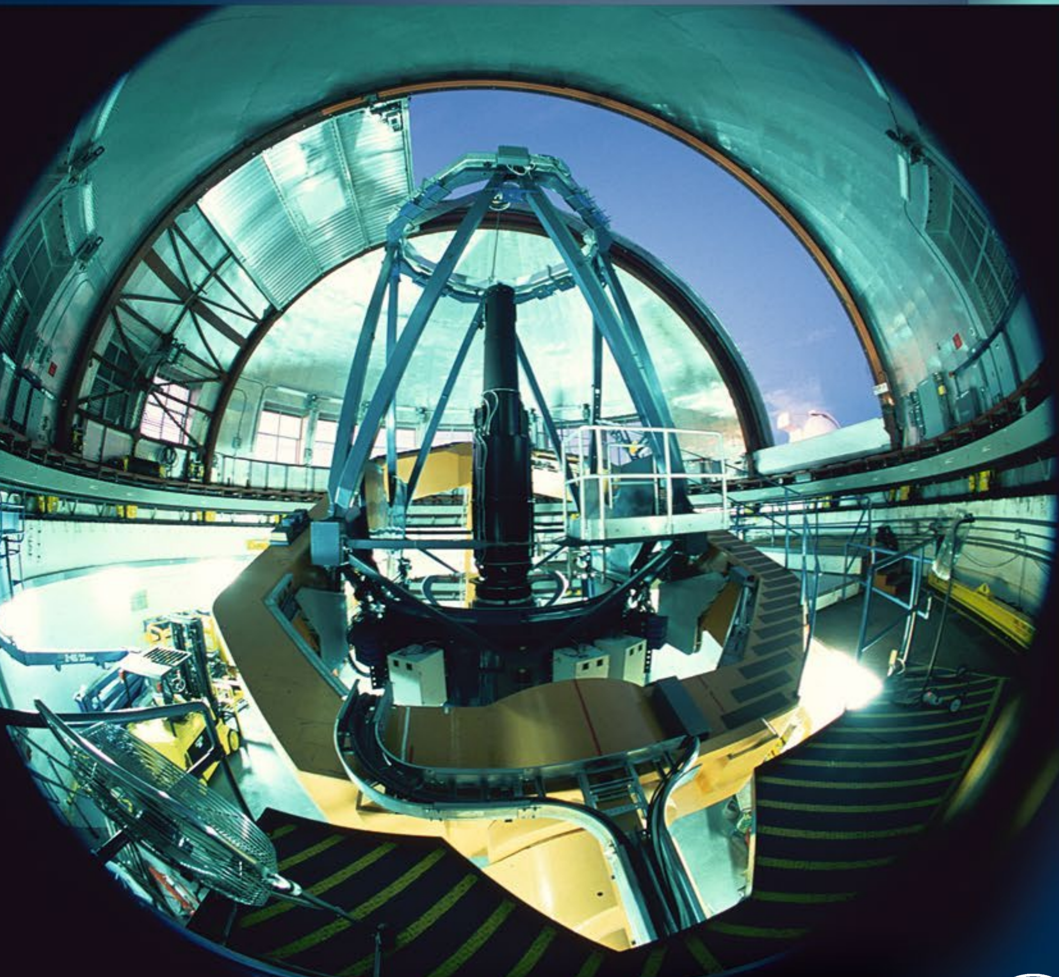
The Life Story of an Infrared Telescope

John K. Davies



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Cover Illustration: This fisheye lens photograph shows the UKIRT Wide Field Camera mounted above the primary mirror of UKIRT. The dome slit is open and the University of Hawaii 2.2 m telescope dome is just visible along the lower edge (Photo Paul Hirst)

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To everyone who contributed to UKIRT and who, in doing so, made this a story worth telling.

Preface

This is a story I have wanted to tell for a number of years, it was in my mind while I was still at UKIRT and the urge grew stronger once I had left. The attempt by the Royal Observatory Edinburgh librarian Karen Moran to organise a history of the observatory fanned the flames and the gathering of a number of key UKIRT people (if I may call them such) at the 30th anniversary conference in 2009 created an opportunity to gather considerable raw material. However it was the sudden, tragic, death of my good friend and UKIRT stalwart Tim Hawarden which provided the trigger to stop procrastinating and get on with the job. Once I had started the task turned out to be incredibly easy to continue, for I did not so much write this story as assemble it. The experience was like drinking from a hosepipe: simple e-mails to people I had not seen for many years, or even never met, produced a flood of material, almost all fascinating, some quite unpublishable, and more photographs than I could ever use.

