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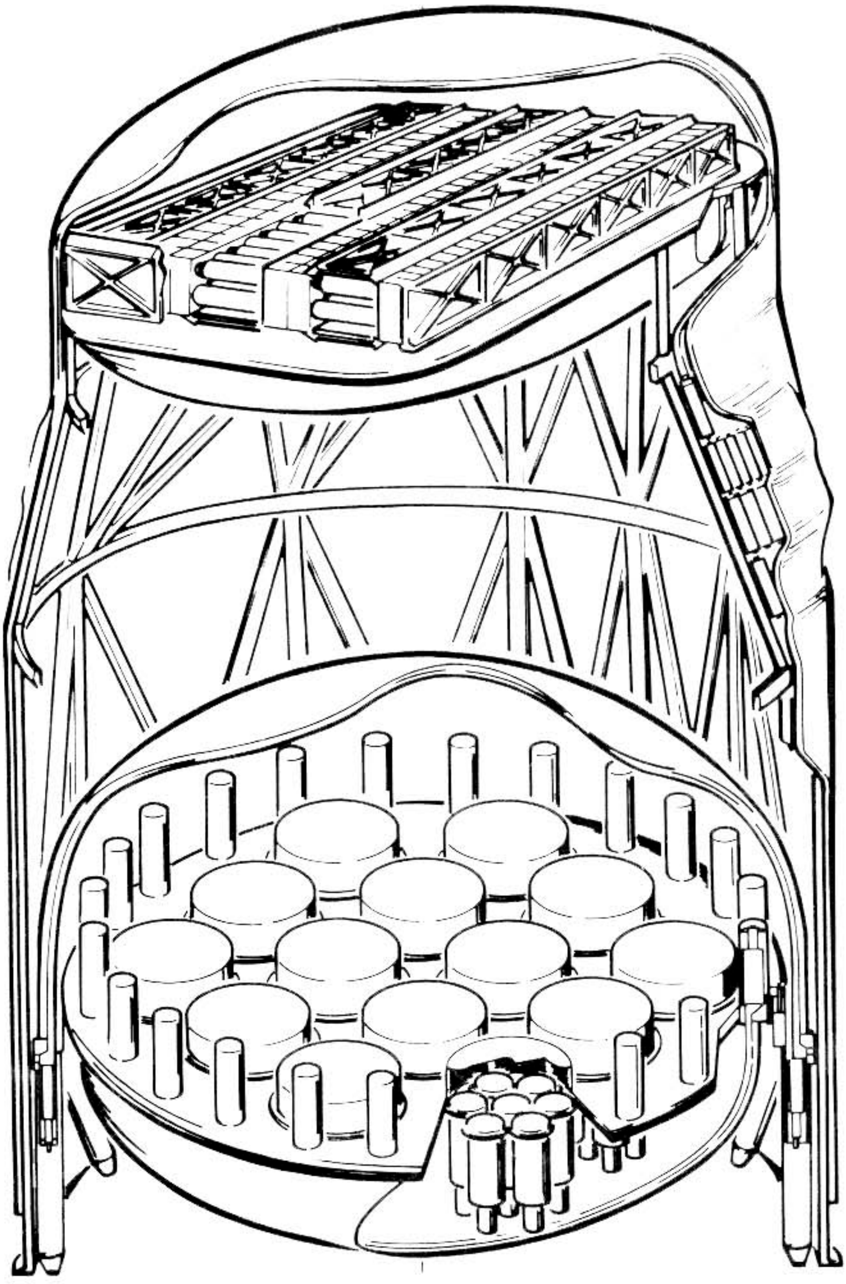
MEASUREMENT OF 1-30 MEV CELESTIAL GAMMA RAYS WITH AN IMAGING COMPTON TELESCOPE

'COMPTEL'

~1477



PROPOSAL FOR A GRO-EXPERIMENT

MANAGEMENT PLAN

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FÜR EXTRATERRESTRISCHE PHYSIK, GARCHING

