Skylark Ascending

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A Training in Space Science

Introduction

Many of the senior space scientists around the world were trained in space instrument design, data analysis and space project management on projects using the *Skylark* sounding rocket as the space platform. In the nineteen sixties and seventies over 200 *Skylark*s were launched from sites in Norway, Sardinia, Australia and South America offering five minutes of observing time above 100 km and substantial payload carrying capacity. Many of the *Skylark* flights delivered data which ended up in Doctoral Theses, launching the careers of the students involved. A PhD gained by this route involved science, engineering, travel and exposure to many different professional cultures.

Starting a PhD

My own training in the use of *Skylark*s started in October 1968 when I arrived at the Mullard Space Science Laboratory (MSSL). As is common in science doctorates, the basic project was decided prior to my arrival by my supervisor who would have applied to the Science Research Council for the allocation of the *Skylark* "rounds" to the specific project many months beforehand.

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Figure 1: a *Skylark* launch from Woomera, South Australia

American scientists had been studying the effect of the Sun on the surface of the Moon using spinning *Aerobee* rockets with radiation detectors which scanned more or less the whole sky. In 1962 a very strong source of X radiation completely unconnected with the Moon was detected in these flights from the constellation Scorpius and this started the very productive science of X-ray astronomy. X rays are absorbed in the Earth's atmosphere and so these sources had never been detected before, indeed the very high energy of the radiation they emitted was a serious puzzle for the theorists. By 1968 twenty or thirty sources had been detected but their celestial positions were known only to a degree or so, not nearly accurate enough to permit the identification of the sources with astronomical counterparts at optical or radio wavelengths. Various instruments had been designed to measure the position of the X-ray source in the field of view of the space borne X-ray detectors and one of these, the Rotation Modulation Collimator (RMC), was proposed for flight on the UK satellite UK5 but had not been tried out in practice. The *Skylark* project on which I embarked was to use the RMC both to test the properties of the instrument and to gain more scientific information about the X-ray sources.

The Rotation Modulation Collimator consisted of a gas filled X-ray detector which observed the sky through two identical

masks all mounted on a spinning platform. The masks comprised linear, parallel bars of absorbing metal, separated by open spaces through which X-rays could pass unabsorbed. Looking through the two masks, the detector observed the sky through a pattern of linear moiré fringes of high and low transmission. As the platform turned these fringes rotated and the different X-ray sources in the sky had a time modulation imposed on them which was different for each position in the field of view. Decoding this time modulation by computer analysis allowed an image of the sky to be built up and hence the position of each source could be measured if the position on the sky of the spin axis of the instrument was known.

The plan for the PhD included the laboratory testing of an optical version of the Rotation Modulation Collimator to test the basic principles and develop suitable analysis software, the testing and calibration of the X-ray detectors and electronics, the delivery of the flight model to British Aerospace in Filton for integration onto the *Skylark* instrumentation bay, accompanying the payload to Woomera for the pre-launch preparation and the launch, and then the analysis and publication of the data. In principle, all this had to be completed within three years - although this timescale was seldom achieved in practice, mainly due to delays in the *Skylark* provision or delays in building the scientific payload. The need for a spinning platform for the RMC experiment coincided in time with the development for the *Skylark* programme of the *Goldfinch* boost motor. This small booster used canted fins to spin the whole *Skylark* about its longitudinal axis at rates of about 3 revolutions per second to give it gyroscopic stability. The Goldfinch booster allowed the vehicle to reach heights of many kilometres before the main motor, the *Raven*, was ignited and this two stage propulsion enabled larger payloads, longer observing times above 100 km or higher final altitudes to be reached. Because the *Goldfinch* boosters were under development the *Skylark*s SL973 and SL974 were allocated to this project on the basis that the "experimenter", as the scientist in charge of the

payload was officially known, had no say in the launch date or other conditions of the vehicle. These were to be chosen to provide optimum conditions for the flight test of the new booster.

The Laboratory Environment

The Mullard Space Science Laboratory is situated a mile or so outside a small village in Surrey. Public transport was limited to a few buses per day from the nearest railway station, which was about fifteen miles away. Accommodation for students was provided in a refurbished stable block. Students appeared in the lab between nine and ten in the morning at the latest and worked through to six in the evening when a communal meal was cooked by them in the students' flats. On most evenings, the students returned to the lab for an hour or two more, often working late into the evening. The laboratory had a very project-oriented ethos, with the main topic of concern being the delivery of space instruments and the scheduling of the workshops. A project progress meeting was held on the first Monday of each month, at which the loading on the electronic and mechanical workshops was discussed and problems reported. The main management tool was the adage that the project with top priority should always be the one that had the earliest delivery date - a very simple, but also very effective, decision making concept.

