and think about the possibilities. The preamble for PROMISE was:

We propose a programme of investigations from several science disciplines. The programme aims to achieve a significant increase in the world-class science compared with that normally expected for a Medium mission. The increased return would be achieved by identifying a programme of missions in which the individual missions would have less scope than a mission for which the whole of the Medium mission budget is necessary, but the return from the complete set of missions would exceed that from a single, full-budget, mission.

The science objectives of the programme could cover a range of scientific disciplines, or could be a series of complementary missions. The exact nature of the programme would be an issue to be decided during the Assessment Study. To provide a focal point for an Assessment Study a range of diverse missions is proposed to enable the Study to be

comprehensive, covering all issues that might arise during a programme such as PROMISE. The missions are diverse in the scientific disciplines, in the countries who potentially would play key roles, and in the present state of mission planning.

To illustrate the scope of the PROMISE programme we listed the major objectives of the potential missions. Those involved study of the Sun, Solar-Terrestrial physics, the ionosphere, the Earth's atmosphere, the Earth's magnetic field, the Universe's cosmic background radiation and the distribution of cosmic diffuse infrared radiation.

At the time of the PROMISE proposal Marcello Coradini and I sat down to dinner at the Hotel De Admiral in Noordwijk and my recollection is that it was rather frosty as we argued the pros and cons of ESA carrying out small missions. But it never reached a heated exchange because neither Marcello nor I were people who became heated. A decade later, after I had worked with Marcello when I was a member of the UK Science Programme Committee delegation and a member of the International Mars Exploration Working Group led by Marcello, we again sat down to dinner at the Hotel De Admiral. This time it was an incredibly warm meeting. I remember looking at my watch as we sat down and it was 20:00. At the end of our dinner I looked at my watch again and it was 23:00, we had chatted cordially for three hours. Apart from space matters, a common interest in football helped the chatting.

PROMISE was too much of a radical change for the ESA Science Directorate but I like to think the seeds were sewn, the main point was grasped – the ESA Science Programme had to find ways of giving more opportunities and for a wider community. What emerged eventually as initiatives by the ESA Directorate were 'Small Missions for Advanced Research in Technology' (SMART) and 'Express' missions, in particular Mars Express and Venus Express. Those missions were to be carried out on a far shorter schedule and provided increased opportunities for the European science community. SMART 1 became ESA's first lunar-orbiting mission carrying a range of science instruments for lunar studies. Scientists called me the 'father' of SMART 1 because my PROMISE proposal had sown the seeds for ways in which the ESA programme might change.



The ESA Lunar mission SMART-1

One other outcome of the PROMISE work was that Eigil Friis-Christiansen from Denmark had been a member of my PROMISE team and proposed a mission for a more accurate measurement of the Earth's magnetic field than had been achieved up to then. He eventually proposed that to the Danish Government as the 'Oersted' mission. I was invited on a three-man international team that reviewed the feasibility of the project for the Danish Government. The question was – can Denmark implement a space mission whose measurements were of global importance? We decided that the answer was yes, and Oersted became the first of a successful Danish programme.

BECOMING A PARIAH

In the 1980s, most other European countries had space agencies with their own budget that had to be spent on space activities alone. Britain's space activities were spread over a range of bodies each with their own budget in which space was just one activity amongst many – spending on

space activities was always in competition with other areas. A need for better coordination of Britain's space activities was recognised mainly because most were carried out through ESA and a more unified approach to ESA was seen as important. The British National Space Centre (BNSC) was the outcome, a body, based within the Department of Trade and Industry, on which all those engaged in space provided representatives, for instance, a Science and Microgravity Directorate staffed by the Science and Engineering Research Council. That Directorate represented Britain's solar system science, astronomy and microgravity activities in all the ESA forums, including for the first two, the ESA Science Programme Committee (SPC). The funding for the ESA Science programme was mandatory, all who took part in ESA had to subscribe according to their economic size. The SPC comprised delegations from ESA's 13 member states. The ESA Science Directorate proposed how the funding should be spent and the SPC had to approve the proposals, choosing which missions from those proposed by ESA would take place, confirming ESA's selection of which scientists would provide the instruments for the missions, and overseeing how the missions and the money being spent were progressing.

My involvement with BNSC had grown gradually, partly through Mike Cruise, who had become my Division Head at RAL, suggesting that RAL take a lead on microgravity activities in the UK and that I should investigate. That meant I spoke with Geoff Findlay and Peter Bradbury of the BNSC Science Directorate to acquaint myself with Britain's involvement and I met with scientists engaged in microgravity studies. Also, my PROMISE proposal was of strong interest to BNSC because it was in line with Britain's pressure that the ESA programme should not be confined to a few, very expensive, missions. Finally, I had become involved in estimating the cost of the payload for the candidate ESA mission Marsnet (see below). That was of a strong interest to BNSC because eventually the SPC would be asked to assess it in competition with other mission proposals.

My final decade in space science was determined when the Science and Engineering Research Council was split into smaller councils, one of which was the Particle Physics and Astronomy Research Council (PPARC). When PPARC was formed, Paul Murdin, an eminent astronomer,

became Head of Astronomy and that included being the Director of Science for the BNSC Science and Microgravity Directorate. I had never met Paul and knew of him only indirectly. He had played a major role in management of the UK's Observatories and RAL astronomers worked in collaboration with the Observatories. The Chief Executive of PPARC was Ken Pounds, a Leicester X-ray astronomer. Ken and Paul decided that a new approach to the ESA Science programme was needed. Paul had worked only in ground-based activities with no experience of space-based activities. Paul decided that he needed an experienced space scientist to work full-time in the BNSC Science Directorate in place of Peter Bradbury whose main background was in science administration. Paul's main work was Head of Astronomy at PPARC and he rarely spent time at BNSC. He asked Mike Cruise, my Division Head at RAL, to suggest possibilities for the experienced space scientist. Unknown to me, Mike suggested me. Soon after the formation of PPARC Paul visited RAL to meet with the Space Science Department Division Heads and I attended the meeting. On introductions being made, Paul said on being introduced to me, 'yes, I've heard about you' much to my surprise. The next morning, Mike called me into his office and said that Paul would like me to take over from Peter Bradbury as the full-time representative of PPARC at BNSC. I would remain an RAL employee but loaned to PPARC to work at BNSC in DTI's offices in Buckingham Palace Road in London.