Why should this be so? A telescope is a machine with an eye of glass, a skeleton of steel and muscles of copper and plastic. Its brain is a computer. It should not have a soul but, somehow, UKIRT does. Almost all of the people who have worked there, or even visited to use it, have an affection for this machine which transcends common sense. They almost love it. There is just something about UKIRT, or about the way it was run, which generated an ésprit de corps which survived long after the original builders and operators had left. So this is their story, or perhaps I should say our story, because I too fell under the spell of this machine.

I hope you enjoy reading about this adventure. If you were part of it, then I trust that I have done you justice; if you were never part of the UKIRT family then I hope that it conveys some of the excitement of working in this very special place.

Edinburgh, UK John K. Davies

A Note on Units

As scientists, astronomers usually work in the SI (metric) system, but the United States and much of the United Kingdom still use many traditional imperial measurements in day-to-day life. This creates an interesting melange of terminology in which it is not uncommon to speak of a 3.8 m telescope on a 14,000 ft high mountain, or an 88 in. telescope at an altitude of 4000 m. In a transatlantic and cross-cultural adventure like this, it is difficult to know in which system to work. So rather than adopt one system and systematically translate into the other, this story is written in whatever vernacular the people of that time, and in that place, would most probably have felt comfortable. Conversions, rounded to a sensible number of digits, are indicated in brackets when a clear understanding of the dimension is important.

Acknowledgements

Much of what appears here is only a lightly edited compilation of the many e-mails received and the interviews I have conducted. Specific quotes are in *italics*, but often the paragraphs in which they are embedded are largely written by the people involved in the incidents described. This material has been supplemented by extracts from newsletters, magazines and a few official papers. I owe all of my correspondents an incalculable debt, for it was their contributions that made this possible. They include:

Alan Bridger, Alan Pickup, Alex McLachlan, Alf Neild, Alistair Glasse, Andy Adamson, Andy Lawrence, Andy Longmore, Bill Parker, Bill Zealey, Bob Joseph, Charlie Richardson, Chas Cavedoni, Chris Davis, Chris Impey, Colin Humphries, Colin Vincent, Dale Cruikshank, Dave Robertson, Dolores (Walther) Coulson, Doug Simons, Doug Whittet, Frances Hawarden, Frossie Economou, Gareth Wynn-Williams, Gary Davis, Gillian Wright, Gwen Biggert (MKSS), Harry Atkinson, Helen Walker, Ian Bryson, Ian McLean, Ian Robson, Ian Sheffield, Jim Hough, Joel Aycock, John Clark, John McCarthy, John Morris (MKSS), John Peacock, John Rayner, John Womersley, Karl Glazebrook, Kent Tsutsui, Kevin Krisciunas, Liz Sim, Malcolm Currie, Malcolm Longair, Malcolm Stewart, Marc Seigar, Maren Purves, Mark Casali, Mark McCaughrean, Martin Ward, Martin Wells, Mathew Rippa, Matt Mountain, Mike Wagner, Nick Rees, Olga Kuhn, Omar Almaini, Pat Roche, Paul Hirst, Peredur Williams, Peter Forster, Philip Best, Phil Daly, Phil James, Phil Puxley, Ray Wolstencroft, Richard Ellis, Richard Jameson, Richard Wade, Roger Clowes, Rich Isaacman, Ron Beetles, Ron Koehler (MKSS), Sandy Leggett, Simon Dye, Sluing Yee Roth (Alfred Yee & Associates, Honolulu), Steven Beard, Steve Beckwith, Steve Warren, Stuart Ryder, Susan Beattie, Suzie Ramsay, Terry Lee, Terry Purkins, Tim Carroll, Tim Jenness, Thor Wold, Tom Geballe, Tom Kerr, Wanda Miller (Observa-Dome Laboratories Inc).

I am also grateful to Jim Gallagher and Winnie Schafer (STFC records office) who granted me access to some of the remaining UKIRT records of the early period, to Roger Griffin who had preserved some of the very early steering committee papers and other correspondence for posterity, and to John Jefferies (IfA) for access to his unpublished manuscript on the development of Mauna Kea.