The Experiment Development

The first year or so of the PhD was spent in familiarisation with the details of the detector and the electronics. As it happened, my PhD supervisor was on a year's sabbatical leave during this time and my main interaction was with the engineering staff at MSSL. The Laboratory had a very strong engineering tradition and, unusually for a university group, the two senior engineers, Tom Patrick and Jim Bowles, were university lecturers. Each had a team of five to seven engineers and technicians working for them doing detailed design, drawing, manufacturing and testing of space instruments, all on the MSSL

site. As a Physics graduate with a little more electronics experience than usual, I was able to participate in some of the electronics testing of the prototype circuits before they were finalised for flight production. Much of the electronics was straightforward - power regulation cards and pulse amplifiers - but there was one novel aspect included in the payload in that the large area of the detectors also meant large background counting rates from cosmic rays above the atmosphere. A relatively recent development at Leicester University had been the discovery that these cosmic ray pulses had much longer risetimes than those of the X-rays that formed the desired signal. A special electronic circuit was designed to measure the risetime of each pulse and if this exceeded a few microseconds a blanking pulse was generated to stop the cosmic ray signal being read out to the telemetry. This risetime measurement was sensitive to temperature and pulse height from the detector. Weeks of testing in the lab were devoted to choosing control voltages within the circuit to maximise the percentage of cosmic rays rejected while minimising the number of X-rays vetoed. The circular shape of the detector made the electrostatic fields within it highly distorted and this affected the risetimes of the pulses creating some difficulties in the optimisation of the performance. When the circuits were functioning to a satisfactory level, the designs were finalised and committed to the flight build phase.

Since only a flight and flight spare version of each electronic card was to be made, mass production techniques were not used in 1968. Circuits were built by drilling holes in a paxolin board for the component leads to be pulled through and the wiring was added “point to point” on the underside of the board. In 1969 a new member of the electronics team, Ray Penny, changed the manufacturing system to use printed circuit boards, previously dismissed as only being appropriate for mass produced electronics. This caused an hiatus in the Lab’s programme as the new system was brought into action and I was told by the Director, Professor Boyd, that my thesis rockets were to be

cancelled as a result. For a period of six months the electronics workshop was to be turned over to installing the new methods rather than manufacture and test new payloads. This was not the news I wanted to hear and I proposed instead that, if the workshop would actually manufacture the electronics, then I would test and integrate them. This offer was accepted.

Integration of the Experiment



Figure 2: *Skylark* payload, instrumentation and experiment.

After assembling the payload at MSSL and spending several weeks checking through the wiring harness and the X-ray detector performance, the payload was taken to British Aerospace at Filton. The scientific instrument was constructed on a circular bulkhead of magnesium alloy which was previously delivered from BAE as part of the *Skylark* "Meccano kit". The 19 inch diameter instrumentation section which was mounted forward of the *Raven* motor was made of cylindrical tubes of magnesium alloy with machined grooves at both ends. A manacle ring was used to connect pairs of these cylinders, or bays, together and a circular bulkhead was usually mounted at each end of a bay. The design of the *Skylark* provided great flexibility for the

experimenter. Holes could be cut in the cylindrical bays or in the circular bulkheads provided the design was approved by BAE at Filton. The strength of the vehicle was in the magnesium alloy cylindrical skin. Generally four or five cylindrical bays would be mounted on top of one another containing the parachute, batteries, the control and telemetry systems and then the attitude control system if one were employed. Usually the experiment bay was mounted at the top under a conical nose cone which split longitudinally in two sections after reaching altitude.

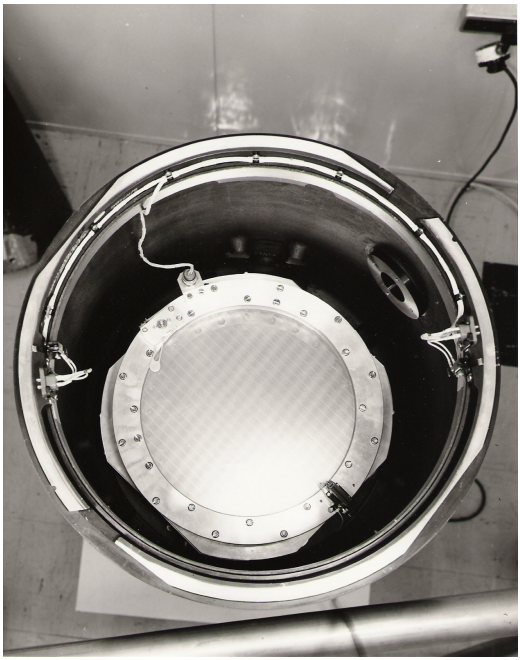


Figure 3: the RMC experiment at the

The experiment, mounted on a circular bulkhead at the bottom of a cylindrical bay was transported down to Bristol in the MSSL van, universally known as "Ted's van" after the driver, Ted Pullen. This was my first meeting with the BAE team and my first experience of working in an industrial environment.

The payload was checked visually and then the signal and control connections to the instrumentation bay were checked prior to mounting it on top of the rather tall column of *Skylark* bays which stood on a wheeled platform. A standard telemetry system was provided operating at about 480 MHz and with a bandwidth of about 7kHz. Checking that the control signals for timing events during the flight were

passed correctly to the payload might only take a few hours but the most difficult and time consuming process was to convince oneself that the RF[2] from the telemetry transmitter was not interfering with the sensitive electronics in the experiment. On some occasions this interference produced thousands of spurious X-ray pulses, on others it saturated the amplifiers and all output ceased. Little effort went into protecting the circuits from RF at the design or manufacture stages and a process of rewiring, ad hoc screening and the addition of various RF filters was used to reduce the effects of the interference to an acceptable level over a period of a few weeks. Much of this work was redone at the range. Seemingly every time the stack of *Skylark* bays was broken down and reassembled the RF impedances changed and the radiation pattern altered. RF from the aerials could be ducted up to the experiment bay along rather loose wiring looms and these also moved, contributing to the variability of the interference.