I had no doubts that that would be an ideal move. From my growing contacts with ESA and BNSC I had already thought that working at BNSC would be in line with the direction that my career was going in trying to get more involved in SPC matters. I would become part of the UK delegation to the SPC with Paul and a leading UK space science academic, Peter Clegg, a QMW infrared astronomer. In particular that job would involve immersing myself in all aspects of the ESA Science Programme. I called my work at BNSC working in the diplomacy of space science and that is a correct description. I interpreted the main objectives to be to secure the best returns possible both scientifically and industrially from Britain's mandatory investment in the ESA Science programme. That meant strengthening my links with (a) the whole UK space science community, (b) UK industry competing for contracts from the ESA Science programme, (c) the ESA Science Directorate and (d) the many other space agencies, especially those in Europe.

The contribution is to PPARC, the space science community, DTI and industry.

The objectives are (1) to support PPARC/BNSC in ensuring a maximum science return within the resources available for space science in the UK and Europe, and (2) advise PPARC, DTI, the UK space science community and UK industry on actual and potential developments and how these might be exploited.

On-going tasks

Maintaining close links with other national space agencies and the European Space Agency (ESA) to ensure that UK policy is well understood and respected.

Maintaining close links with PPARC, the space science community, DTI and UK industry to understand aspirations and concerns, discuss these with the appropriate organisations and recommend actions.

Summarising issues and recommending lines for the UK to adopt at the ESA Science Programme Committee

Representing the UK on international bodies such as the International Mars Exploration Working Group, International Lunar Exploration Working Group, the European Utilisation Board for Space Station and the Rosetta Lander Steering Committee

Seeking to better integrate UK (PPARC and DTI) technology programmes and to better integrate those with that of the ESA Science programme.

The formal description of my BNSC duties

I never found the commuting into London arduous. On arrival at Paddington station, eventually, I found walking to and from BNSC in Buckingham Palace Road near Victoria station was a good way of getting there – walking through Hyde Park and Belgravia. It took only 15 minutes longer than going on the Underground on a good day for the Underground. On a bad day with delays on the Underground, it was quicker. I soon found the time on the train between Didcot and Paddington was useful time when daily preparation for work could be carried out. Travelling First-Class helped that.

I went as an observer to my first SPC meeting whilst Peter Bradbury was still in his post. On the Eurostar to Paris with Paul and Peter I was shown the steps that were being taken by PPARC to press for cost savings within ESA. Britain thought ESA to be too expensive. Steps had been taken

to put pressure on the other member states to agree to follow the UK's line but, rather than communicating with the equivalent science funding organisations in the other countries, PPARC had asked the Foreign Office to contact its equivalents in the ESA member states pressing the message that ESA was far too expensive. That upset just about all the other member states' delegations. It meant that their Foreign Offices were arguing that their countries' science budgets should be reduced.

The response of the other SPC delegations to PPARC's actions (stabbing them in their backs was how it was described) was a nearly complete boycott of the UK delegation; science colleagues of long-standing would not speak to us, none would have lunch or dinner with us – we were the 'pariah' of the SPC. It was too much for Peter Clegg, he was soon replaced by Mike Cruise who had moved to Academia as Head of Department at Birmingham University. Mike was much more thick-skinned. Mike and I had worked well together at RAL with me as a Group leader and Mike as my Division Head. Also, we both got on well with Paul; it was Paul who introduced us to *Sancerre Red* and it became our tradition that for dinners together when in Paris for SPC meetings we always shared a bottle.

A key task for me was to rebuild the UK's status and influence in the eyes of the other member states whilst carrying the message that cost reductions were possible. I spent the next nine years explaining Britain's financial arrangements to the other delegations and how it was different to the other countries and accounted for the UK's continual concern about the cost of the ESA programme. I tried very hard to form better relations with all the other delegations. Whenever a new delegate appeared I always introduced myself and helped them understand how the SPC and ESA worked. I also made visits individually to the other delegations to share ideas. I remember, specifically, going to Brussels to speak to the Belgian delegation, the delegation that seemed most often to be a loggerheads with the UK. I also visited Budapest when Hungary was debating whether to join the ESA programme. I gave them an independent view to answer their uncertainties about working within a Western European-wide programme.

One of my first tasks on joining BNSC was to organise a meeting in Copenhagen of SPC delegations to discuss how cost reductions might be possible. I had several difficult telephone conversations, this was soon after the SPC meeting when we were cold-shouldered; there was reluctance from delegations to attend such a meeting, none were prepared to contribute to the meeting except Germany which was also becoming concerned about the distinction between ESA costs and the cost of similar activities in national programmes.

I also sought to build better relations with the ESA Science Directorate, trying to convince them that we, the UK SPC delegation, were working to improve and support the programme and that the complaining was because we had no other means of doing space science, we did not have a separate national programme; the national programme was support for instruments for the ESA Science programme. When Tomas Galinski took over from Gernot Hartmann as head of the German SPC delegation I found myself, partly through my frequent visits to Germany for Cluster and the Rosetta Lander, visiting Tomas and his colleagues at their request and introducing them to the main issues facing the SPC.

A major help for me personally was when David Southwood took over from Roger Bonnet as the ESA Science Director. I had known David well since AMPTE days and found him very approachable, something I always felt difficult with Bonnet mainly because my introduction to him came at the time when the UK delegation was the pariah of the SPC. Bonnet never changed his view that that the UK should be treated as a pariah.



With some of the SPC Delegates at ESTEC. Risto Pellinen is third on my right; Lennart Nordh fourth.

One of my main tasks as part of the UK delegation was to prepare the briefing paper before each SPC meeting. That meant analysing ESA papers, speaking to the other national space agencies, the ESA Directorate, the UK space science community and UK space industry to gain more background. Then summarising the meeting papers and suggesting a “line to take” for the UK delegation. My briefing was reviewed by the UK’s Space Science Advisory Committee (SSAC) which comprised the UK’s lead scientists and industrialists. I took it as a challenge to produce lines to take that needed little modification by the SSAC. The arrangement was that at the SPC, Mike and Paul, the other UK delegates, used my ‘line to take’ as the basic building block and embellished it, Paul with his eloquence and Mike with his humour. I think it worked well. I also wrote a summary of the meeting; the formal minutes took months to appear because of the need for checking and translation but the community wanted to know straightaway what had happened. I usually completed my report on the Eurostar journey back from Paris where the SPC meetings were held. My reports were not quite the minutes, I included key points made by the

various delegations and the ESA Executive but also tried to capture the drama of the meetings, including the strategic use of coffee breaks. Matt Griffin, who eventually replaced Mike Cruise in the UK delegation, called my reports 'legendary'.

