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APPLETON LABORATORY
NEWSLETTER

No. 170 July 1975

SATELLITE DATA PROCESSING AND CONTROL AT THE APPLETON LABORATORY

Part I

Satellite data processing began at the Appleton Laboratory in March 1964 following the launch of the second British Scientific Satellite, Ariel 2. For the first British satellite, which was launched about 3 years earlier, all the data reduction prior to passing data tapes onto the experimenters was carried out at the Goddard Space Flight Center in Washington.

Our early involvement consisted of using hardware to convert satellite telemetry, recorded in analogue form, into digital form and at the same time to produce chart records of the experiment data. The digital data tapes were passed on to AWRE at Aldermaston where they were further processed on STRETCH and then distributed to the experimenters for final scientific analysis.

A similar system was used for Ariel 3 which was launched about 3 years later, but for this project the computer processing was split into 2 parts, the first of which was carried out at AWRE on STRETCH and the second on ATLAS at Chilton. Data tapes were then made available to the experimenters, many of whom carried out their final processing on ATLAS. By the time that Ariel 4 was being planned, an ICL 1905 computer had been installed at our own Laboratory. Also both STRETCH and ATLAS were coming to the end of their working lives and the ATLAS Laboratory were planning to take delivery of the 1906A. For this satellite therefore the computer processing was split between ourselves and the ATLAS Laboratory and was all carried out on ICL 1900 series machines.

Ariel 4 was launched in December 1971. Its objectives were to carry out research into wave-particle interactions in the ionosphere. It carried 4 experiments, one from Birmingham University, one from Sheffield University, a joint experiment from Jodrell Bank and our own Laboratory, and one experiment from the University of Iowa. The satellite was built at the British Aircraft Corporation at Bristol and the project managed by the SRC's Space Management Unit which was at that time situated in London but was later to come to Slough as one of our Space Divisions. Considerably more attention was paid to the data processing for this project than had been the case with the previous Ariel satellites and the following system was designed. In the operational stage, data were collected from several

ground stations in the NASA STDN network; these data were later sent to Slough. At Slough the data which were recorded on magnetic tape in analogue form were first converted to computer compatible form, and at this stage 'quick look' charts and listings were produced so that the experimenters could check that their experiments were functioning correctly. The data were then thoroughly checked on the Appleton Laboratory's 1904A computer and sorted into chronological order. The output tapes from this process were then despatched to the Atlas Computer Laboratory, where they were merged with orbital data produced from the RAE computer and attitude data from RRE Malvern. At this stage of the processing the raw data was converted into meaningful scientific units, a certain amount of processing carried out and Master Tapes containing all the processed data were produced for further analysis by the experimenters. Most of this processing for the British experiments was also carried out at the Atlas Laboratory.

Apart from the 'quick look' charts there was no demand for 'real-time' data processing and a typical time for the data to pass from the satellite to the experimenters was about 6 months.

There was a small control requirement for the Ariel 4 project. This was for two reasons. Firstly to switch the experiments on and off and secondly to control the pointing direction of the spin axis of the satellite. The latter requirement was needed by the Iowa experiment: it was handled by means of a magnetic torquing system which consisted of a coil attached to the four paddles of the satellite, with its axis aligned parallel to the satellite spin axis. Using a fairly simple approach it was usually possible to point the satellite spin axis to within 5^{o} of a required direction.

The total amount of data processed for the Ariel 4 project filled more than 500 Master Tapes: that is to say more than 250 miles of magnetic tape.

The programs needed for handling Ariel 4 were not complicated in the sense that they required any advanced software concepts, but they were large and they had to operate on a great deal of data and so great attention was paid to run time efficiency. In fact the final package that became operational at the Appleton Laboratory was a factor of 10 times faster than the similar system run on STRETCH for the Ariel 3 satellite. The ATLAS package was about 3 times larger than the Slough package and included a substantial amount of preliminary experimenter's analysis. By the time that the satellite was launched the Slough 1905 computer had been replaced by a 1904A, and all the software at both Laboratories thus made use of the GEORGE 3 operating system, which we have always found very pleasant to use.