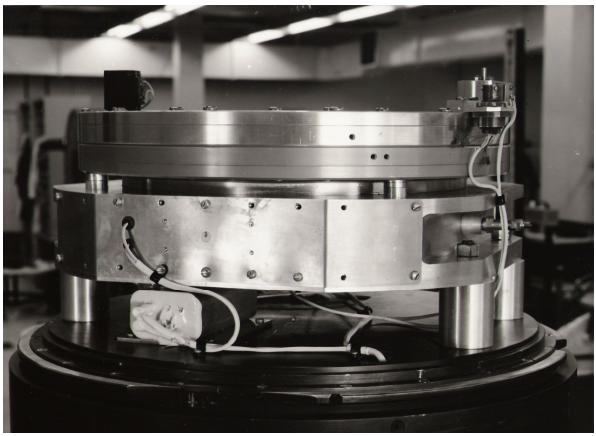


Figure 4: the RMC experiment mounted on a bulkhead.

[2] RF – Radio Frequency. The radio signals being broadcast from the telemetry transmitter could be picked up by the electronics in the experiment.

All this work was done from step ladders which brought you up to the level of the experiment bay, perhaps three metres from the ground with oscilloscopes and specialised test equipment perched at the top. From about 1967, *Skylark*s launched from Woomera were organised on a campaign system meaning that a single team of BAE personnel went out to the range for about ten to twelve weeks to launch perhaps four or five payloads. For this reason, the integration of the payload at Filton would be conducted alongside other payloads from different universities planning for launches in the same campaign.

Rockets and space always sound exciting and it was not uncommon to have to explain what you were doing to clients of BAE visiting other departments. On one occasion, I gave a ten minute talk from the top of the access ladder about my payload and how it worked to two German visitors. They seemed very interested. Ten minutes later the BAE guide who had led them away returned, convulsed with laughter. After having two or three *Skylark* payloads described to them, one of them said 'Ach so, very interesting but vere are ze blast furnaces?'. The two visitors had been picked up by a BAE car from Bristol Temple Meads station and driven to Filton to be given the grand tour before their meetings. Unfortunately they had come to visit a steel works, not BAE at all. We quickly worked out that there were two similarly surprised Germans Aeronautical engineers now visiting the steel works who would have been even more interested in the *Skylark* payloads. At midday, during these integration sessions, all the experimenters were shepherded off to a local pub for what seemed to a young research student to be a splendid lunch. Without doubt the BAE personnel enjoyed the process of hosting these lunches to the full. Given the fact that the several university teams and the BAE staff were going to travel and live together for ten or twelve weeks this hospitality played a useful part in getting to know one's working partners prior to departure.

By today's standards the working atmosphere was extremely informal. I cannot remember a single document or specification

beyond a mechanical drawing of the payload general assembly, a list of pin connections to the instrumentation bay and a short list of five to ten event timings. Clearly the BAE side worked to full military missile standards and was governed by independent EQA[3] processes, but the experimenters were assumed to be in complete charge of the experiment and its operation. The only formal stage in integrating the payload in the UK was the taking of the "Final Records". This happened a few weeks before the shipments to Australia and consisted of essentially a simulated flight recorded on tape over the telemetry system with the round running from its own internal batteries. This had to be signed off in agreement that the *Skylark* instrumentation had performed all the events required of it. A separate test was carried out of the nosecone separation with nets surrounding the vehicle to catch the nosecone halves as they were ejected. A week or so after final records came the last date for packing everything that was to be freighted out to Woomera. Another trip in Ted's van was arranged for all our test equipment and spares to be sent to Filton where it was professionally packed to the very highest standards. Every item left in the pile of equipment was packed into specially made boxes of 2 cm thick multilayered cardboard which had a sort of tar paper in the middle to protect against moist atmospheres. These boxes were beautifully constructed on site by the packers and were worth more than some of the equipment they contained. Unpacking the boxes in Australia held some surprises. On one occasion a cylindrical tube 4 cms long and 2 cm in diameter cased in antifungal packing paper was found at the centre of such a box. No-one could think what it was until we opened it to find half a tube of polos left by one of us on our equipment pile in Filton and dutifully packed to military standards for us to enjoy in Woomera. Some of the equipment we took was quite specialised, in particular the Pulse Height Analysers to check the performance of the X-ray detectors. After

[3] Electronics Quality Assurance

nearly four weeks of trying to get some sense out of one of these machines in the middle of the Australian desert, far from sources of serious technical help and within days of the launch window, we discovered that the packers had removed from the back of the unit a small plug which carried a vital shorting link. Again the plug was beautifully packed and found lying in the empty boxes waiting for the journey home.