When the Ariane rocket launching the Cluster mission exploded scattering the remnants of the four spacecraft and their instruments into the swamps of French Guiana, planning a replacement Cluster mission offered an opportunity to demonstrate how an ESA mission could be achieved at a much lower cost. Even before ESA started consideration of a recovery mission, Gerhard Haerendel and myself got together and suggested how a recovery mission might be achieved in a way that would be affordable within the ESA budget without major impact on the rest of the programme. We proposed a mission based on requirements identical to those of the original Cluster mission but with a different mission implementation approach. We sent an informal invitation to tender to industry for industry to demonstrate to ESA the impact that ESA's implementation approach had on costs. We demonstrated also that substantial savings were possible if the "automatic" use of Ariane launchers by the ESA Science programme was broken. The Haerendel-Hall study claimed that a mission was possible at a cost of 127 Mecu, compared with ESA's original estimate that Cluster replacement mission would cost 350 Mecu and would not be affordable. We were not surprised when ESA rejected the German-UK option but it sowed enough seeds that eventually ESA identified sufficient savings that a mission at 214 Mecu was implemented and was a major success.

By this time, in addition to my SPC work, I was also involved more directly with teams producing planetary and cometary landers for ESA missions. Also, at my initiative, I eventually became more directly involved in the arrangements for the Mid-InfraRed Instrument (MIRI) of the James Webb Space Telescope.

PLANETARY AND COMETARY LANDERS

Marsnet and Philae

My involvement in landers for space science missions started when ESA selected for study the Marsnet mission early in the 1990s when I was still at RAL. Marsnet was one of four potential candidates for the third Medium mission of the ESA Horizon 2000 programme. The intention of Marsnet was to place four landers on Mars to make seismic measurements. Our policy in Mike Cruise's Division was to get involved in all candidates for ESA missions at the study phase to position ourselves for taking part in the candidate mission that won the competition. Because of my group's interest in solar system studies, Mike suggested that I should take the lead on Marsnet. I agreed willingly. UK involvement seemed a long shot because the Research Council policy was that the UK did not participate in planetary missions, a decision that had been made many years earlier. To persuade the Research Council that it should fund planetary science it was necessary to demonstrate a broad community interest in the Universities rather than just interest at RAL.

On attending early ESA Marsnet meetings an opportunity arose for me to play a role in the Marsnet studies at ESA's expense. Because Marsnet intended to include four landers a potential criticism was that that would need four sets of science instruments all of which would, according to ESA rules, have to be funded by national agencies. Could the payloads be afforded? ESA asked Matra Marconi Space (MMS) to calculate the cost of the science instruments but MMS felt that because they were not usually involved in production of instruments – those were produced by the science community – the costing should be carried out by someone from the community and suggested that I should do it. I felt well placed to do that because through my role in the ESA Cluster mission we had already embarked on a programme that meant producing four sets of instruments for a mission. I accepted that ESA contract (the money went to RAL, not me!) and put together an experienced team of engineers from RAL, of which Ray Turner, the most respected and experienced engineer at RAL, was a key member. I think we did a thorough job

and satisfied both ESA and the Marsnet Science Team. The work meant that I was invited to Marsnet Science Team meetings and that strengthened my interest in Mars exploration. It also gave me a more thorough understanding of ESA and meant working closely with Marcello Coradini.

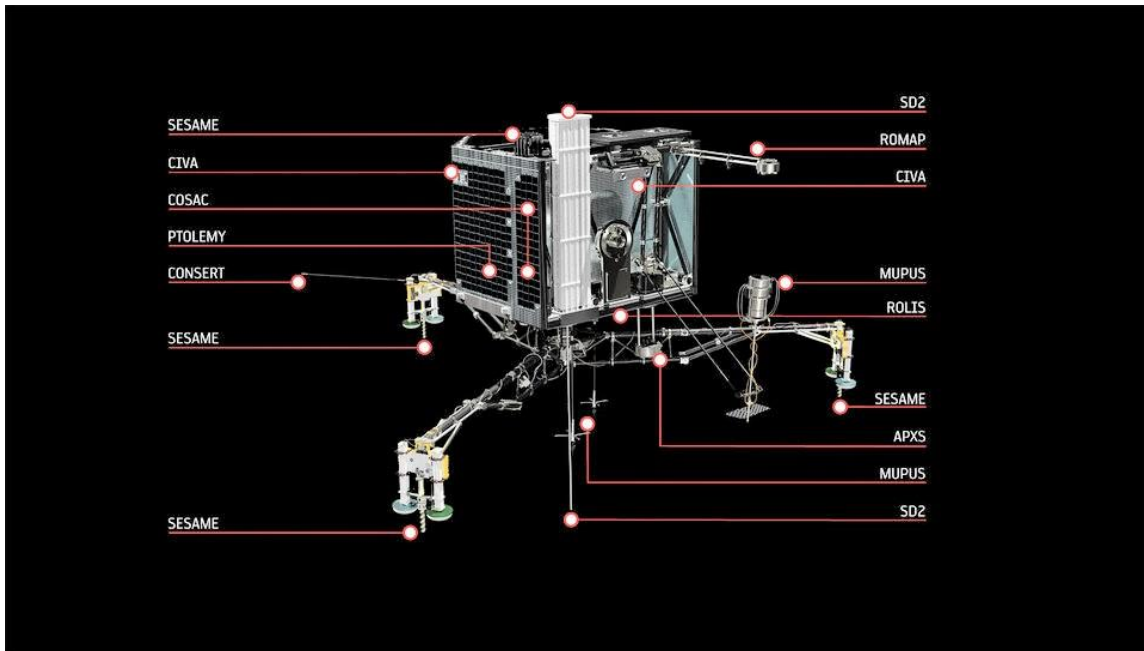
I now had two reasons to visit teams in the UK who produced for whatever reason instruments similar to those anticipated for Marsnet. One reason was to understand better their instruments and what was involved in their construction; the second was to encourage them to think about science involvement in Marsnet. One team that I visited, not because they produced space instruments, but because they had a strong interest in Mars studies was Colin Pillinger's team at the Open University. Colin had built his team around studies of lunar material collected during the NASA Apollo programme. Also, the team could make a strong case that meteorites found in Antarctica had originated on Mars. I went to the Open University and was shown their equipment for studies of lunar material returned to Earth. My recollection is that the instrumentation, looking like a giant chemistry set, covered up to the ceiling an area of about 6 paces by 6 paces. Colin was involved in studies for the prospective ESA Cornerstone mission, Comet Nucleus Sample Return (CNSR), which intended collecting cometary samples and returning them to Earth. Colin was placed excellently for study of cometary material returned for study in terrestrial laboratories.