COSMIC RAY WORKING GROUP, UNIVERSITY OF LEIDEN

SPACE SCIENCE CENTER, UNIVERSITY OF NEW HAMPSHIRE

SPACE SCIENCE DEPARTMENT OF ESA

Measurement of 1-30 MeV Celestial Gamma Rays with an Imaging Compton Telescope
"Comptel"

Proposal for a GRO-Experiment

Management Plan

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1. Introduction

This proposal in response to AO-OSS-3-77, to fly an Imaging Compton Telescope to measure 1-30 MeV Celestial Gamma Rays on the Gamma Ray Observatory is submitted jointly by:

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The management and execution of the programme is based on and will closely follow that successfully implemented by the Caravane Collaboration (of which three of the four institutes here are members) for the ESA COS-B gamma-ray astronomy satellite.

Each institute will contribute to the design of the overall configuration and participate in instrument calibration and data analysis. The instrument is divided into four well defined work packages each being the specific responsibility of a single group.

All institutes have amassed a wealth of experience in space research, particularly in high-energy astrophysics with the development of rocket, balloon and spacecraft borne instrumentation comparable in complexity to that proposed here either individially or in international collaborations.

2. Management Structure

The management structure and deployment of principal staff are shown schematically in Figure 1. The single point contact with NASA will be the principal investigator (PI). V. Schönfelder of MPI who, vis à vis NASA, will be responsible for the total programme including scientific goals, engineering, programmatics and data reduction and analysis.

The PI will be assisted by three Co-PI^{S}: B.N. Swanenburg of CRWG, J.A. Lockwood of UNH and B.G. Taylor of SSD. These four, with the PI as Chairman, will comprise the Steering Committee and will be responsible for all policy decisions affecting the collaboration and will co-ordinate the scientific objectives and ensure the proper engineering implementation of these objectives and the timely execution of the programme.

Within each institute, one of the co-investigators will take on the rôle of experiment manager (EM) responsible for the day to day execution of the programme for the timely provision of the hardware, for which the institute has been charged, in accordance with the scientific goals and engineering requirements.

In each institute one of the co-investigators will take on the rôle of experiment scientist (ES) responsible for keeping the scientific goals and instrument performance under review and in particular for the preparation of all data reduction and analysis tasks of the programme and calibration.

Separate boxes in Figure 1 indicate the areas of responsibility, but naturally there will be a very close liaison between the PI, EM and ES within each institute.

The PI will be assisted by an experiment co-ordinator (EC) responsible for overall programme co-ordination and charged with the tasks of issuing all necessary documentation, exercising configuration control, monitoring programme schedule and providing data management. The EC rôle will be taken on by the DFVLR-BPT in Bonn.

The EC and EM will constitute the Technical Management Group under the Chairmanship of the EC and will concern itself primarily with engineering implementation, particularly with regard to interfaces, integration, environmental testing and schedule.

The experiment scientists will form the Data Reduction Group, for the co-ordination of data reduction and analysis tasks and experiment calibration. Each institute will be responsible for distinct software packages (not necessarily directly associated with the hardware tasks) with the overall co-ordination responsibility resting with the ES of MPI. The scientific results will be published jointly.

At each institute, adequate manpower to support the planned programme (and to cover emergencies) is available in the form of scientists, engineers, technicians, programmers, contract officers and project controllers. An indication of direct support is given in Figure 1, together with the percentages of the time that the key personnel are expected to be available for the programme.

3. Responsibilities for Instrument Acquisition

The Imaging Compton Telescope has been broken down, as shown in Figure 2, into autonomous hardware elements each having well identified functions and interfaces and each element being the prime responsibility of one of the collaborating institutes.

Each institute is responsible for the design, development, fabrication, testing, checkout and calibration of that element assigned to it. Associated with each element is the necessary Ground Support Equipment, both electrical and mechanical, to support the programme.