The next satellite in the Ariel series, Ariel 5, was launched in October last year. It was evident at an early stage that the data processing and operational requirements of this satellite were very different from those of all previous Ariel satellites, and that a completely new philosophy would have to be adopted. The objective of the satellite was to carry out research in X-ray astronomy, the prime objective being to make detailed studies of the known X-ray sources which were discovered and catalogued by the American satellite UHURU which was the only previous satellite to carry out research in this field.

UHURU was launched in December 1970. It was equipped with X-ray proportional counter detectors covering the range 2-20 keV. The spacecraft was spin stabilised

and as it spun the detectors scanned a 5^{o} strip of the celestial sphere. It was, and still is manoeuvred by a magnetic torquing system and it has now carried out a complete sky survey, but with a limited and somewhat variable sensitivity.

Ariel 5 is also spin stabilised, but it has a propane gas system for manoeuvring the spacecraft spin axis. The ability to point the spin axis at will is made use of directly by four of the on-board experiments. These experiments have been given letter designations A, C, D, F. Experiment A, built at the Mullard Space Science Laboratory, is designed to measure source positions accurately. Experiments C, D and F from MSSL, Leicester University and Imperial College respectively, are designed to measure source spectra.

Ariel 5 also has two scanning experiments, B and G. Experiment B is another Leicester University experiment and looks at a strip of the celestial sphere 15^{o} wide around the equator of the spacecraft. This experiment is designed to carry out a survey of the celestial sphere and final sources which may warrant a more detailed look by the four pointing experiments. Experiment G was provided by the Goddard Space Flight Center. It scans the whole celestial sphere and its aim is to detect transient X-ray sources.

It can be seen then that Ariel 5 is a very dynamic satellite and that there are interactions between the pointing and scanning experiments. It was therefore necessary to plan a dynamic data processing and control system to handle the satellite and the experiments, but at the same time it was necessary to keep a strict eye on cost as such systems have a habit of becoming very expensive. We therefore decided that rather than planning a completely dedicated system we would make as much use as possible of the 1904A, which we enhanced with some additional disc and core store. The control centre we built for handling the satellite was then based on three PDP8/I computers, but the two largest machines were second-hand in that they were originally bought by Marconi, the spacecraft manufacturers, for prelaunch checkout of the satellite.

There were four clearly defined tasks that the control centre had to be capable of carrying out. These were :-

1. The joint planning and execution of the experimenters' observing programme.

2. The collection and processing of 'live' data from the satellite and the transmission of these data to the experimenters as quickly as possible.

3. The collection and processing of 'bulk' data from the satellite and the transmission of these results to the experimenters within 48 hours or less of the data leaving the satellite.

4. The control of the experiments, the control of the satellite attitude and the monitoring of the health of the experiments and the satellite.

The observing programme is the name given to the plan concerning where to look in the sky at any given time. It has three modes of operation. Firstly,

there is a rough plan which defines where the satellite will be pointed during the next 6 months, then there is a tighter plan which defines where the satellite will be pointed on a day to day basis during the next 4 weeks. Finally, there is a very short term mode of operation whereby immediate plans can be changed as a result of information that comes to light due to the rapid analysis of experiment data.

The input to these plans comes from information provided by the experimenters. The plans themselves are output by a set of computer programs which have to take into account several constraints.