The cometary mission CNSR had become dependent on NASA collaboration because of its cost and complexity but in 1992 NASA pulled out. CNSR, now called Rosetta, had to become a mission to study cometary material in situ at the comet rather than return it to Earth. Soon after the change was made, my recollection is that it might even have been the day after, I was sat at my desk at RAL early in the morning and the phone rang and it was Colin. The conversation was along the lines – Rosetta will no longer deliver a sample to my laboratory; I want to send my laboratory to the comet, can you help? I agreed that I would and over the next few weeks I spoke to the relevant people at RAL, with Ray Turner the key contact again, and Ray eventually took over the lead and started working with Colin's team on what would be needed for a space instrument

capable of the measurements Colin saw as necessary for the science objectives. That was the birth of Ptolemy, Colin's instrument for the Rosetta Lander.

The lander for the Rosetta mission was treated in the ESA programme as a science instrument – that meant it had to be funded by national agencies and not ESA. At first two competing versions were studied, separately by Germany and France. France intended to collaborate with NASA but NASA withdrew and the 'Rosetta Lander' as it was then called became a single, cooperative, effort led mainly by Germany and France with significant contributions from others, notably Italy and Hungary. Through the Open University interest in providing a key science instrument for the lander I was a member of the Rosetta Lander Steering Committee, which was the equivalent of a Board of Directors, representatives of those funding the activities who reviewed progress and planning. Because the French and Germans had started with separate landers, each with their own management team, and differing ideas on what was needed, early Steering Committee meetings were fraught with arguments between France and Germany about who would manage the programme and how the lander would be constructed.

It was soon clear that the project could not go ahead effectively until there was clear agreement on the management structure and who did what within that structure. Karoli Szego from Hungary was the Steering Committee Chairman and he suggested that a sub-group should get together to agree a management plan and who did what in that plan. He said 'we need a neutral to lead this – how about David' looking at me. I eagerly took on the task. By that time I was very experienced in drawing up management plans with a reasonably clear idea of what each role involved. Also, I knew the SPC delegates sufficiently well that I felt I could get them to work together to agree a plan. Gernot Hartmann from Germany and Richard Bonneville from France were the key people. I put together a plan and iterated it through Gernot and Richard and others from the sub-group until I was satisfied that we could all meet and reach agreement easily, and we did. The plan was put into operation and from then on the planning went rather more smoothly and the management held together for the 20 years of the mission, with the lander (Philae) making measurements on the comet in 2014.



Philae – the spacecraft of the Rosetta mission that landed on the comet. The names are those of the many instruments carried by the lander. The main body of the lander was about a 1m cube.

What had not been covered in my brief to sort out the management was to sort out what the lander should be called. France had wanted to keep the name of their version – Champollion, the name of the Frenchman who had been key in deciphering the Rosetta Stone. Germany, more prosaically wanted to call it Roland, short for Rosetta Lander but also the name of a Teutonic knight. I remember a meeting of the Steering Committee at Schloss Elmau in the Bavarian Alps. The meeting was marked by fear of being snowed in and gave a feeling of isolation. That enhanced the intrigue when, I think it was the French scientist Jean-Pierre Bibring, circulated a note late one evening pressing for the lander to be named Champollion and independents such as me were lobbied (berated) strongly to support that name. Eventually it was realised that there needed to be an agreed name. Once again I was asked to lead a sub-group to choose a name all could accept. We decided that France, Germany, Italy and Hungary as the main contributors to the lander should have priority. Each ran a schools competition to come up with a selection of names. I devised a selection procedure that would reduce the names to one. I arranged a one-

day meeting at Frankfurt Airport and the procedure worked well and Philae emerged as the name accepted by all, Philae being the name of an obelisk that provided important clues on how to interpret the hieroglyphics of the Rosetta Stone.

I thoroughly enjoyed the role of mediator for the management plan and the selection of the name. In particular I thought it demonstrated that I was trusted to be disinterested and that I could communicate easily with representatives of the various countries involved in the mission. It also confirmed to me how comfortable I felt working with the other Europeans. The respect I gained through those Philae activities helped me through the minefield of seeing a UK lander get to Mars - Beagle 2.

Beagle 2

Beagle 2 demonstrated how my work in my later years was very much walking on eggshells. I saw my job as securing the best return scientifically and industrially from our investment in the ESA Science programme and Beagle 2 seemed an excellent demonstration of the UK science community and industry working together to exploit an opportunity in the programme. Colin had persuaded Astrium at Stevenage to work with him on Beagle 2. The dilemma was that no UK funding organisation could afford Beagle 2 and all tried to avoid expressing too much interest for fear of ending up with the bill. I had to encourage the organisations from the inside whilst Colin pressed from the outside. My activities were possible because the Minister for Science, Lord Sainsbury, was strongly in favour of Beagle 2.

Mars Express had come about because the ESA Science Directorate had responded to calls for increased opportunities in the programme by introducing two 'Express' missions, one to Mars and one to Venus. The intention was to carry out the missions far more cheaply and in a far shorter time that was usual for the ESA programme. Through my PROMISE proposal I had led the call for such opportunities and wanted those missions to succeed. But because planetary science had been treated for many years as a low priority by the UK Research Council the strongest UK

interest in Mars Express was that of Colin. Understandably, Colin, having made the transition from ground-based studies to space instruments to take part in the Rosetta mission, now wanted his instruments landed on the Martian surface. My first personal conflict for Beagle 2 was that I wanted to see the UK successfully exploit Mars Express but realised that adding a lander threatened the low-cost, short-timescale, philosophy.

With Mars Express being deliberately a quick and fast mission, ESA could not include a Lander in their budget, the only hope was for one to be paid for nationally as was the case for the Rosetta Lander. Colin persuaded the reluctant Mars Express scientists that there should be a lander, it was my task to do the same at the meeting of the national agencies with the ESA Science Directorate. Colin was well aware that if he asked for the money from PPARC, whose budget was meant to cover instruments for ESA missions, there was no way that PPARC could afford to pay for the Lander. Colin set about trying to raise private sponsorship. A major help was that Astrium at Stevenage had agreed to take on implementation of Beagle 2 despite the uncertainties in the funding.

A positive step within the UK was that PPARC decided to review the science and I was a member of the panel led by David Hughes. We had little difficulty in deciding that it was top notch science, and PPARC agreed to fund UK instruments on 'Beagle 2', the name Colin had decided was appealing and representing the objective of understanding development of life on Mars, reflecting the role that the ship, Beagle, had played in Darwin's ideas on development of life on Earth.