The Journey to Woomera

Travel to Woomera was a rather extraordinary process which contributed greatly to the mythology of the *Skylark* system. All the equipment and most of the personnel travelled on the "charter", meaning the regular Britannia flights from Luton run under contract by Monarch Airlines solely for the Ministry of Defence. This service supported all the trials work that was carried out at Woomera under the Joint Project agreement between the UK and Australia. There were two planes: the passenger charter, G-ANCF, referred to by the call sign Charlie Foxtrot, and another "explosives" Britannia that carried the motors and the heavy payload items. The explosives plane had special doors to accept the long *Raven* motors.

Charlie Foxtrot was reconfigured for each flight by fitting only the number of passenger seats required, somewhere between ten and thirty on most flights. Forward of the passengers the space was cleared for equipment. G-ANCF left every two weeks from Luton and took three days to get to Adelaide. Leaving early in the morning there would be a stop at Bahrain for an overnight rest then on to refuel in Madras in the middle of the next night and a stop overnight in Singapore. The next day came the flight over the South China Sea to Darwin to refuel followed by a long haul across the red Australian desert to Adelaide. Being on the plane for three days with the same crew was a different experience to commercial flying now, or then. One got to know the crew, especially Wal and Ginge who were the armed guards who stayed on the plane at the overnight stops. They were officially engineer

guards and they did mend things on the way. It was believed that G-ANCF had been bought by an airline which went bankrupt soon afterwards and spent many years unused on a runway somewhere in South America. All the instructions in the toilets were in Spanish and English. Even in 1968 it was an old plane and most flights had some technical trouble. Loss of nose-wheel steering, a defunct radar transponder, a damaged propeller were all taken in their stride by the crew including Wal and Ginge. Diversions were arranged to strange RAF airfields en route where there were other Britannias to be cannibalised. No journey seem totally uneventful. Several of the BAE team had done their electrical apprenticeships wiring up Britannia aircraft and it was not uncommon for the engineer guards to ask for volunteers to help them trace a piece of aircraft wiring harness that they were interested in during the flight.

It was also a strange experience as a research student with only three shirts, one pair of trousers and one jacket, to be waited on for three days with drinks before meals, drinks with meals and drinks after meals. With a good book, this kind of travel was definitely survivable. And then there were the overnight stops. Bahrain, with troops stationed on street intersections and not a blade of grass to be seen, followed by Madras airport, admittedly at three in the morning, with geckos on the ceiling and drinks of Coke out of bottles with slightly rusty crown caps. But the star of every trip, out or back, was Singapore. I remember the smell as the aircraft door opened for my first experience of the East. The air crept in , a slightly scented mixture of exotic flowers and dodgy drains. Not unpleasant but definitely different to the clinical absence of fragrance in the UK and adding to the mystery of being "out East".

Many of the BAE staff had done National Service and spent some time there previously. They were keen to show us the sights, where to shop and where to eat. Despite being thoroughly disoriented in time-zone and climate, we joined in the party of six or seven out on the town. We ate in Fatty's restaurant near Bougis

street with many courses bought by negotiation from nearby street stalls. I had never had a Chinese meal in my life before and it all seemed so colourful, tasty and different. In the mid sixties the UK economy and exchange rates made the high technology items starting to be exported from Japan far too expensive to consider, but here in Singapore with no duty to pay and a dubious process of bargaining to try out, things seemed different. The hardened members of the *Skylark* team knew where to shop and what to buy to sell in Woomera for a modest profit. How the plane struggled off the ground from Singapore I never knew. There were no baggage restrictions and the passengers assembled with all their purchases for the coach back to the airport the next morning, some with sore heads. The larger items needed a little negotiation with the crew and I did see a harmonium being loaded on one flight with a fork lift.

Adelaide

The sight of the South China Sea below one on the way from Singapore to Australia brought back memories of Conrad novels and Somerset Maugham. It was a magical experience, actual Chinese junks with sails set for ports with exciting names were visible from the plane. Australia was different again and no less amazing. Adelaide was a rather prim and pretty small city in the mid sixties but well behind the UK in obvious cultural experience. Very few bookshops but several temperance hotels and some very old fashioned manners. We used to arrive on a Friday leaving the weekend to acclimatise somewhat before visiting the Weapons Research Establishment, WRE, at Salisbury on Monday to meet the local BAE team and the UK liaison staff at BDRSS[4] led by Bruce Gordon.

Bruce had served in many capacities in the civil service overseas and had a most compelling after dinner explanation of why no country that played cricket could ever turn to

[4] British Defence Research and Supply Staff

communism. At the time the arguments seemed highly logical and well researched. It was slightly unnerving as a very junior research student to be met by a huge government car with a uniformed driver who called me 'Sir' and asked me to sign his timesheet. I was told with great formality that I should always say 'Thank you driver' on leaving any government car. This kind of thing had not happened to me before and took some getting used to. Bruce and his assistant sat in an office and welcomed British scientists to WRE and Woomera. I never really understood what else they did although there were many scientists visiting then for weapon trials. Once a week they would catch the plane from Adelaide to Woomera, spend an overnight at the mess for a few games of snooker, and return the next day to WRE.

The BAE team were in a different building and the atmosphere was certainly very different. They wanted to know what the experiment was, what special issues there were going to be in launching it and what use the data might be. We also met again the UK BAE colleagues who seemed extremely at home in this strange environment which was so new to us.