Considerable use was made of articles published in the UKIRT Newsletter and in the ROE Bulletin, an internal staff newsletter published in the 1970s and 1980s, and I am grateful to STFC for permission to use this material.

Tom Kerr's blog "A Pacific View" kept me up to date with developments after about 2009 without me having to ask too many questions.

Finally, Tim Hawarden's talk at the UKIRT 30th anniversary conference formed the basis of Chap. 11. This whole story would have been so much better if he had been able to contribute directly.

As always, ultimately as author I am responsible for any errors, especially if I have misunderstood what I was told.

Contents

Chapter 1
Conception

The father of the telescope we today know as UKIRT was Professor Jim Ring of the Imperial College of Science and Technology, London. He was an experimental physicist who graduated from Manchester University in the 1950s, lectured there for a time, moved to the University of Hull in 1961 and then to London in 1967 where he set up an infrared astronomy group. Jim Ring was interested both in both astronomical instruments and in telescope design and wanted to explore the limits of telescopes as the diameters of their primary mirrors was increased. In particular he sought to challenge the canonical cost-to-diameter relationship for telescope construction which said that, because of the cost of steel and concrete, the budget for a telescope of traditional design increased as about the third power of the primary mirror diameter. At a time when one arcsecond seeing was assumed to be the limit achievable from the ground, he wanted to know how big a mirror with acceptable image quality could be made. He believed that by replacing a conventional primary mirror, i.e. one with a diameter to thickness ratio of about 6 to 1, with a thinner one supported by air filled pads the mass of the mirror and its supporting cell could be significantly reduced. In turn, the mass of steel and concrete needed to support the optics, and hence the cost, would be lower and this virtuous circle would make larger telescopes more affordable.

Preliminary calculations of a thin primary mirror supported on an axial support system of 80 pads positioned along three radii were performed by John Long, a mechanical engineer in Ring's group at Imperial College. These showed that with such a support system the root-mean-square deformations of the primary mirror, and therefore degradation of the telescope image, could be limited to a fraction of a micron over the entire surface of the mirror, giving an image that would be diffraction limited at mid-infrared wavelengths. Since the internal noise in the lead sulphide (PbS) detectors used for infrared astronomy at the time was greater than the combined thermal noise from the sky and the telescope, photometric measurements taken through apertures of several arcseconds diameter did not require particularly good image quality. So a telescope of this design, often referred to as a "flux collector" or less flatteringly as a "light bucket", would be quite

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acceptable for observations that did not need images limited by the atmospheric conditions.

In 1966 Sir Harrie Massey and Jim Ring organized a Royal Society discussion meeting on the newly developing field of infrared astronomy. The proceedings of the meeting, which were not published until 1968, included a paper by Peter B. Fellgett entitled “Large Flux Collectors for IR Astronomy”, although a popular version of essentially the same paper had already appeared in a magazine called Science Journal. Fellgett, who was by then the Professor of Cybernetics at the University of Reading, had written a PhD on infrared spectroscopy at Cambridge in 1949 and subsequently worked at Cambridge, the Lick Observatory and at the Royal Observatory, Edinburgh (ROE) during the 1950s and 1960s. Fellgett’s paper described low-cost, lightweight infrared flux collectors of relatively poor image quality with a typical upper size limit of 120 inches (3.05 m). The paper remarked that ‘*2 or 3 such units located in Britain and Europe (one at a high altitude station) offer great discovery potential*’.

By 1967 thinking along these lines had advanced to the point that a proposal to build a medium-sized prototype of an IR Flux Collector (IRFC) was made by Ring to the UK’s Science Research Council (SRC) and was approved in 1969. The instrument was originally conceived as a portable telescope housed in a roll-off shed that could be moved to various locations to conduct site testing for a larger, as yet unfunded project, but was eventually turned into a more permanent facility located at Izana on the island of Tenerife. The 1.5 m telescope saw first light in April 1972 and was used by UK astronomers, including those who had returned from undertaking PhD studies in the USA, to develop their skills in building instruments and making observations in the infrared. Crucially, the IRFC also indicated that the low-cost flux collector design concept was sound and in 1973 design studies for a scaled up 4 m version were commissioned from the firms of Grubb Parsons in Newcastle and Dunford Hadfields in Sheffield, both of whom had been involved with the 1.5 m IRFC. These studies proved encouraging and Ring proposed to SRC that they should follow up this prototype with either a 3.8 m flux collector situated at Izana or a 3 m version to be built on Mauna Kea, a dormant volcano on the Big Island of Hawaii.[1] Gillian Wright, then a PhD student at Imperial College who was making infrared observations of interacting galaxies under the supervision of Bob Joseph, remembers that it was Ring who pushed the idea that the UK should build these telescopes, and who spent his time at committees and reviews and the like. While admitting that her detailed memories are dim, she says that ‘*The things I remember were the impression of the passion and enthusiasm of it all*’.