PPARC made it clear that it would consider funding the UK instruments carried by Beagle 2 but not the lander itself. DTI did not have a role in funding instruments for the ESA Science programme but Astrium's involvement meant DTI wanted me to keep them informed on developments. The message I had to carry to the ESA meeting in which member states discussed potential funding support for instruments for Mars Express – the Beagle 2 team would raise the

money themselves through sponsorship. Richard Bonneville, the French Delegate, feared (not totally seriously) that would mean Beagle 2 would look like a Formula One racing car.

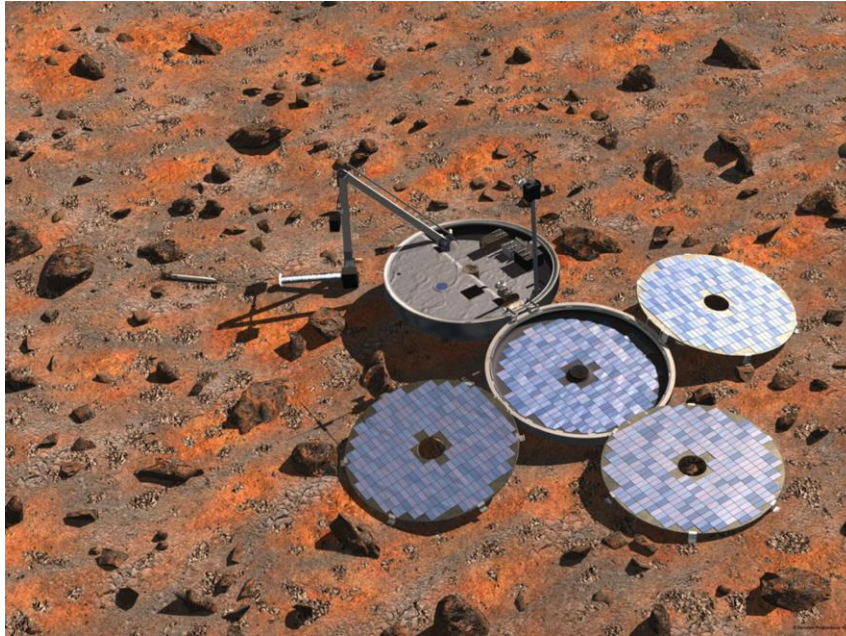
Beagle 2 was kept in the programme under those conditions. Sponsorship was never forthcoming and in the end Beagle 2 was funded, as reported in the UK National Audit Office report of 2004, by a combination of, mainly, the Office of Science and Technology, ESA, the Open University, PPARC, Astrium and DTI (because of the Astrium interest). But that became available bit by bit and there was always uncertainty during the five years of the project about whether sufficient money would be available until about one year before launch.

Through my BNSC role I was involved in most of the significant political steps for the Beagle 2 programme acting as a go-between for Colin and his team with the DTI part of BNSC, PPARC, the ESA Science Directorate, the ESA Mars Express team, the other space agencies of Europe who were called upon to approve Beagle 2's inclusion in the Mars Express programme, the Office of Science and Technology, and, finally, the Minister for Science, Lord Sainsbury.

In addition to my role as political go-between, my technical background enabled me to take part in many of the project technical and programmatic reviews, including leading the reviews of the parachute for landing on Mars and the readiness of the ground segment (operations centre). I went to many of the team meetings but tried to maintain independence especially because I was there as representative of the Government funding agencies.

What Colin found difficult to accept was that the ESA Science Directorate does not decide how its money should be spent – it is the member states who decide through the SPC. Colin grumbled at the Science Directorate but it was the other member states that had to be persuaded; that persuasion was another key part of my job. It was helped because I was working with many other member states trying to get the Rosetta Lander problems sorted, acting as an independent intermediary to resolve inter-agency problems. Many of the other agencies were sympathetic to what we were trying to do with Beagle 2 but Colin did get up their noses with his self-centred

approach that seemed not to give due worth to the other scientists involved in Mars Express whose investment was at risk because of the need to accommodate a lander. It was my job to help those agencies clear their noses. If the lander failed to separate the mission would be lost. Also accommodating a lander meant other restrictions on the orbiter instruments. The ESA team worked hard to strike the right balance but to Colin that seemed to be favouring the Orbiter instruments rather than giving Beagle 2 the highest priority.



A simulation of Beagle on the surface of Mars. On the left is the 'mole' that would have dug into the surface and collected samples

At that time, the success rate for past attempts at landing on Mars was 50%. With all its uncertainties, looking back with hindsight the chances of Beagle 2 succeeding were never more than that but at the time all did their best to minimise risk, including DTI and ESA stepping in with specific financial support to retire risk. The National Audit Office (NAO)'s main criticism was that the risks were not clearly spelt out to the Minister. I think they were. I remember a television interview in which he specifically mentioned the risk but none of us put a specific figure on the chances of success. A good test would have been to place bets with bookmakers and see what odds they offered on the chances for success. They could not have been better than 2-1 against success, 1-2 on for failure.

Beagle 2 successfully landed on the surface of Mars but did not transmit any information. The piecemeal funding of Beagle 2 was identified by the team, and independently, as a major cause of its failure to return science measurements. I think that is a fair judgement. The project was always uncertain about what funding would be available and that made project implementation extremely difficult. The team went ahead with a Mr Micawber approach, money did turn up but each step was a major struggle. The organisations that eventually funded Beagle 2 would not normally have funded science instruments for the ESA programme. No financial rules were broken but were certainly stretched to their limits. We in the 'bureaucracy' did our best to help Colin make Beagle 2 measurements on Mars and nearly succeeded. One major, positive, outcome was that it enabled Astrium at Stevenage, because of the experience gained through Beagle 2, to secure the multi-million Euro contract for the ESA ExoMars mission, a mission in this case funded by the ESA Exploration programme.

The other achievement of Beagle 2 was to raise the awareness of space activities in Britain. Because private sponsorship had been the target Colin had deliberately courted the media and the mission got high publicity and sympathy when it failed. The ESA programme for human exploration of the solar system had started by then and when giving public talks on that it was clear to me that there was far more public interest in that than in some of the more esoteric astronomy missions. Beagle 2 started the culture change that led to the UK belatedly joining the Space Station programme and to its first, UK Government-funded, astronaut.