The prime constraint is that gas utilisation should be minimised. The initial quantity of gas available for manoeuvring was 10 lb; sufficient for 4500^{o} of manoeuvre. For a 1-2 year active life of the satellite this allowed for a possible expenditure of 6^{o}-12^{o} per day. There is a sun constraint due to the fact that the solar cells on the satellite can only generate sufficient power to maintain the spacecraft functioning correctly provided that the angle between the spin axis and the direction of the sun from the satellite is greater than 50^{o}. Another major constraint is due to the fact that observing time can be lost if the area of the sky in the spin axis direction is occulted by the earth. These are the three major constraints, but there are several minor ones. The observing programme software produces 6 month and 4 week plans, given a list of source positions by the scientists, which minimises the effects of all the constraints, in addition there is the possibility of changing plans in the event of major discoveries. There have already been several instances of plans being changed. The first occurred when a fault was discovered in the Leicester scanning experiment. The observing programme was altered so that maximum use could be made of that experiment before it ceased to function. The discovery of CENXMAS also caused a change in the observing programme. Figure 1 shows where the satellite was pointing for the first 3 months after launch.

The observing programme is an off-line activity, but if we now look at the control centre configuration we can discuss the other three main activities of the control centre.

If we consider first a live data pass. The satellite is in a circular equatorial orbit, and our prime ground station is at Quito in South America. As the satellite comes over the horizon, data are relayed from the ground station, via the Goddard Space Flight Center into a PDP8/1 computer which starts to record the data. In addition the data are recorded in analogue mode for back up purposes and at the same time critical spacecraft parameters are carefully checked to see that they lie within laid down safety limits. In addition to real-time telemetry data, the satellite has an on-board core store and this is used to store all the experimenters data collected during an orbit and also certain housekeeping information, in particular the readings from the sun and earth sensors which are used to compute attitude. In the middle of the pass the core store is dumped three times and then real time telemetry transmission is continued. At the end of the pass the data are taken to the 1904A computer for processing. The experimenters' information is sorted into blocks for each experimenter. The attitude is calculated and orbital information is added. The output of these programs is what we call an experimenters master tape. This is returned to the control centre and transmitted to the 4 British universities by means of 1200 kb lines.

The control centre is operational for 14 hours in every 24 and during this time about 7 live passes are received and appended to the same digital tape.

During the night additional passes are received at the ground station and transmitted to Goddard where they are stored. Early the next morning these data are transmitted to Slough and appended to the previous day's live data. It is this tape, containing about 15 passes, that we refer to as the bulk data. Prior to analysing the bulk data we have to update the orbit of the satellite by means of minitrack data that have come into the control centre via the teleprinter on 5 track paper tape. This is fed into the 1904A and the RAE orbit determination program PROP is used to update the orbital elements. The bulk data tape is then processed and as a result of the updated orbit more accurate estimates of satellite attitude are computed. As a result of additional studies carried out since launch we can now calculate the attitude from sensor information to within 0.1° which is 10 times more accurate than the original specification. The processed bulk data is then returned to the control centre where it is transmitted to the universities. The MSSL data are actually sent to the Rutherford Laboratory by courier, as at present we have no means of transmitting data directly into the 370/195, but it is interesting to note that the discovery of the new binary system GENXMAS was made from MSSL bulk data with the aid of the Rutherford computer. This I believe highlights the immense amount of computing power available to this project.