→ EGSE, MGSE

MPI is responsible for the integration and testing of the complete instrument and will lead the calibration effort.

The clear division and allocation of the tasks of the programme has been made among the collaborating institutes in accordance with the projected availability of financial and manpower resources over the timescale of the hardware development and in accordance with expertise. Some of the work will be undertaken "in-house" at the institutes premises but the majority will be contracted to industry in accordance with the rules and procedures of the responsible institute.

4. Data Management

4.1 Software Development

The scheme outlined below leans heavily on the experience of the Caravane Collaboration in developing software for the COS-B experiment and implementing it in the operational environment. It is considered essential that software development proceeds, in parallel with the development of the hardware, so that the programs which will be used to analyse flight data will also be available for analysis of pre-launch calibration data.

The Data Reduction Group will carry out a full system analysis, incorporating:

- identification of all data to be processed, including data from sources external to the experiment which are needed to complete the analysis (e.g. time, spacecraft attitude, orbit, position)
- breakdown of the analysis process into separable steps
- definition of interfaces between software packages
- specification of formats for media used to transfer data between process steps (e.g. magnetic tapes)
- consideration of contraints imposed on programs by the need for compatibility with the different computer systems in the various institutes.

Once the analysis is complete, specific packages will be assigned to the different institutes for coding. The programs will be integrated into one system and tested with simulated data or data from laboratory models of the instrumentation.

4.2 Data Analysis

The analysis of experiment data has two objectives: in the first place calibration and verification of the instrument performance, both technically and scientifically; and ultimately derivation of the scientific conclusions of the investigation. These objectives will be carried out over different timescales. Five systems of data reduction are currently foreseen, using appropriate combinations of programs from the basic software systems:

1. Technical checkout of the instrument during qualification and acceptance testing.
2. Assessment of scientific performance during pre-launch calibration.
3. Monitoring of technical performance in orbit.
4. Monitoring of scientific performance in orbit and fast derivation of preliminary results.
5. Complete analysis of flight data.

The first and third of these are considered to be real-time processes while the others require the off-line use of a main-frame computer to a greater or lesser extent.

Three computer systems are immediately recognised to be involved: the checkout computer which forms a part of the experiment electrical ground support equipment, the ground station/control center computer used in flight-data acquisition, and the complex of computers used by the collaboration of experimenters for the final analysis. In addition it may be necessary to adapt the checkout software for use with the satellite EGSE during and after integration of the experiment into the spacecraft.

An overall flowchart of the main analysis processes is shown in Figure 3. The process labelled "pre-launch analysis" represents an adaptation of appropriate parts of the software for flight-data analysis. Checkout and monitoring will consist mainly of monitoring housekeeping data.

Further comment is necessary only in the case of the system numbered 4 above. Experience with COS-B has shown the great value of implementing the major programs for final analysis in a system to which a significant fraction (20-30%) of the data can be made available within a relatively short time (say 24 hours) from acquisition. Preliminarily (predicted) attitude and orbit data are adequate to match the limited statistical accuracy of such samples. The functions of this system are threefold:

- the scientific performance of the experiment is continuously monitored and so can be maintained at an optimum level by appropriate commanding
- significant new discoveries can be rapidly notified to the scientific community (e.g. by means of IAU circulars)
- preliminary conclusions can be taken into account in planning the future observation programme in advance of the availability of the final analysed data.

5. Programme Control

5.1 Specifications and Documentation

On the basis of the scientific objectives and the engineering solution outlined in the proposal, a detailed instrument requirement specification will be drawn up. With this as baseline, the lower level specifications including design, interface, product assurance, testing etc. with associated plans and procedures, will be established.

Configuration management will be exercised by the experiment co-ordinator who will be responsible for maintaining and controlling these basic documents and their revision to account for changes approved through a formal change procedure.