Through my involvement with ESA and encouraging within the UK a stronger interest in planetary exploration, I became a member of the International Mars Exploration Working Group (IMEWG), a group that included all agencies, mainly European and American, interested in Mars exploration. The intention was to make everyone aware of each other's plans and to look for cases where joint activities would be appropriate and to avoid duplication. My main task was reporting on Beagle 2, seeking whether there were others who might contribute or where assistance might be given, for instance, a Mars Orbiter providing communication support for

Beagle 2 when it was on the surface of Mars. The main value for me was the chance for increased networking with ESA, NASA, CNES and DARA – the last two being the French and German space agencies. I hosted one IMEWG meeting in London and other meetings were held in Capri, Montreal, Venice, Budapest and Florida, the latter coincident with the launch of Mars Observer.

The meeting in Venice was held in a palace on the Grand Canal just a 100 metres or so from the Rialto bridge. There was a balcony and we had coffee overlooking the canal. I remember talking about Beagle 2 to Jeff Hoffmann the NASA representative in Europe. NASA were very helpful all the way through, providing assistance with design reviews. Also, the atmosphere entry, descent and landing system for Beagle 2 used facilities developed for the NASA Mars programme.

Risto Pellinen from Finland, who was the SPC chairman, was also at the Venice meeting and I remember the two of us going for dinner alone because he wanted to discuss SPC matters with me and seek my help in resolving issues through my strong contacts with the other delegations. Risto also reported that Finland was having problems funding its space instrument programme and invited me, together with ESA's Henk Olthof, to Helsinki to review costs. What emerged was that manpower costs were not properly being taken into account partly because it was unclear who actually paid for the manpower – the Institutes or the central funding agency.

Because Beagle 2 raised interest in UK space activities, the National Audit Office (NAO) decided to review the UK's spend on space and commented specifically on the investment in Beagle 2. I was the science contact with the NAO team and found it a fascinating experience, though when the review was first announced we were very concerned at what they might find. Many organisations had bent their funding rules to make money available for Beagle 2 and my task was to encourage that bending wherever possible. The PPARC Chief Executive in Swindon asked me to keep the NAO 'out of PPARC's hair' and I successfully did that, acting as the main point of contact and meeting in London – the NAO office was just a two-minute walk down Buckingham Palace Road from BNSC. Beagle 2 was a topic that took much discussion and I provided most of the background information. The NAO concluded:

Beagle 2 represented a high risk, high reward project. The prospects for valuable science were assessed to be at the highest level and confirmed under the usual arrangements for rating the value of potential projects. And the technical risks surrounding the project were sensibly approached and mitigated.

In appraising the case for supporting the project the inherent risks to achieving a successful landing on Mars were not explicitly discussed alongside the costs and benefits. Although the project was widely known to be risky, judgements on the relative merits, net of risk, of Beagle 2 against other possible space projects were not transparent;

Beagle 2 has given UK industry a good position in the preparatory work for future robotic exploration, e.g. as a study leader for ESA's Aurora programme. An unprecedented level of media interest in Beagle 2 has resulted in a high level of public awareness about Space exploration and continuing interest in ESA's Mar Express mission that has already found the first direct evidence of water on Mars.

If high risk, but high benefit, projects are to be fairly appraised and tightly managed from the start, ESA and National Agencies should ensure that National Agencies become more strongly integrated in the formation and management of consortiums for provision of instruments from the start.

The criticism was justified. The last paragraph were my actual words and described exactly the arrangements I had already started for MIRI, the Mid-InfraRed Instrument for the James Webb Space Telescope (JWST) (see below).

A DIVERSITY OF TASKS

Paul Murdin retired in 2002 and I took over as Director Science at BNSC and was promoted to Senior Principal Scientific Officer. My BNSC years were very busy years but with the great advantage that I decided what tasks I took on and my time management was left entirely to me. Just about all the tasks needed travel within the UK or overseas. Every day, on the train traveling from Didcot to Paddington each morning, I listed tasks that had to be carried out sometime in the near future (one or two months) and assigned the priorities for the day.

I became involved in the topic 'Near Earth Objects' when Richard Tremayne-Smith who had been responsible for that work at BNSC had a heart attack. Until Richard recovered I took over his work which involved mainly making sure the UK was well integrated into international observations of space objects that might collide with the Earth. There was an active community in the UK and Lord Sainsbury agreed that a 'Task Force' should be set up. It was reported from within that Community that:

Since July things have not proceeded smoothly. The job of setting up the task force was given to the British National Space Centre (BNSC), more specifically to Richard Tremayne-Smith. Sadly Richard suffered a heart attack in the early autumn, and this work was placed on a back burner. The task fell to Dr. David Hall of the BNSC. Dr Hall has greatly impressed those who have met him with his open minded and enthusiastic attitude.

'Open minded and enthusiastic' meant I treated them seriously, not like others at BNSC who thought it all a waste of time.

I was also asked to serve on a NASA committee reviewing American proposals for 'sub-orbital' missions (i.e. rockets) and that meant a fascinating three days in Washington working with NASA headquarters staff.

Running alongside my work with the ESA Science programme, I had also become involved in the programmes of the ESA 'Manned Spaceflight Directorate', programmes that involved mainly using the Space Station. That required considerable diplomacy because the UK policy was to not contribute to programmes involving people in space – that was always thought to be not worth the considerable additional expense. That policy had started with Margaret Thatcher and was strongly supported by Lord Sainsbury, the Minister for Science for most of my time at BNSC. But British scientists wanted to carry out studies under microgravity conditions which needed access to the Space Station. Fortunately, UK industry occasionally won (small) contracts from the Manned Spaceflight Directorate and DTI contributed small financial contributions to the Directorate to allow UK industry to obtain contracts. That opened a small window that allowed UK scientists to take part in microgravity experiments.

When I was appointed to represent PPARC at BNSC headquarters in Buckingham Palace Road, my tasks included the day to day running of the UK involvement in microgravity experiments. The main areas of science were life sciences (human, plant and fungi), fluid physics, crystal formation, and combustion. Potential applications of the studies were a better understanding of plant, fungi and crystal growth which might enable higher yields to be obtained; a better understanding of, and potential cure for, the changes in bone structure that leads to brittleness in the bones of old people. The Groups involved were from the Universities of Glasgow, Manchester (3 separate groups), Nottingham and Imperial College (2 separate groups) and Brunel University.

Better coordination of the community was needed for it to be able to win funds in the UK for carrying out their experiments. Specifically, there was a need to open discussions on the potential for funding space activities with the Engineering and Physical Sciences Research Council, (EPSRC), the Biology and Biotechnology Sciences Research Council (BBSRC) and the Medical Research Council (MRC). Before joining BNSC I had investigated whether RAL should play a role in coordinating microgravity activities and after joining BNSC that seemed appropriate because there were also needs for technical support. Also, RAL already worked with those other Research Councils. Eventually, I passed the coordination to Jeremy Curtis at RAL.