B. R. Martin

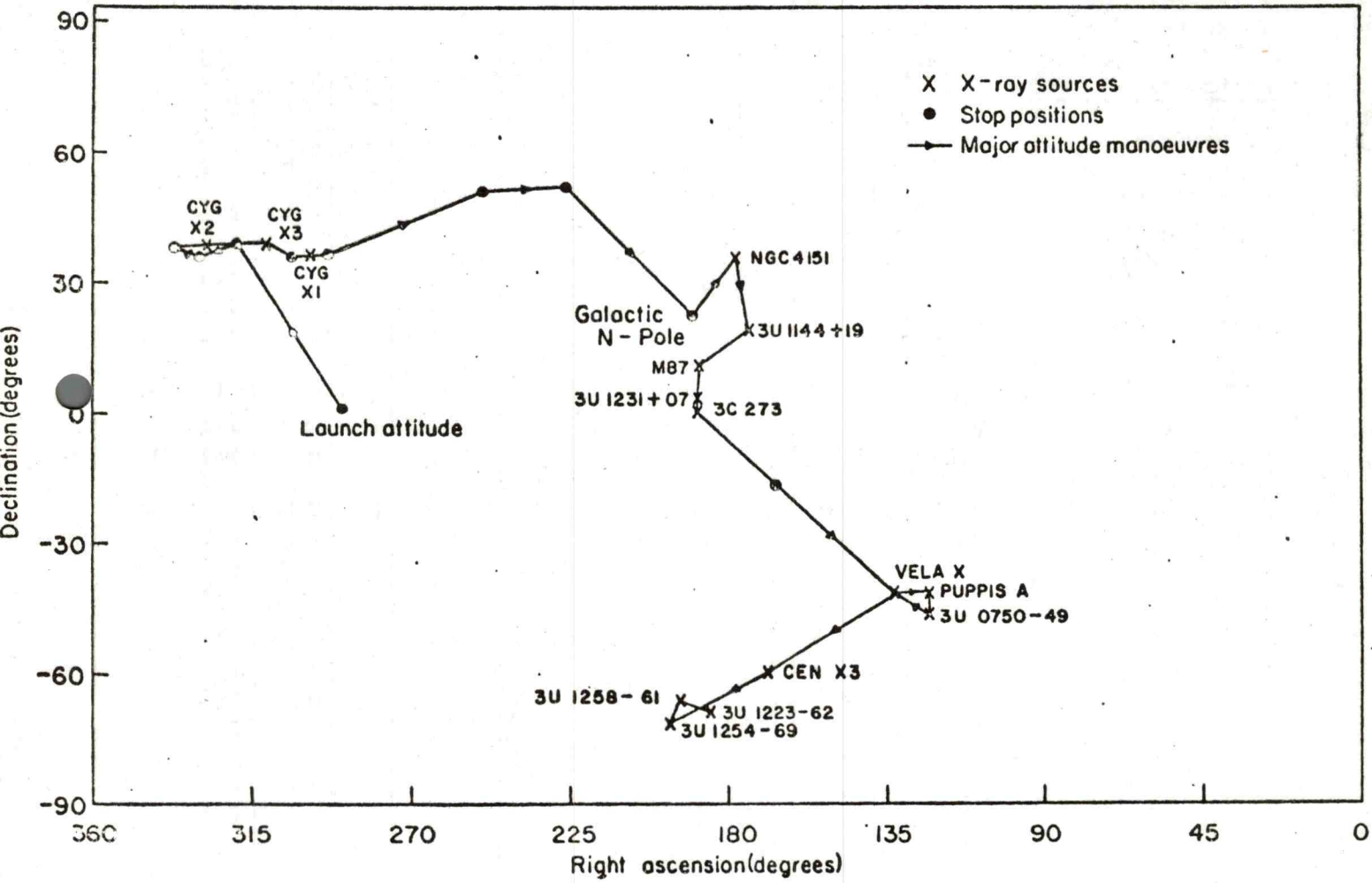


Fig. 1

STAFF NEWS

Congratulations to :

Richard Browning and Janet Hodges, who were married at Addlestone on 14th June.

Elsie and Peter White on the birth of their second son, Cameron on 15th July.

Brian Stewart and Angela Bourke, who were married at St. James Church, Spanish Place, Marylebone on 26th July.

Mrs. B. M. Tamkin now A.S.O.

Mr. T. E. Cooper now P.T.O. IV.

Mr. H. A. Cook now Chargehand

Welcome to :

Miss B. Okolotowicz	S.O.	
A. W. Wild	Dvr.	
Mrs. A. Galpin	S/H Typ. Culham	
J. W. Errington	S. Ex. O.	
D. R. Brazier	Ex. O.	

Resignations, etc.

Z. Warhaft	S.S.O.	
M. A. Stuart	A.S.O.	
T. N. Adams	Craft. I	
D. E. Cam	Craft. I	
Mrs. P. Rhind	Per. Sec.	Returned to UKAEA after period of secondment at Culham
P. L. Davies	S.C.S.	