[1] The state of Hawaii is a chain of islands and while the majority of the population and the centre of political and business life are in Honolulu, on the Island of Oahu, the largest island is Hawaii itself. Hawaii is known locally, and for obvious reasons, as “the Big Island”.

Fig. 1.1 Hawaii from space. The town of Hilo is around the bay almost covered by clouds in the upper right. The summit of Mauna Kea is the small brown area surrounded by green pastureland near the centre of the island (Photo NASA STS-61-50-57)

The Hawaii option was of interest for two reasons, one scientific and one programmatic. The summit of Mauna Kea is 14,000 ft (4200 m) high, so the air above it is both thinner, and crucially, drier than is found at lower altitudes and so offered obvious scientific gains, indeed it was already the site of an 88 inch (2.2 m) telescope operated by the University of Hawaii who had been granted a 65 year lease of the summit area in 1968. On a practical level the UK had been drawing up plans for a suite of new optical telescopes for what it called a "Northern Hemisphere Observatory" or NHO for a number of years. Site testing of three sites in Italy, Almeria in mainland Spain and on Tenerife was planned and, while the Almeria programme fell foul of political issues (the Germans also hoped to build here), site testing in Italy and Tenerife was under way in 1972. By 1973 the Canary Islands and Hawaii were the clear front runners for the location of the national observatory and John Hutchinson of the SRC's Astronomy and Space Research (ASR) division had been discussing with John Jefferies, the then Director of the Institute for Astronomy (IfA) at the University of Hawaii, the possibility of building the NHO on Mauna Kea. If that plan came to fruition the NHO might incorporate the proposed IR Flux Collector as well. However, the NHO decision was yet to be made and the UK was actively pursuing options for it to be located closer to home so, in late 1973, Hutchinson wrote to Jefferies to explore the possibility of building the IR Flux Collector as an independent facility close to the existing telescopes along the summit ridge on Mauna Kea. Jefferies' reply was encouraging and the SRC's Astronomy II committee, chaired at the time by Professor Walter Stibbs, made the bold decision to go for the larger telescope and to site it in Hawaii. In January 1974 the 3.8 m IR Flux Collector proposal was accepted in principle by the SRC's Astronomy and Space Research Board who asked for a detailed submission to be prepared for final approval.

To finalise the proposal it then became urgent to establish the terms of any agreement to build on Mauna Kea, so Hutchinson arranged to visit Hawaii as soon as practicable. He was to be accompanied by Gordon Carpenter of the Royal Observatory Edinburgh. Carpenter, who was sometimes known by the nickname "Chippie", had relinquished his position as the head of the instrumentation division at the ROE to work full time on the flux collector project and found himself seconded, on a part-time basis at least, to Jim Ring's group at Imperial College. The visit to Hawaii was set for early March 1974 and, in preparation for the negotiations, the Astronomy Policy and Grants Committee prepared a detailed brief for the two men to take with them. This briefing included a guideline that 10 % of the observing time could be offered to the host institution in lieu of rental costs for the site. The visit went well, with the two men visiting the University of Hawaii on the 4th and 5th and agreeing, subject to the legal details being worked out, on a site 200 by 150 ft (61.5 by 46 m) along the summit ridge, near the University of Hawaii's (UH) 88 inch telescope and the then proposed Canada-France-Hawaii Telescope. Since it was en-route to the existing UH 88 inch telescope building the proposed site had the advantage of requiring no new infrastructure. The lease was expected to be for 25 years (after many delays it would end up being 27 years), extendable in 5-year increments, with the UH to be given the option of taking over the building, and perhaps the telescope itself, when the site was vacated.