The International Space Station

My tasks included also looking after the UK's involvement in Space Station activities more generally, UK X-Ray astronomers were also wanting to use the Station. I was accepted as an 'observer' at meetings of the European Utilisation Board for Space Station even though the UK, unlike the other ESA member states, did not contribute to the cost of Space Station. My final activity for the Space Station programme was to see through negotiations of formal "Access Rules" for experimenters from non-contributing countries such as the UK to use the Space Station.

In addition to membership of the International Mars Exploration Working Group, I was a member also of ILEWG, the International Lunar Exploration Working Group. That was partly encouraged by the ESA SMART 1 mission to the Moon with ESA keen to build links with the Russian experience of Lunar missions. We had a meeting in Moscow and visited a space research institute as well as seeing Moscow. Standing in Red Square was an unforgettable experience for someone who grew up with the Cold War at its most intense. Another unforgettable experience was going to a Tchaikovsky concert in Moscow for which the audience was an enthusiastic group of young people – it was the cheap night for student tickets.

A visit to Beijing came from my connections with the ESA Cluster mission. ESA were keen to start collaboration with China and Chinese involvement in Cluster was proposed as a way to start the collaboration. Representatives of the Cluster programme, including myself, discussed the possibilities with the Chinese in Beijing. It was decided that China would have a data centre and free access to the Cluster data and would also launch a mission, Double Star, that took measurements in the magnetosphere whilst Cluster was operating. The collaboration was successful and there is now a combined ESA/Chinese magnetospheric mission, SMILE, planned for launch in the 2020's.

Whilst I was still working at RAL we had a Chinese theorist, Chen Zong, working with us for a year on space plasma studies. On knowing that I would be visiting Beijing I contacted Chen Zong, who was then working at the Chinese Remote Sensing Institute which was just a ten-minute walk from the University where we were having our Cluster discussions. He invited me to talk about the European space science programme at his Institute. The talk in a crowded meeting room was attended by a young and eager audience with a much higher proportion of young women than I encountered at meetings outside China. I gave the talk in English and Chen Zong translated – a few sentences at a time. That meant I had long pauses and could survey the audience.

I also made the most of my visit to Asia by going from Beijing to Taiwan (via Hong Kong, there was, of course, no direct connection). In our space plasma work we had established contact with a Taiwanese group and I visited them to talk about our AMPTE studies.

I also later visited Taiwan to discuss the possibilities for 'microsatellites'. An Institute in Taiwan was hoping to establish a Taiwanese programme and wanted to hear about the possibilities. I was invited partly because I was seen as an advocate of 'small satellites' in Europe but also because of the UK's strong position as a provider of small satellites through Surrey Satellites. My talk in Taiwan as part of the microsatellite conference was to report UK experience, which effectively meant the Surrey Satellite experience and, in particular, I was able to show how successful that programme had been in terms of the numbers produced and the overall

reliability. I had made RAL resources available to help Martin Sweeting, the head of Surrey Satellites, when he was building his second satellite and was not taken seriously by funding agencies in the UK. Eventually, he built the company into a successful and respected provider of small satellites. In preparing for the Taiwan meeting I visited the company and found my initial help (17 years earlier) was remembered and still appreciated. And the 'radiation sensor' that we had provided for the satellite was still working.



Testing UOSAT-2, the second satellite of Surrey Satellites

As a result of the combination of my involvement in Manned Spaceflight discussions and Mars Exploration I became involved in ESA's initiative for a programme for human exploration of the solar system. ESA called the new programme 'Aurora' not because of any connection with auroral studies but after the Greek Goddess of dawn, the programme being seen as a 'new dawn' for Europe. Specifically, I was a member of the Programme Board. It was anticipated that the first step in a programme of human exploration would be a robotic mission (ExoMars) to study exobiology on Mars. That meant that some of the issues that we had had to fight through to get support for Beagle 2 became a common interest with other space agencies, especially the French

agency CNES. I had had many (friendly) discussion with CNES on support for Beagle 2. Privately, they were supportive of Beagle 2 though they understandably were more reserved at SPC meetings. We now had very strong common interests in the Aurora programme and I was flattered to be invited as the only foreigner to a French national meeting to discuss potential future science activities. My French was good enough that I could follow well the various presentations on potential future activities by the French scientists. I gave talks on human exploration of the solar system, in particular to PPARC staff, Astrium Staff, the Open University (and, much later, to the WEA in Wellington, New Zealand!). DTI held a series of lunchtime internal seminars on its various activities. Those were poorly attended and intended attendees had to email ahead that they would attend, for some there was no interest. I offered to give a talk on human exploration of the solar system and there was considerable interest – we had to change to a bigger meeting room twice to accommodate all those wanting to attend. And even then the meeting room was overflowing for the actual talk.

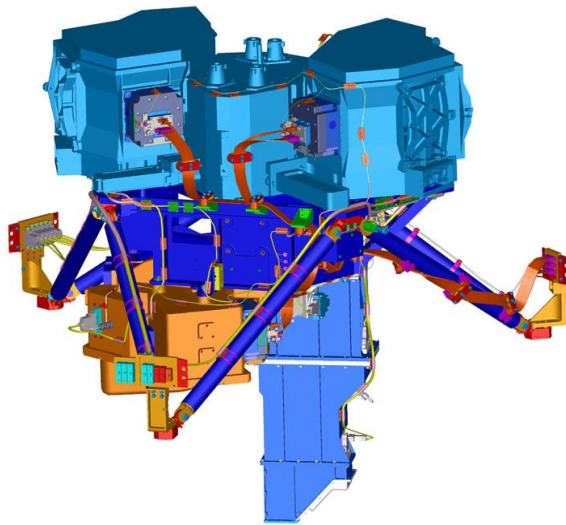
Dick Holdaway, head of RAL Space Science, asked me, just before I retired, to continue with the Aurora activities after retirement up to the time of the next meeting of European Ministers. There was a growing push by industry to make sure that the UK joined the full Aurora programme because, following on from Beagle 2, Astrium UK were front runners to become Prime Contractor for the programme's first lander on Mars. The Ministers' meeting would be when the key decision was made. But Margaret and I intended to spend three months of each year in New Zealand and I declined. Eventually, the UK did join the programme with Astrium playing that key role in ExoMars and my successor at BNSC, David Parker, eventually became Director of the ESA programme for Human and Robotic Exploration.