Other changes :

D. B. Shenton	S.P.S.O.	Transferred from Division Head (Divn. 7) to Special duties in connection with SRC mm-wave astronomy facility.
A. H. Gabriel	S.P.S.O. (SM)	Appointed Acting Head of Division 7.

Participation in the URSI General Assembly

at Lima

The 18th General Assembly of U.R.S.I. is to be held in Lima, Peru, from August 11th to 19th. The Director has been asked by the Royal Society to be leader of the U.K. Delegation, which will also include the Deputy Director, Dr. J. W. King (Vice-Chairman U.R.S.I. Commission III) and Dr. L. Thomas.

SPORTS & SOCIAL CLUB NEWS

By a combination of foresight and careful planning your Committee managed to choose the first rainy Saturday for six weeks on which to hold the Bar-B-Q. However, undeterred by showers the connoisseurs of "Bangers and Beans" cheerfully turned out for the 74/75 tasting. On this occasion we welcomed foreign experts from France and Spain who, although more used to tasting the "Grape" were prepared to enter into the spirit of our festival.

After partaking of the solid vintage the many liquid varieties were sampled in abundance. Dancing followed and with the passing of the rain the less energetic and those suffering from indigestion were able to take the air. After a liberal sprinkling of meths the campfire roared to life to provide romantic light for groups of small talkers and singed eyebrows for the less cautious.

Rick Street

SPORTS DAY

We came, we saw and we were saved from total failure by the Chess and the Tug-of-war. Still it could have been worse, after all, it might have rained. But everybody tried hard and in the tennis, bowls and football we came very close and everybody enjoyed themselves and things, so thats alright then.

You know it's not in the field that we shine, it's those other little things that we do so well. Frank Bennet slaughtered them in the First Aid, with Daresbury coming a very poor last, and Les Mitchell easily won the Amateur Radio. The Disco provided another win for Mark 'Music' Witney, despite strong competition from the person who provided our most decisive victory, in the bar. Our one man team carried all (and on) before him.

So do not despair there is always next year, and it was such a nice day and we know we would have won more if we had really wanted. Congratulations to the Brains and the Brawn for our two wins and thank you very much to our 'volunteers' for the first aid and disco and to everybody for taking part and watching and things.

Alan Buck

CHESS

This year's chess competition was once again organised on a teams-of-three basis, each player being allowed a total of ten minutes for his moves. Of the eight teams that took part three were from Appleton and all were human.

Encouraged, no doubt, by the (very remote) possibility of being invited to play, under similar rules, on BBC2's Master Game programme, the A team, with six wins and one draw from their seven matches, won the event, just ahead of Rutherford A. Individual scores (out of seven) were: Eric Bramley 6½, Dudley Long 6 and Rodney Buckland 5. Our other teams finished in the middle of the final table, the B team scoring 3½ match points and the C team 2½. The most successful members of these teams were Paul Dickinson and David Willis, who both scored 4½ points.

D. H. Long

CRICKET CLUB

We seem fated not to win the SRC cricket cup. With two pulled muscles the day before and two during the day itself, a depleted team went out in the semi-final to Rutherford, the eventual winners. However, this apart, we are enjoying a most successful season to date, having won 16 of the 22 matches played so far.

The results of the last ten matches are summarised below:

25 June v De la Rue (WON)

De la Rue 77-4	Appleton 80-5
	Porter 21
	Paterson 19 N.O.

26 June v Lillie Research (WON)

Lillie Research 71-8	Appleton 72-2
	Hassan 32 N.O.
	Sandal 28

29 June v Phoenix (WON)

Phoenix 61	Appleton 62-4
Bevan 4-15	Paterson 20 N.O.

1 July v William Glyns (WON)

William Glyns 89-8	Appleton 90-4
	Hassan 45 N.O.