5.2 Technical and Scientific Review

The experiment co-ordinator will receive monthly reports from the experiment managers in relation to the technical development, particularly regarding technical performance as determined by testing. Meetings of the Technical Management Group will take place at regular intervals and as the programme may dictate.

Regular reports will be issued by the co-ordinator of the Data Reduction Group and meetings of the group held accordingly for the development and testing of the data reduction and analysis software.

Internal design reviews involving the participation of at least the functionaries of Figure 1 and encompassing scientific, technical and schedule aspects will be held as indicated in Figure 4.

5.3 Schedule Control

A master network prepared by the experiment co-ordinator and as agreed by all participants will serve as the basic reference for the total programme for schedule control and reporting. Every second week the experiment co-ordinator will receive a telex report from each experiment manager reporting the progress in activities at the institutes in the past two weeks and a projection for the future two weeks. The EC will review the schedule on a two-week basis and will initiate actions for the recovery of any slippage appropriately.

5.4 Reporting to NASA

On the basis of inputs received, principally from the EC and the chairman of the Data Reduction Group, the PI will prepare and forward progress reports to NASA as and when required during the development phase, detailing scientific, technical, software and programmatics with emphasis on deviations from the planned or expected.

6. Schedule

The programme milestones set out in AO no. OSS-3-77 are "tentative selection May 15, 1978", "hardware phase ... begin ... fourth quarter 1978" and "launch of GRO in 1983". In order to make a first approximation to the schedule it has been assumed that the instrument should be delivered for integration with GRO in May 1982, i.e. four years after tentative selection. However, there would appear to be sufficient slack to bring the delivery forward to January 1982 (it being considered that delivery of instruments one year before launch is adequate) thereby meeting a January 1983 launch date.

Should the planned launch date be delayed than the instrument definition and breadboarding activities at the 4 institutes will stretch. A later selection of subcontractorswill maintain the experiment hardware development phase at approximately 36 months.

A schedule bar-chart is set out in Figure 4 encompassing design and development review milestones and the hardware and software parts of the programme. This figure is intended to be self-explanatory but it should be seen in the context of the management proposal as a whole and assumes that:

(i) a single complete instrument will be delivered for flight with one full set of MGSE and EGSE.

(ii) spares will be provided on a sub-unit or module level.

(iii) representative models of the upper and lower detectors will be built and tested during the "instrument definition and breadboarding" and "design and critical breadboarding" activities.

7. General Information

7.1 Biographical Data of Programme Participants

To provide a simple overview of biographical data, Table I has been drawn up. This gives the names of the key personnel, their rôle in and percentage of time available for the programme, the date of their Ph.D. or equivalent and number of relevant publications, their present position in their institute and length of tenure and applicable experience over the last twelve years.