The BAE(Australia) team was led by Ted Chambers, an inspiring and likeable aeronautical engineer with a touch of well meant piracy about him. Indeed, Ted was building an ocean going yacht in his back garden. He was a real engineer not a paper pusher and had bought the plans for his yacht for five dollars from an engineering magazine. Many weekends were spent with highly educated university scientists sanding down decks and fittings on Ted's boat at the weekend. Beers and steaks were forthcoming as payment. This was no fantasy boat - Ted's son sailed it to New Zealand years later. Another important character was Betty Cook, an English applied mathematician who did all the calculations of the trajectory, attitude measurement, launch slots etc. A half hour conversation with Betty could optimise your observing programme or help you grab another ten seconds data by a different nose cone release time. Things which were difficult to arrange in the UK suddenly seemed simple out at the range as

the whole trials team was focussed on what you wanted to do, not what a group of officials twelve thousands miles away had agreed.

Woomera

After a day or two of very informal discussions in Salisbury the next step was to move to the range. The flights were from the main Adelaide airport using either Convairs, Fokker F-27's or a DC-3. On Monday mornings there might be three or even four flights full of engineers and scientists going to Woomera. Woomera village was five miles or so to the west of the airport, and had all the accommodation for visitors and the permanent population. Twenty six miles to the north east was the range. Everyone had a (light blue) car or a (light blue) utility, a 'Ute', which was a two seater vehicle with an open flat back. The main danger on the road were kangaroos at night. They slept on the tarmac surface which cooled down more quickly than the red desert sand. Hitting one could cause a lot of damage - an adult was the size of a small cow.

The automatic accommodation for university scientists was somewhat strange - in the late sixties we were booked into the Senior Officers Mess, a cluster of white wooden huts each having three or four bedrooms and a living area. We were booked into the Senior Mess because the military simply didn't know what equivalent rank we had.

There were probably about ten accommodation huts and at one end was the Mess itself. A large bar, snooker room, dining room and some offices were contained in the one building. There was a veranda outside on which films were shown on Saturday evenings from a rather rickety projector. The films were obscure B movies and often so bad that no one knew from the plot that a reel had been missed out until the titles appeared at the wrong point. Since there was little else to do but drink and play snooker, no-one minded very much. Seeing films outdoors with strange insects flying into the screen was certainly a new experience not least

because of the stunning backdrop of the Southern sky with unfamiliar constellations which we tried to recognise. Indeed during the reel changes for one film some of the UK scientists were trying to identify one constellation which was known to be the scientific target of one of the up-coming campaign launches. When we had all agreed which one in the sky it was, a slightly worried voice pointed out that there might be a problem. The *Skylark* on which the experiment was to be launched used a sun-pointing attitude control system and yet we could see the target at night when the Sun was quite obviously not visible. Some hurried calculations on the back of the napkin showed that it might just be possible given all the angles concerned and this was verified the next morning with a call to Betty Cook.

The Senior Officers Mess was run on military lines with Mess nights and formal dress (a white shirt and tie at least). My military education owed more to the Goon Show than to Sandhurst and I found the regime slightly bizarre.

At the range, *Skylark*s were assembled in Test Shop 1, not far from the range centre. This was a large building with a green painted concrete floor. A large preparation area ran the full length from one set of huge sliding doors to the other. On the left were the offices of the BAE staff and on the right were the labs for the attitude control staff from Marconi together with the preparation area for the canted fins and other vehicle items. A team from BAE Australia was always on hand. Bob Beatty was the explosives officer, John Ison worked on the attitude control units, John Thomas was the EQA inspector, Keith Wilson looked after the telemetry systems. At the left hand side of the test shop there was a separate white portakabin for the experimenters to work in finalising their instruments prior to reintegration. It was usual for the experiment to be dismounted from the instrumentation bays and handed over for calibration or filling with specialised gases until it was needed again for another 'Final Records' back with the *Skylark* instrumentation bays to confirm that all was functioning as required.

A few hours prior to launch, the stack of *Skylark* bays with the nosecone at the top and the parachute bay at the bottom was mounted on a small trolley and taken by road to the *Skylark* launcher. The vehicle was rail launched - that is, there were three parallel rails mounted vertically in the launch tower and metal shoes were fitted at various positions along the length of the vehicle to engage with these rails. The fins extended outside of the rails, in the azimuthal spaces between them. An important task before and after a launch was to lower down the launcher a jig which just fitted between the rails and was used to measure the clearance between the shoes and the rails. The launcher tower was about 50 metres tall and the whole launching assembly could be tilted to angles of about 15 degrees from the vertical to adjust the trajectory for winds.

It was necessary to make calculations of the ballistic winds at various heights to predict the trajectory as the vehicle was only powered for 35 seconds of the ascent phase and had no guidance system. Balloons were launched and tracked by radar for several hours beforehand to provide this data on the winds up to ten or fifteen kilometres altitude. In addition there were various instrumentation checks and the firing of sighter rockets to check that all the radars and kine-theodolites were functioning correctly before a firing took place. At the launcher, the payload would be lowered down onto the motor and fastened by the normal manacle rings. Some experiments required access in the launch tower for gassing up detectors or for charging batteries and this was only possible for experimenters who had gained an explosives certificate by attending a day long course at High Down on the Isle of Wight.