2 July v Burton Biscuits (WON)

Appleton 156-4	Burton Biscuits 92-7
Martin 83	

Sports day 3 July

v Atlas (WON)

Atlas 73-6	Appleton 76-0
	Paterson 46 N.O.
	Porter 24 N.O.

v Rutherford (LOST)

Appleton 76-6	Rutherford 77-2
Porter 24	

9 July v British Aluminium (WON)

British Aluminium	78-9	Appleton	82-1
Ambrose	4-29	Porter	36 N.O.
		Kitt	26

12 July v Wargrave II (WON)

Wargrave II	77	Appleton	78-1
Paterson	4-25	Sandal	43 N.O.
		Hayes	22 N.O.

16 July v Lillie Research (WON)

Lillie Research	70-8	Appleton	74-1
		Kitt	51 N.O.

17 July v Royal Holloway (LOST)

Royal Holloway	114-5	Appleton	86-9
Bevan	4-14	Rodger	19
		Whitlock	18

23 July v Eton C.C. (WON)

Appleton	102-7	Eton	78-7
Carter	64	Kitt	2-4

S.R.C. TOURNAMENT TENNIS

No Gus, except as a spectator, and no tennis trophies for the first time since the S.R.C. tournament began. But Paul Gardner and Ernie Westbrook came virtually within an ace of winning the men's doubles title by finishing just one game behind the champions and Jack Moore and Joan Scislowski reached the final of the mixed doubles without conceding a set. Once again we were able to provide the maximum number of entries, our other players being Phil Muzlish and Rich Brazier, Dr. and Mrs. Horner, Arthur Roberts and Marie Huggins, Neil Bramley and Wendy Willard and Richard Smith and Marie Bramley. A special mention for Joan, Wendy and Marie who, in their first Chiswick tournament, played splendidly.. In fact Wendy and partner gave the champions thier hardest match and Marie and partner finished second to the champions in their section.

R. W. Smith

NETBALL

The Appleton Netball Team were very happy with their performance this year at Sports Day. Although they were narrowly defeated in all their four matches against Atlas, Daresbury, RGO and Rutherford, they thoroughly enjoyed the games and forced their more experienced opponents to work hard for victory. We gained the distinction of leading Rutherford, the overall winners of the competition, 1-0 at half time, but we couldn't contain them, and they eventually won 6-3.

The Appleton team members: Julie Coombes, Yvonne Dias, Sally Harris, Shelagh Mackinnon, Veronica O'Keefe, Gloris Sandford, Carol Spears, Mary Thrift and Jacky Willmott.

Thanks to our loyal supporters who cheered us on.

S. Mackinnon

FOOTBALL

Due to unprecedented masochism on our part we managed to field three six-a-side teams this year. The competition was organised as three leagues of five teams with the first two from each league and the best two thirds going into the quarter final. The first team managed to get into the best league and did well to come third, thus getting into the quarter final as the best of the thirds. The second team and the third team both came fourth in their respective leagues, the highlight of the third team's performance being a good goal by Glyn Daniels who was playing goalkeeper at the time.

The first team lost the quarter final game 3-2 in a very close game with Rutherford, who eventually reached the final.

Results

Team	Played	Won	Drew	Lost	G.F.	G.A.
1	4	2	1	1	5	2
2	4	1	1	2	3	5
3	4	1	1	2	2	10

Team 1 lost the quarter final 2-3.

Scorers

Team 1 - Dave Collerton (3)
Joe Bains (2)
Dave Stanley (2)

Team 2 - Paul Springate (2)
Phil Newton

Team 3 - Glyn Daniels
Bob Young

Alan Buck

LETTER TO THE OUTSTATIONS

Dear Colleagues,

I do not recollect referring to the new computer buildings at present being grafted on to what were the new buildings of five years ago. I therefore refer.

They progress and are like to add to what must surely already be the longest corridor in any building for miles around. Newly formed, too, is a curious chamber fitted with a raised roof like an inverted baking tin. Herein, I'm told will dwell 'The Plant'.