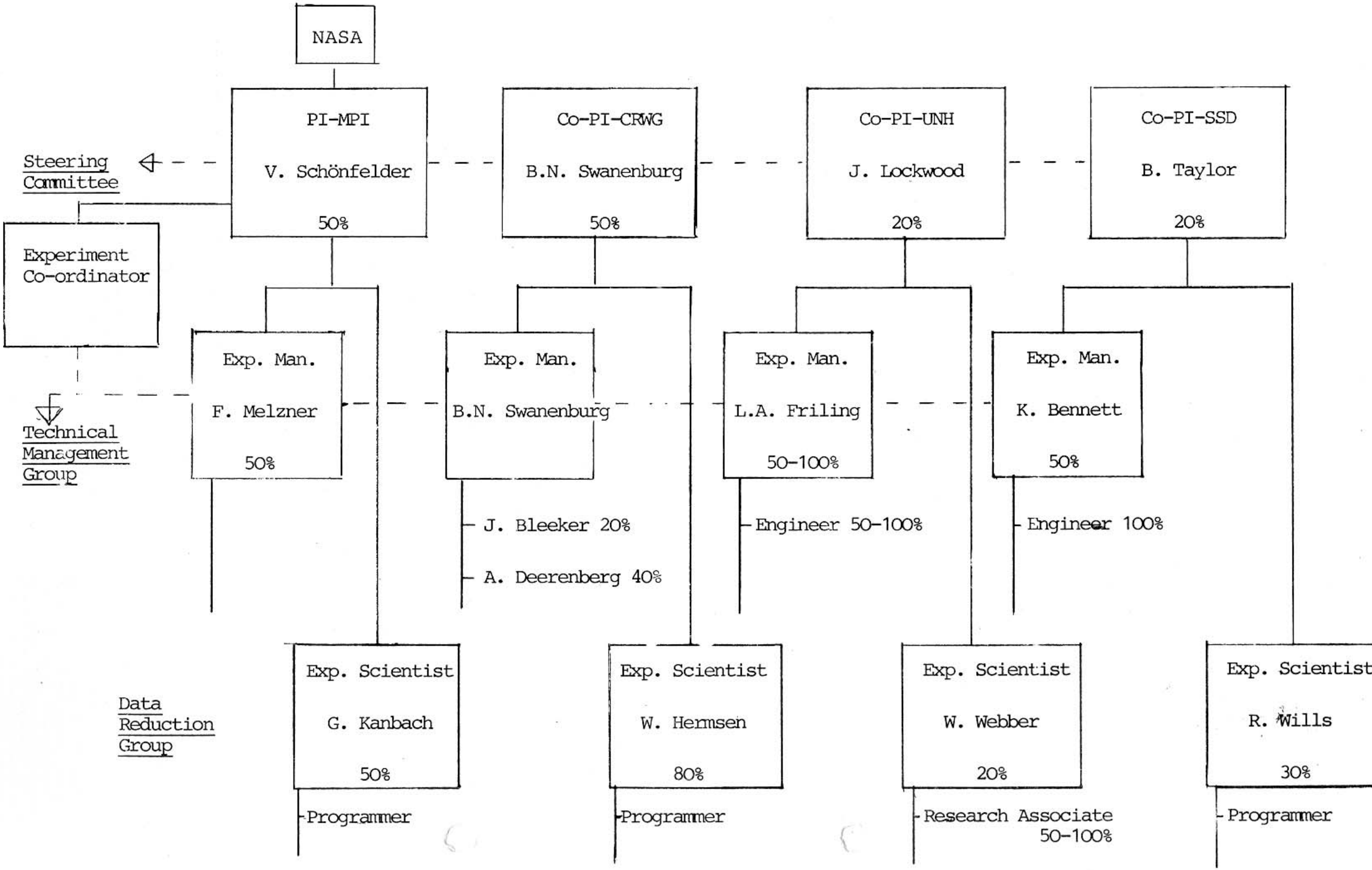
7.2 Experience of Institute in Balloon and Satellite Borne Instrumentation

All four institutes have undertaken the development of instrumentation for space research flown on NASA or ESA spacecraft and have been responsible for the analysis of orbital data. MPI and UNH in particular have experience of balloon borne payloads similar in scale to the instrument proposed here. All are involved in the analysis of data from presently operational satellites and in the development of hardware planned for flight on spacecraft over the next six years. Table II lists the experiments flown by the institutes over the last 12 years.

7.3 General Facilities and Resources

Table III lists the general facilities and resources within the institutes themselves or in close proximity which are available to the collaboration for this programme.