Launching a *Skylark*

Normally the experimenters watched the launch proceedings from the block house, EC2, a concrete building below ground level, built into the edge of the concrete launch apron. All the control connections to the vehicle came to EC2 and there were

telemetry receivers to check data from the instrumentation and the experiment. In a separate room in EC2, an Australian military technician did the actual firing by starting an automatic sequencer two minutes before launch. This counted down and issued the firing pulse to the detonator in the booster motor at the pre-programmed time. Up to 2 seconds before launch the launch could be stopped using a line attached via a small snatch connector to the side of the instrumentation bay. Several people in EC2 had "Stop Action" buttons which could abort the launch via this route. The snatch connector was left in place as the launch proceeded and the wires literally snatched from the side of the vehicle as it departed.

Nothing was worse than a misfire - when the ignition pulses were sent but the vehicle did not move. This could be extremely dangerous if there was electrical energy stored somewhere that could in the end cause a detonator to fire while people were examining what had gone wrong. On one of my thesis launches a severe electrical storm and tornado hit the range while the vehicle and motor were in the tower. Most of the personnel had been ordered back to take cover in EC2 when the storm was spotted and were sheltering there when a huge bang occurred and all the lights went out. The immediate assumption was that the round had been hit and had ignited but the instructions for a misfire were that everyone had to remain in place for 30 minutes and do nothing. That was a very long 30 minutes standing in the dark and not knowing what had happened to those left at the launcher. All the communications were dead. When the time was up we crept out into the daylight to see the vehicle and motor intact and the launch apron drenched in water. It took over a week to restore power to the range as the lines to Port Augusta were down and we lost the whole launch slot, having to return to the UK and wait for better luck next time.

The launches of other people's *Skylark*s were very spectacular but you saw little of your own, being heavily occupied inside EC2 watching things happen on the telemetry. The person in charge of

the range for a firing was denoted Con 2 (I never quite worked out who Con 1 was) but he or she was just a voice over the intercom.. Everywhere on the range there were intercoms with various nets you could select using a switch on the front. The preparations for every launch could be followed by just listening at any intercom location. Everyone knew when a firing had got into difficulty when the ominous request was broadcast 'Con 2, can you switch to the private net please?' Every room had an intercom because of the need to warn staff in the event of a misfire or a vehicle going out of control. In the late sixties there were one or two tests if not launches, each day. Bloodhound, Sea Slug, Sea Dart, HASP, etc were all being developed at that time. Quite a few were tests of missiles fired from aircraft at targets towed by a pilotless plane called the *Jindivik* and these were great fun to watch. In EC2 the person in command, usually Ted Chambers, had the title OISC , Officer in Scientific Charge. He had the power to halt launches and make the important decisions, generally after conferring with the experimenter.

Shortly after my PhD launches I had the chance to try to observe a lunar eclipse of an X-ray source as a further means of measuring its position for identification purposes. Since the position of the Moon is known to great accuracy, if you could time the moment when the X-ray source appeared or disappeared, you could place it accurately on a very narrow curved line in the sky. Two such lines would fix the position. Lunar eclipses repeat every 18 years or so and the timing of the launch had to be accurate to about two seconds making them very tricky launches indeed. On this occasion the wind at ground level was close to the permitted limit and the wind monitor, a member of the attitude control team, was concerned about the size of the gusts although things were better at higher altitudes. At minus two minutes, I had frankly given the launch away in my mind, but the wind monitor had a theory that the gusts around the launcher were somehow periodic, and when the time came for stop actions to be called out he remained silent and the vehicle was launched. He believed that

the wind would drop in the last few seconds. It didn't. Cine film of the launch showed that the vehicle took a huge gust immediately on leaving the launcher and veered wildly off track. In fact it landed just outside of the Woomera territory and close to the North-South railway. We missed the eclipse - the detectors were never in the right place to observe it due to the unexpected trajectory. The team of experimenters drove at some speed down to Woomera village to hear the evening news since the arrival of the train from Alice Springs was normally reported on the local radio. Luckily there was no disaster such as the train being hit by a descending *Skylark* but we knew soon afterwards that the wind monitor, who was trying his best to help, had received a good deal of trouble from the range authorities.

Another launch presented a challenging problem and illustrates the rather free technical atmosphere in which people worked at that time. The night before this particular launch we stayed behind in the test shop to calibrate a mechanical mechanism which deployed the detectors after the nose cone was jettisoned. The vehicle pointed at the Sun for stability and then rolled around that axis using the local magnetic field to find the correct direction to view the source. The way the angles worked out, detectors that stood vertically under the nosecone could not easily see the source and so they were mounted on a mechanism that let them swivel through 47 degrees from the vertical once the nosecone was gone. Our last task was to check that angle. To our dismay there had been an error in the UK. The detector deployment could be adjusted to be 47 degrees by altering a screw although it had been set at 43 degrees, clearly 90-47, by mistake. But the microswitch that registered that deployment had been successful was on a bracket that could move from 43 degrees by a small amount but not as much as the 4 degrees needed to get to 47. My colleague and I were on our own and most of the labs with hand tools and power tools were locked. After an hour or so of searching unlocked drawers and dusty shelves, one of us spotted exactly what we needed. Each of the intercoms had a hand