In his unpublished manuscript about the setting up of the Mauna Kea observatories, John Jefferies wrote about the setting up of the agreement. *'We at the IfA had adopted the policy of asking for a guaranteed share of the use of every telescope as a sort of ground rent. Of course the land did not belong to the University, still less to the Institute for Astronomy, and the State could have insisted on a monetary payment for rent had they wished, but the issue simply never came up and I was certainly not going to raise it'. 'I suppose no one thought to question our appropriating to ourselves the effective right of ownership. Certainly it was the fact of receiving guaranteed telescope time in exchange for use of the land that underlay the growth of the Institute for Astronomy. The negotiations with the UK people were* *characteristic of the ease of our relationships – I said we needed 20% of the telescope time – they (I guess it was Gordon [Carpenter]) said that they were thinking of 10% after which 15% was suggested and immediately adopted. The exchange took less than a minute'*. In fact it was slightly more complicated, the SRC representatives' brief was to surrender 10 % of the time and they had no authority to agree to an increase in this figure. They merely agreed to take the proposal back to higher authority in the UK who did indeed accept the 15 % figure.

With the basis of an agreement in hand the proposal for the project went back to the ASR board, who on the 15th of March 1974 agreed that the case should go forward to the highest decision-making level of the UK scientific process, the Council of the SRC. The Council considered the proposal at its meeting on the 17th of April and gave the go-ahead. The budget of the proposed telescope, excluding instrumentation, simulators to be built at ROE and instrument related work to be done in universities, was set at £2,500,000. Since this exceeded £1,000,000, the project had to be approved by the government's Department of Education and Science, but Stibbs and Ring were able to make the case and the project was fully approved on the 18th of June 1974. Jim Ring was appointed project scientist and, with the ROE put in charge of construction and commissioning, Gordon Carpenter was made project manager. The project was publicly announced by SRC in early August 1974.

Chapter 2
Design and Planning

Design

Once the project was approved the Astronomy Policy and Grants Committee of SRC appointed a steering committee for the construction stage of the project, still known officially as the “3.8 m IR Flux Collector”. This was chaired by Jim Ring with Robert “Bob” Stobie of ROE as secretary and included Richard Jameson, David Allen, Phil Marsden of Leeds, J. C. D. “Lou” Marsh, Mike Selby, Michael Smyth and Gareth Wynn-Williams. Roger Griffin, of Cambridge University, was asked to join the committee to represent the views of optical astronomers. Victor Clube was included in the original appointees but resigned after the first meeting and was replaced by ROE astronomer Terry Lee. Although the SRC records of the committee were destroyed in the 1990s the terms of reference survive. They were to:

1. Within the broad scientific objectives and financial and other constraints laid down by the Astronomy II committee, advise those (normally the project manager) with direct accounting responsibility for the construction of the project about the specification and other aspects of the project to attain the desired scientific ends;
2. Regularly consider progress reports and financial statements by the Project Manager and advise him accordingly; and, similarly, consider proposals to commit expenditure on items of value £5000 or more;
3. Advise the Astronomy II committee on progress periodically or whenever the broad framework laid down by the Committee is in question.
4. Maintain close contacts with those planning the Northern Hemisphere Observatory.

The first meeting of the steering committee was held on the 6th of June 1974 in London. Papers were presented by Gordon Carpenter and Jim Ring on the state of ongoing negotiations with the University of Hawaii and on the plans for the

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telescope and its building. The draft specifications of the telescope presented were as follows

Primary diameter	3.8 m, as near as possible to f/2.5
Focal stations	f/9 –f/12 Cassegrain, ~f/16 Coudé
Image quality	98 % Encircled energy in a 2.4 arcsec circle
Nod time	2 seconds
Tracking	5 arcsec per hour
Pointing	30 arcsec rms

Other key design considerations were for a thermally clean structure (so no complicated optical baffles were included), a lightweight structure with no central box to minimise costs, the ability to move quickly for nodding and chopping and a computer controlled system to avoid the need for a lot of analogue circuitry. The input of pointing information was to be via a keyboard, doing away with the need to dial up values on thumbwheels. Much of the technical support, and the use of a telex machine in Hilo, was expected to come via agreements with the University of Hawaii. The observing floor control room was specified for up to three people, as was the combined lounge/kitchen to be built downstairs.