What Plant? well, that's not quite clear - a mathematical tree possibly, yielding the tasty forbidden fruits of statistical truth, much too good for the lower orders and guarded from them by an inner Priesthood. Thus it will flourish, housed in sumptious surroundings 'neath a painted ceiling whereon is shown a cosmic finger about to digitize a primal abacus.

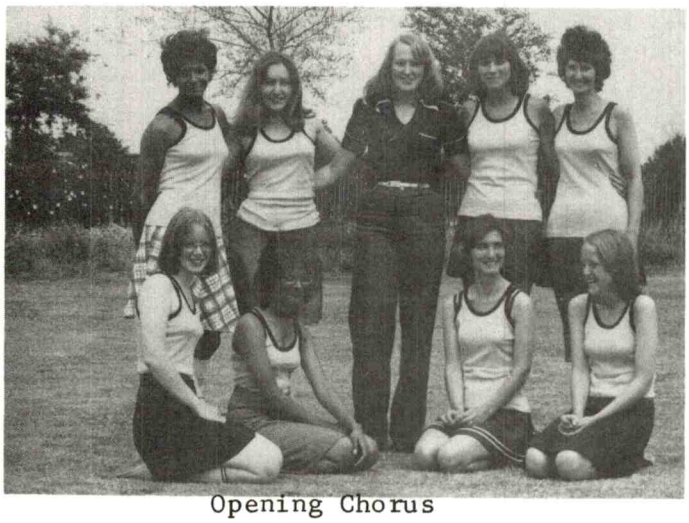
All this is not yet come to pass, yet, if it does, the new age should surely be ushered in with proper ceremony - real Consecration of the House stuff, with appropriate neo-classical trimmings; Minerva springing from the head of Jove supported by a gaggle of irrelevant but ornamental figures, nymphs and suchlike with the odd Satyr or two, all symbolising binary joys.

Further extensive research (well, I spoke to a chap in the corridor) revealed that this odd roof will cover cooling apparatus, not transcendent mysteries. Still, all's not quite lost. Let us substitute gimmick for grandeur and, instead of ordinary louvres, cool the mechanic brain with a vast pith helmet, a tribute to that Empire, now vanished, along with the youth of many of us, including,

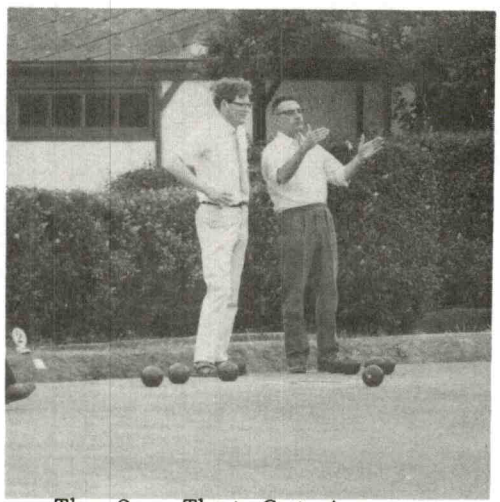
Yours sincerely,

The Editor

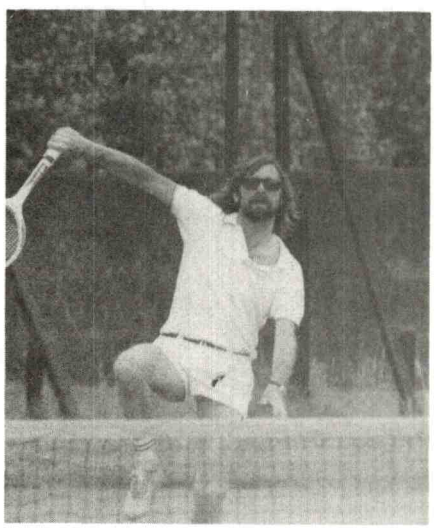
That's Entertainment
- Games & pastimes at Chiswick