microphone connected by a plug and socket on the side of the unit. The bracket holding the socket looked just right. Unfortunately these intercoms were mains powered and directly wired into the mains so that they could not be switched off accidentally, leaving someone unaware of a warning message. We unplugged the microphone and then unsoldered the wires from the back of the socket, with sparks flying as the unit was still powered up. When the wires were off we unscrewed and removed the socket from the bracket, removed the bracket from the intercom box and then resoldered the wires onto the socket again leaving it hanging in mid air. The bracket did indeed work beautifully and we soon had the detector deploying through 47 degrees and coming to rest on the repositioned microswitch. By midnight we were away down to Woomera village for some sleep.

The next day the round was launched on time and the deployment worked perfectly. Parachutes seldom worked on Sktylarks and so the payload was usually badly smashed but the presence on board of a small radioactive source to calibrate the X-ray detector in flight made it necessary to try to locate the payload despite the damage. One of us flew in the Alouette III helicopter down range and found the landing site. The parachutes were good markers. The payload was recovered and returned in the helicopter to the test shop. We waited until everyone else left for the village, post launch parties were necessary even when the launch failed. We then took the bracket off the detector, unsoldered the wires from



Figure 5: an experiment after landing - another parachute failure

the microphone socket on the intercom, fed them through the bracket and resoldered them onto the socket with accompanying sparks and fixed the socket back onto the body of the intercom, most likely the only intercom on Earth with parts that have been into space.

The overall plan for my thesis work had started to run into trouble at quite an early stage. The two *Goldfinch* proving rounds, SL973 and SL974, were originally due for launch in early 1969, only six months or so after the start of my PhD, but delays in the development of the booster set their launch back to 1970, a delay at that time considered unacceptable to my supervisor.

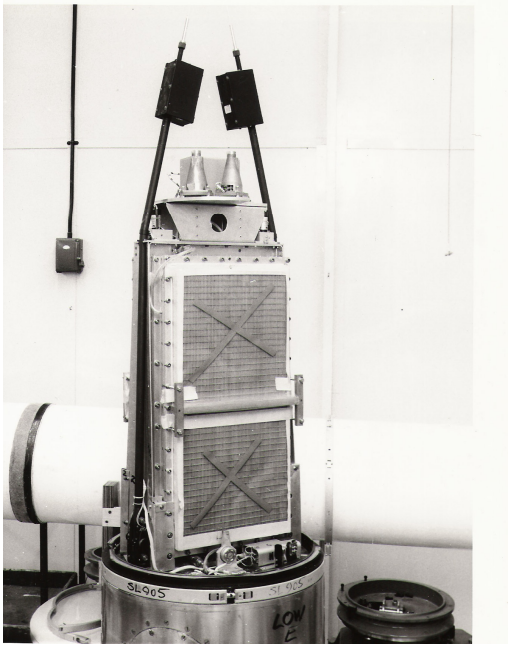


Figure 6: the large area detector, with folded boom experiments.

We were therefore allocated a "non-proving round", i.e. a round from the normal sequence, SL921. Meanwhile, personnel movements at MSSL were causing changes. I was the only research student in the X-ray group at that time and my thesis rounds were now being badly delayed. A member of staff, Peter Sandford, had been recruited from Leicester to complete the instrument for the Lab's first X-ray satellite project, OAO-C or Copernicus.

This project was moving very slowly indeed in the US, and he wanted to get some science data more quickly by using sounding

rockets like *Skylark*s, so he passed the leadership of OAO-C over to a postdoctoral scientist and started building a large area X-ray detector for a *Skylark* flight planned for 1969. When the postdoctoral scientist left for a job in the states, Peter Sandford had to take back the work on OAO-C and I was asked to take over the work on the *Skylark* since the electronics were identical with that for my RMC rounds. My first visit to Australia was with this large area detector payload. This, too was launched on a spin stabilised *Skylark* with canted fins, but the large area detector occupied almost all the room under the nose cone as figure 6 (above) shows. The payload also contained some booms which deployed after nosecone release with electron density probes attached.

Unfortunately the dynamics of releasing a split nosecone from a fast spinning vehicle had not been thought through by the design authorities at RAE Farnborough, or at BAE. Once released, the nosecone halves began to rotate about their longitudinal axes, unable to dispose quickly of their angular momentum. The following edge of each half nosecone chopped through the detectors before the heavy nosecones drifted away from the vehicle and no data was obtained.

My next attempt to get data was in 1970 with the launch of the newly allocated SL921 in July. All the preparations went well for this launch with the sole exception that I had not yet really examined the data analysis problem for RMC devices. I knew the basic method, and had produced images from the optical tests, but I had been too busy on the hardware side to think seriously about the amount of data I might have and the scale of the problem if difficulties arose.