One of the first actions of the new committee was to evaluate and propose amendments to those requirements and they recommended an increase in the payload of the instrument support system to 200 kg, anticipating the day when instruments outgrew the typical 25 kg of contemporary photometers (but quite failing to appreciate the size of instruments like CGS4 which would arrive almost two decades later). The other main change was to increase the enclosure diameter to 60 ft (18 m) to allow for the addition of a chopping secondary system on the top-end. That would provide an alternative to using a chopper in the telescope's focal plane as had been done at the 1.5 m prototype in Tenerife.

The decision to provide the option of a chopping secondary mirror is an interesting example of how improvements in technology happening in parallel with the development and approval of a large project can change the specification and impact the cost significantly. When the telescope was first considered, infrared detectors were such that observations short of about 3.5 μm were limited by intrinsic detector noise rather than by the thermal characteristics of the telescope structure. It was only for observations at wavelengths longer than about 5 μm where the thermal noise was the dominant problem, and experience showed that in that situation using a chopping secondary mirror gave better results than chopping in the focal plane. Chopping secondary mirrors had other advantages too, such as increased chopping range and offered possibilities of image stabilisation. However advances in detectors, for example the Indium Antimonide (InSb) semiconductor devices that were becoming available, were steadily moving the detector limited constraint to shorter and shorter wavelengths. The strong case put by Gareth Wynn-Williams and from astronomers in the US convinced the Steering Committee that a building that could not accommodate a chopping secondary presented an unacceptable risk to the potential future scientific exploitation of the telescope. Nonetheless, since the project design and cost was based on the smallest building that could accommodate the telescope; the inevitable consequence of a longer telescope was a larger, and more expensive, building.

The provision of the chopping secondary itself would take a while to resolve, but the issue was solved by an agreement that an f/35 chopping secondary would be bought from the instrumentation, rather than the telescope, budget. The size of the secondary mirror was also debated at some length. An undersized secondary prevents thermal emission from the telescope structure being seen by the infrared instruments but is of little value to optical astronomers for whom it simply wastes some of the light garnered by the main mirror. Bob Joseph, an American astronomer then working in London, is *'fairly certain the initial specification did not include an undersized secondary, because I remember rather extensive discussions with Jim Ring about this. He really thought of the telescope as a flux collector, rather than an optimized infrared telescope... It took some extensive pressure to get him to relent and accept an undersized secondary mirror'.*

As early as the first steering committee meeting it seems that attempts were already being made to talk up the idea of improving the mirror performance from the bare minimum needed for a flux collector. After the meeting, which he had been unable to attend, Roger Griffin wrote a letter to Jim Ring supporting the idea, already floated by others, of improving the mirror specification. He wrote *'It seems to me that every slight improvement that may be made in the figure will bring benefits in the way of improved potency of the telescope'* although he recognised that such an improvement might make the telescope *'too attractive to optical people who might then offer significant competition for observing time'.* Jim Ring replied supporting the idea of going for the best possible image specification provided that it was done within the other constraints. He went on to note that the only reason they could build a 150 inch (3.8 m) telescope for just over £1,000,000 was because they had relaxed the image specification somewhat. There was, he said, *'little point in polishing the mirror to a better figure than its support will allow or than the drive accuracy will allow us to use'.* In about August 1974 the agreed 3.8 m IRFC performance specification was sent to companies who might wish to tender for the contract.

The proposed optical and mechanical design was based on those primary mirror blanks that were immediately available at a reasonable cost. A Zerodur blank could not be available before May 1976 but Owens-Illinois had a 3.8 m CER-VIT blank in stock. This blank had been cracked but it was sawn in half to produce the very thin mirror demanded by the flux collector design. After that dramatic piece of surgery it weighed about 7 tonnes, about one third the weight of a traditional mirror of that size. Grubb Parsons of Newcastle upon Tyne were selected to grind and polish the optics on the basis of their recent experience producing the mirrors for the Anglo-Australian Telescope. Grubb Parsons were unsure of how accurately such a thin mirror could be figured, but in view of the recommendations of the steering committee, the contract contained a provision for continuing to figure the primary mirror if testing indicated that it was possible to reach a higher specification. If such further polishing were to prove feasible, then a price for any improvement could be agreed.