From the experience of Beagle 2 and also problems caused for the ESA programme by piecemeal funding by national agencies of other instruments, I decided to take the initiative and work with the ESA Science Directorate to put in place a more formal process in which guaranteed funding, and how the instrument programme would be managed, had to be in place from the start. In my SPC work it became obvious to me that, though member states complained about delays and

cost increases in the ESA programme, a major cause of problems that partly accounted for ESA's delays and cost increases was the ad hoc ways in which member states funded instruments for ESA missions. First there was the cart and horse problem. Member states would not commit funding for instruments until they had successfully been selected by ESA. Teams proposed instruments and were selected and then had to search for funding. Beagle 2 was the classic case – a team going ahead knowing that funds were not available from the usual sources for payload funding and hoping that the money would turn up - as it did but in a very uncertain manner which made project implementation difficult. Also instrument teams were usually international consortiums and the Principal Investigator had no control or certainty over the funding of the other consortium members. Instruments were produced inefficiently and that caused delays and expense for the whole programme. I decided that National Agencies from the start should become more strongly integrated in the formation and management of consortiums for provision of instruments. I decided that better procedures were needed.

I took the initiative and wrote to David Southwood, as Director of ESA Science, proposing new procedures for selecting and funding instruments for ESA Science missions. He reacted positively. The first opportunity to put new procedures in place was MIRI, the Mid-InfraRed Instrument for the James Webb Space Telescope (JWST). MIRI was a European/US collaboration. The European part of MIRI was to be constructed by a European-wide consortium of ten member states including the UK. I got together with the other nine funding agencies from outside the UK that would need to support the scientists/engineers who would work on MIRI. The eventual outcome was a document describing how the consortium would operate, how the project would be managed, and a guarantee that appropriate funding would be provided, including, for the first time, how contingencies would be made available in case of unexpected problems and how those contingencies would be controlled. The document was written by myself and iterated with the other funding agencies, the ESA Science Directorate, and the ESA Legal Department. The main intention was to get the funding agencies to make firm commitments before ESA finally selected MIRI as part of its contribution to JWST. All agencies signed except Italy. Italy still wanted to wait for the ESA selection before making a commitment. As chairman of the national agencies team,

I was quite ruthless and determined we would avoid the Beagle 2 difficulty of the instrument being selected even though it was uncertain whether sufficient funding would be available. We found a way of going ahead without the Italian contribution.



MIRI – the Mid InfraRed Instrument of the James Webb Space Telescope. The overall size is about a 1m cube

Lennart Nordh, the Swedish SPC delegate, and possibly my closest acquaintance amongst the delegates if measured by the duration of telephone conversations, was chairman of the MIRI consortium after I retired. He said he had me to blame for him getting that job! I met him frequently through my work on the Swedish SSAC and he reported the MIRI consortium working well. And the instrument is now in space and operating successfully on the James Webb Space Telescope.

David Southwood, when interviewed by the House of Commons Select Committee on Government support for Beagle 2, described how the Beagle 2 situation would be avoided in future – ‘Member states will never start anything and will not put anything to ESA without having a clearly defined agreement at the starting point as to where the money is coming from, who is responsible and a managerial structure in place. That is what we are doing already with new programmes, for instance, the Mid-InfraRed instrument for the James Webb telescope’. David

said developing those new procedures has been led by BNSC. In that case, BNSC meant me, alone.

The MIRI consortium agreement was my last major contribution to space science. The agreement was very legalistic and thorough and was one reason why, in retirement, I had no doubt I could cope with working with Judges and QCs in reviewing complaints against UK Barristers. What also persuaded me (and persuaded the Bar Council) was the number and range of diverse matters that I had had to review in the preceding decade.

The MIRI agreement demonstrated to me the expertise I had developed in understanding how ESA and the European national agencies worked and that I was well qualified to propose how things might be improved. That might sound arrogant but I think it is justified by the most satisfying SPC moment for me, just before I left the SPC after 9 years. Hannu Koskinen, the Finnish delegate who I knew well from our auroral physics days, said, during a SPC coffee break: “David, one day you must explain to me how the UK has gone from being the pariah of the SPC to the most influential delegation”.

POSTSCRIPT

I had for a long time anticipated that after retirement I would study humanities. Possibly because there was always that lurking feeling that I should have chosen arts in place of science and also, I wanted an excuse to write essays. I enrolled with the Open University to begin an undergraduate degree in Humanities and after six years of part-time study got a first-class degree in Humanities with History. In parallel with those studies I managed to get accepted by the UK Bar Council to sit on their Barrister Disciplinary Tribunal, the highlight of which was sitting with a Lord Justice to hear an appeal in a courtroom at the Royal Courts of Justice. Also, as mentioned above, Sweden asked me to serve on their Space Science Advisory Committee (SSAC), the committee that reviewed Swedish proposals for space science and identified priorities for the Swedish Government to support. I served two three-year terms with the Disciplinary Tribunal and the Swedish SSAC before moving to New Zealand.

In New Zealand I wanted to continue my studies and work towards a PhD. I approached Victoria University of Wellington proposing that I study the UK-New Zealand relationship in the second half of the twentieth-century, a period when I was closely familiar with developments within the UK. I met Jim McAloon and he suggested a suitable area for study was how primary producers in New Zealand, a very conservative group according to Jim, coped with the changes in relations with Britain. After one year doing an Honours degree on the Royal Commission on the Sheep Farming Industry, I started my PhD thesis on *Emerging from an Entrenched Colonial Economy: New Zealand Primary Production, Britain and the EEC, 1945 – 1975* and in 2016 graduated. Palgrave Macmillan published the thesis in their Economics History series; Malcolm McKinnon called it a record time for a thesis to turn into a book.



Probably my last certificate

I was also fortunate to be appointed to two New Zealand Law Society Complaints Committees, one that dealt with general complaints from Central New Zealand, and the other the national committee that dealt with costs complaints. That gave me monthly opportunities to mix with New Zealander lawyers and to gain insight into many facets of New Zealand society.

An offshoot of my PhD was that in reading the farming journal *Straight Furrow* I noted that there were 'family pages' for the wives of farmers. I briefly looked at those and noticed over time how the topics and attitudes changed. After completing my PhD and first book, I proposed to Charlotte MacDonald at Victoria that study of those farm wives should be a PhD topic but decided that I would carry out the study myself and write a book.

On getting the farm wives book (*New Zealand's Invisible Women*) to the stage waiting for publication I decided that another farming topic which lacked a substantial record was the history of Federated Farmers and researched and wrote a book that Palgrave Macmillan have published

in their Agricultural Economics and Food Policy series. The farm wives book, published by the New Zealand publisher Atuanui Press got seriously held up by Covid and became my third rather than second book.

What next? I think it might be time to apply to become a television repairer – who knows what that might lead to