As it happened the telemetry systems on board *Skylark* SL921 failed after 10 milliseconds, so the experiment was launched and presumably worked but no data came back to Earth for me to analyse. At this time most *Skylark* payloads and the allocated rounds were produced in pairs, possibly a result of the many hardware failures in the early years. This was markedly different

from our colleagues and competitors in the States. They were used to going on a campaign with more *Aerobee*[5] motors than payloads, and when everyone had had one successful launch, the spare motors were used up relaunching successful payloads a second or even third time. Their parachutes actually worked so that two years building an instrument might result in many flights and a great deal of data. This advantage was magnified by the fact that once you have published data from an instrument you know it inside out, and further data can be analysed quickly and effectively.

We had the second large area detector experiment of the pair originally approved, and decided not to use a spinning platform for the observations but to despin before the nosecones were jettisoned. The attitude was then to be controlled using the Sun as a reference, performing slow scans in roll to survey the chosen parts of the sky. This round worked well in late 1970 and provided my first data, though not using the RMC technique that my thesis was supposed to be about.

Analysing the Data

In 1971 two RMC rounds were launched, SL973 and SL1021 and these provided the data required. The key to the RMC technique was the time modulation that varied across the field of view and this modulation was at quite high frequencies, sufficiently high to challenge the telemetry bandwidth. The preparation of the data therefore required some care. The tapes recorded in Australia were analogue tapes of the telemetry sub-carrier and a standard digitisation was available for *Skylark* experimenters. Because the high frequency modulation was so important, I requested permission to attend the digitisation process and check what was being done. These tapes were

[5] The Aerobee rocket was a small (8m) unguided suborbital sounding rocket used for high atmospheric and cosmic radiation research in the United States in the 1950s. The rocket had two stages with a solid-fuel boost and a nitric acid/aniline sustainer.

digitised at RAF Aberporth because they were used carrying out to trials work, being the base for bombing practice in the UK.

Three or four days in wet west Wales resulted in digital tapes in which I had some confidence and they were mounted on the MSSL IBM 1130 computer with 4 kilobytes of core store. Simple analysis showed no images of sources in the field of view. Complex analysis showed no sources in the field of view. Careful analysis showed no sources in the field of view. I was now in my fourth year of a PhD with my first serious datasets showing no results from three years of work, with none of the failures being due to the instrumentation I had worked on. I decided that the standard attitude analysis of the rounds was not accurate enough and I began to consider what more complex motions of the payload could do to the process of forming an RMC image. Gradually, my more sophisticated analysis of the sun sensor timings showed that the payload did not simply spin about the geometrical axis of the payload but carried out a coning motion with a half angle of about 0.33 degrees. This is not a large angle but the RMC device had quite high angular resolution and the coning was significant in comparison.

In parallel with this analysis, my theoretical work on what would happen to an RMC image (which has negative sidelobes) when the spin axis moved in a small circle showed that large reductions in the image brightness would occur as the negative parts of the image were smeared across the positive parts. In the end, my analysis showed very good agreement between the sun sensor derived explanation of how the payload actually moved and the several faint images that were finally detected in the field of view. The main outcome of this analysis was that the RMC instrument proposed for the UK5 satellite might also suffer from this problem of smearing images over quite small circles. A simple additional control was hurriedly added to the UK5 instrument to limit this smearing to only half of the rotation cycle, dramatically reducing its adverse effect.

A paper was published in 1973 with the results of the two flights and the full mathematics of the image degradation that RMC devices were prone to. The theoretical work necessary to understand the smearing effect suggested a novel method for building up better RMC images from several different masks - a kind of aperture synthesis - and this was the first time this had been considered at X-ray wavelengths, resulting in a further paper shortly afterwards.

Reflections

What did the *Skylark* programme produce in the way of benefits to the UK and the students concerned? Some very new science in most cases. Studies of the ionosphere, the middle atmosphere, X-ray sources, UV spectra of stars and, towards the end of the programme, some Earth observation data - all were progressed by *Skylark* experiments and contributed to the early development of space science. The *Skylark* engineering design was conservative to say the least, and most of the experiments were far in advance of the instrumentation that supported them. Mechanical switches were still being used to multiplex the telemetry while semiconductor storage was being employed to capture science data in the experiment. This conservatism was a lost opportunity for UK space companies who, given a freer hand, might have built more advanced equipment with consequent spin-off for the emerging satellite telecommunications industry. Undoubtedly the restraining hand of RAE Farnborough was at work in this respect.

The parachute failures dented the effectiveness of the whole programme and were a factor in letting the US pull ahead in many scientific fields. As the payloads became heavier and longer, the parachute design remained the same and success rates suffered. It must be recorded that, by the middle seventies, sounding rockets were losing their place to satellite borne equipment. Why spend three years building rocket borne equipment to gather five minutes of data when you could spend five years building satellite borne equipment that would deliver three years of data? The

economics were against investing in new rocket technologies. The range at Woomera was extremely effective in the late sixties and the BAE team did their very best within the hardware limitations to ensure the experimenters gained the data they wanted.

The big contribution of the programme was the opportunity for young scientists and engineers to experience a space project from beginning to end within a PhD duration of three or so years. Vicarious benefits included seeing a snapshot of the whole British colonial experience in the space of a few days journey across the world and the opportunity to test oneself in management terms against time, technology and resource constraints. The nostalgia felt by those who experience a *Skylark* PhD is fuelled by the current lack of any replacement for the horribly realistic management training it provided.