Preparing the Mirror

Once the mirror blank had been delivered to Grubb Parsons in 1975, polishing operations began with the provision of an 80-pad axial support system, cutting out the 1 m diameter central hole and the grinding of the inner cylindrical edge surface around the hole. Next came grinding the cylindrical edge surface around the outer diameter and the grinding and figuring of the top surface of the mirror. Grubb Parsons also cemented three radial defining Invar pads in the inner bore of the mirror and 24 Invar pads around the outer diameter to provide contact with the counterweighted outer radial lever arms of the mirror cell. For the required paraboloidal shape to be reached, the volume of CER-VIT glass that had to be removed by grinding the top surface of the originally flat disc resulted in a depression nearly 10 cm deep at the centre of the mirror. The figuring of the primary mirror required the manufacture of supports for the polishing laps, which were attached to a programmable rotating mechanical drive, fitting the laps with new pitch surfaces for each polishing stage, and then operating the system with progressively finer abrasive material as the process continued. Each figuring cycle took 2–3 days after which the mirror was washed, dried and then moved across the floor of the optical shop to a test tower where the surface profile was measured. That was done by Hartmann (knife-edge) measurements at the mirror's centre of curvature, some 19 m above the mirror, and also by shearing interferometry so that the optical performance at each polishing stage could be evaluated. The total time between each testing cycle was 7–10 days, including the time that it took to analyse the optical test measurements. Before each new polishing cycle began the entire surface was carefully inspected to determine whether there were any air bubbles near the surface that would be penetrated by the next polishing stage. If any such bubbles were found they were drilled out to prevent tiny shards of glass from the broken bubble being dragged round by the polishing laps and scratching the polished surface.

The work on the mirror was performed in the optical polishing workshop of Grubb Parsons where, by a strange coincidence, the foreman was named Jim Ring. Normally the figuring operations were done during the working day and then stopped overnight before restarting the following morning. One night a fluorescent lamp high in the roof of the workshop, and immediately above the mirror, disintegrated and when the staff arrived in the morning the shattered remains of the 1.5 m fluorescent tube were lying on the mirror surface. Fortunately, the damage to the mirror was negligible; there was only one very small scratch on the surface where the largest fragment of the tube had impacted. To prevent any recurrence of this potentially disastrous accident all of the fluorescent lighting tubes in the optical workshop were covered with fine mesh screens.

In addition to figuring the telescope primary mirror, Grubb Parsons was also responsible for providing a 1 m diameter f/9 secondary mirror and a flat mirror for a coudé focus.

Building the Telescope

The firm of Dunford Hadfields of Sheffield was chosen as the contractor for the telescope structure and its drives, all of which had to be designed to survive the effects of the frequent earth tremors expected on a volcanic island. The industrial project team included: Des Hickenson (Project Manager), Alan Deeley (design and production of control system hardware), Alex Gaymond (mechanical engineering), and Les Wilson (mechanical engineering). Design engineering was the responsibility of consultant Denis Walshaw. The telescope mounting was an English yoke type, with two columns carrying the north and south bearings resting on concrete piers extending down into the cinder cone on which the telescope would be built. The 20 tonnes, 12.2 m $\times$ 6.7 m, rectangular yoke that carried the telescope's open-tube framework was constructed as a welded steel box section that rotated about the polar axis which, at the latitude of Hawaii, would point at an angle of approximately 20° above the horizontal.

Fig. 2.1 This model of the telescope features a cut-out photograph of Alex McLachlan which was pasted onto an original picture and then re-photographed. The picture appears in the 1974/75 ROE annual report

A consequence of the decision to use an English yoke mounting was that the telescope would be unable to point further north than about 60° declination because the northern pier would prevent the tube being moved low enough to see the polar regions. The northern limit would make it impossible to observe a number of interesting astronomical objects, but it was considered an acceptable penalty of opting for the cheapest possible telescope. Learning lessons from the IRFC in Tenerife, the declination bearings of the new telescope were designed to be stiffer than those of its predecessor to reduce shaking by the wind, but that effort would turn out to be only partially successful. The radial bearings for the rotational axis were supported by the two steel columns, the feet of which were tied by a braced under-frame. The gravitational load of the whole assembly, some 80 tonnes, was taken by a set of three ball bearing races resting on the concrete piers under each of the support columns. The telescope framework (a Serrurier truss system) carrying the primary mirror cell and the secondary top-end unit rotated within the yoke about the declination axis radial bearings.