Figure 1. Management Structure and Staff Deployment



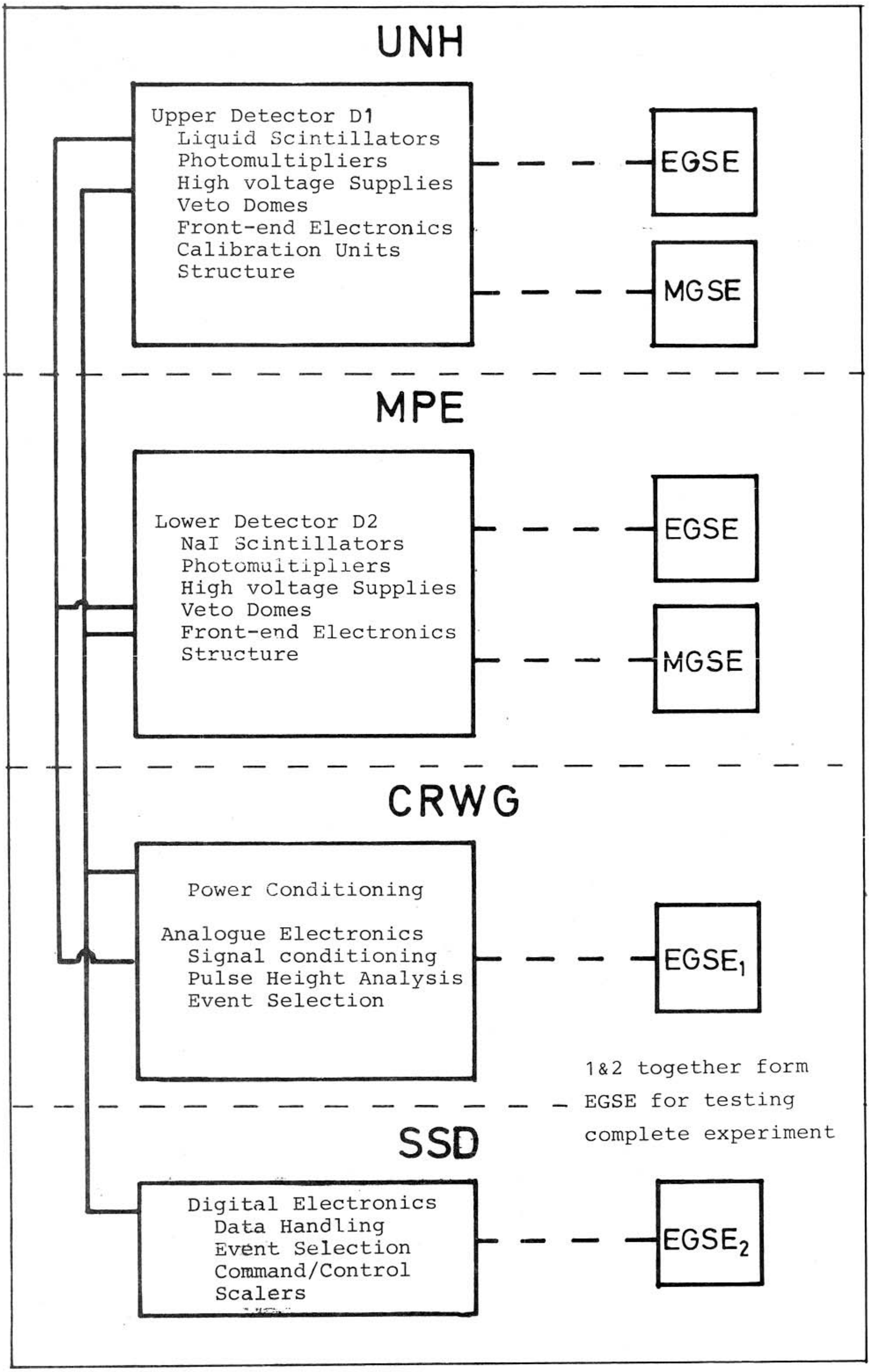


Figure 2. Responsibilities for instrument acquisition