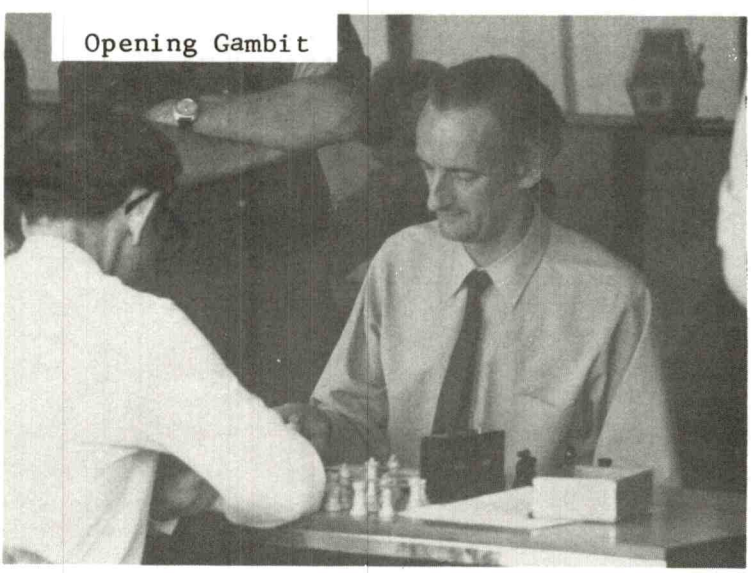
Opening Chorus



The One That Got Away

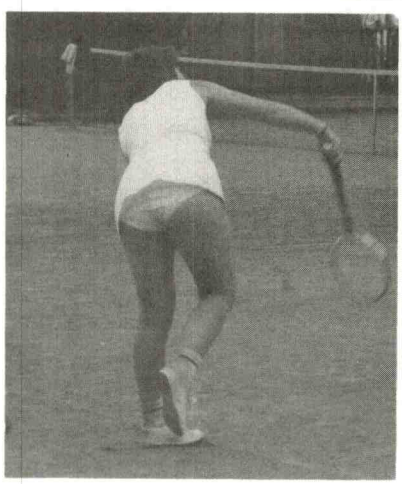


Smash Hit



Opening Gambit

Knight's Move



Endgame

REPRINTS JULY 1975

A.1094	W. C. Bain	Long term periodicities in the sunspot cycle	Nature	1975 p 362 Vol. 254 No. 5498
A.1091	B. N. Harden D. Llewellyn Jones M. Zavody	Investigations of attenuation by rainfall at 110 GHz in south-east England	Proc.IEE	1975 pp 600-604 Vol. 122 No. 6
A.1124	R. Holdaway	Satellite ephemeris prediction and orbit manoeuvrability by low thrust	American Inst. of Aeronautics Inc.	1975 pp 1-8
A.1053	D. A. Bryant M. J. Smith G. M. Courtier	Distant modulation of electron intensity during the expansion phase of an auroral substorm	Planet. Space Sci.	1975 pp 867-878
A.1073	H. Rishbeth	F-region storms and thermospheric circulation	JATP Vol. 37	1975 pp 1055-1064
A.1103	B. C. Fawcett R. D. Cowen	The identification of solar flare Fe XVII to Fe XXIII emission lines from $25^{w}\ 2p^{n}$ - $25^{w}\ 2p^{k+1}$ transitions	Mon. Not. R astro Soc.	1975 pp 1-7 Vol. 171
A.1105	J. W. King E. Hurst A. J. Slater B. Tamkin	Agriculture and Sunspots	Nature	1975 pp 2-3 Vol. 252 No. 5478
A.1128	J. W. King	Sun weather relationships	Astronautics & Aeronautics	April pp 10-19 1975
A.1097	J. W. King	Geomagnetism and the tropospheric circulation	Nature Vol. 252 No. 5482	1974 p 343 and pp 363-371

INTERNAL MEMORANDA

I.M. 371	M. R. Bowman L. Thomas	Seasonal Variations of Oxygen and Hydrogen Constituents in the Mesosphere and Lower Thermosphere