Altitude Worries

Even before either project had been approved, the protagonists of both the 3.8 m IRFC and the NHO were aware that a location on Mauna Kea would expose both staff and visitors to the challenges of working at high altitude, and that the risks needed to be fully understood before any decisions were made. So in October 1973 Gordon Carpenter, Professor Roderick Redman from Cambridge, who sat on the NHO Planning Committee, John Pope, a telescope engineer from the Royal Greenwich Observatory in Sussex, and John Hutchinson from the SRC visited the Royal Aircraft Establishment (RAE) at Farnborough.

The RAE, then the centre of the UK's aviation research expertise, had considerable experience of the effects of altitude on pilots and so was an obvious place to look for advice. The report of the visit includes discussions regarding the need for oxygen masks and introduced an interesting non-SI unit indicating that the effect of altitude is roughly equivalent to alcohol and that 'A man coming up to 14,000 ft from sea level would be 1–2 Martinis down'. The conclusion seems to have been that a 3-day period at an intermediate mid-level facility would be needed for acclimatisation and this conclusion was transmitted to the steering committee. However, Roger Griffin argued for a bedroom to be included in the building design since he felt that the proposed mid-level accommodation at a place known locally as Hale Pohaku (altitude 9200 ft, (2800 m)) was too low for it to be a suitable place to acclimatise. He also wrote a paper to the Northern Hemisphere Observatory Planning Committee in which he advocated building the residence for astronomers on the summit itself and allowing a two-night acclimatisation period.

Griffin had actual experience of the situation in Hawaii; he had hiked up the nearby mountain of Mauna Loa half a dozen times, staying for about a week or so in a National Park Service hut on the summit. He discovered that although he certainly felt the altitude upon arrival, the effect wore off altogether after 3 or 4 days. To prove the point on one occasion he took a picture of himself (with the self-timer on his camera) standing on his hands next to a notice indicating an altitude of 13,000 ft. He '*had 8 seconds to get stabilized in a handstand after pressing the button, and I did it at the first try! But when I showed the picture to someone, he thought it proved the reverse of what I thought it did!*' The whole issue would surface again a few years later when construction and commissioning of the telescope was set to begin.

The Long Road to a Lease

Despite the enthusiasm of John Jefferies and the IfA for building telescopes, the summit of Mauna Kea was a state conservation district so before any commitment could be made to construction work it was necessary for the Institute for Astronomy to provide an Environmental Impact Statement on the likely effect of the present and planned facilities. Jefferies was aware of the potential delays that this might engender and in late November of 1974 he had met with the Governor of the State of Hawaii who had provided assurances of support from himself and most of his cabinet for astronomical development on Mauna Kea. Nonetheless, an impact statement was required and one was duly drafted in the spring of 1975. While noting the potential visual impact on the landscape and various related issues such as effects on the dirt road, soil, drainage etc, it concluded that the negative effects of both the UK Flux Collector and a similarly-sized NASA telescope, the InfraRed Telescope Facility (IRTF) would not be serious. More encouragingly, it also remarked that the socio-economic impacts (basically money and employment coming into the state) would be positive and long-term, if only "moderate". Permits for both the UK telescope and the IRTF were approved on the 29th of August 1975 and by October a sub-lease agreement between SRC and the University of Hawaii was in preparation. In it the SRC committed to design, gain approval for and then fabricate the telescope and its building on the summit. It further committed to paying a, still to be negotiated, share of the building and operational costs of new mid-level facilities to be built at Hale Pohaku and a share of the cost of maintaining the road from Hale Pohaku to the summit. The new mid-level facilities were to include a complex of office, laboratory and apartment buildings within which five apartments and two townhouses plus two laboratories were to be set aside for the use of the SRC. Until such facilities were built, SRC was empowered to build its own temporary structures for its contractors and staff. In return for its 15 % of observing time the University of Hawaii agreed to provide an access road, electrical power up to a maximum of 75 kW and a telephone connection to the Hawaiian telephone company network.

In fact, finalising the lease and some associated documents concerning the commitments on both sides took quite a long time. SRC were anxious to proceed with the project and did not want the whole process held up by detailed negotiations over the proposed facilities at mid-level which although "promised" by John