Data Analysis Flow Chart

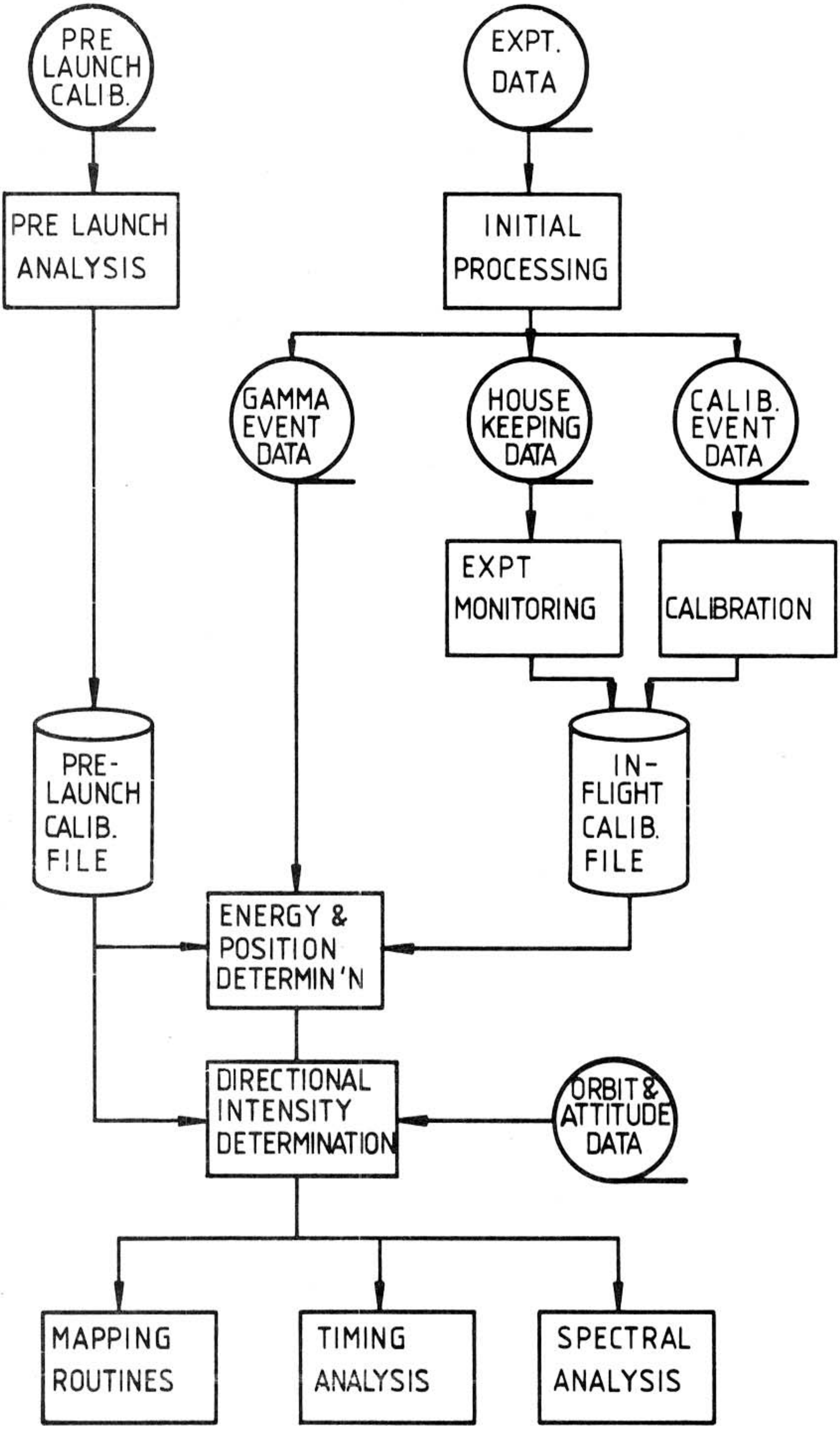


Figure 3

Figure 4: TENTATIVE DEVELOPMENT SCHEDULE IMAGING COMPTON TELESCOPE GRO

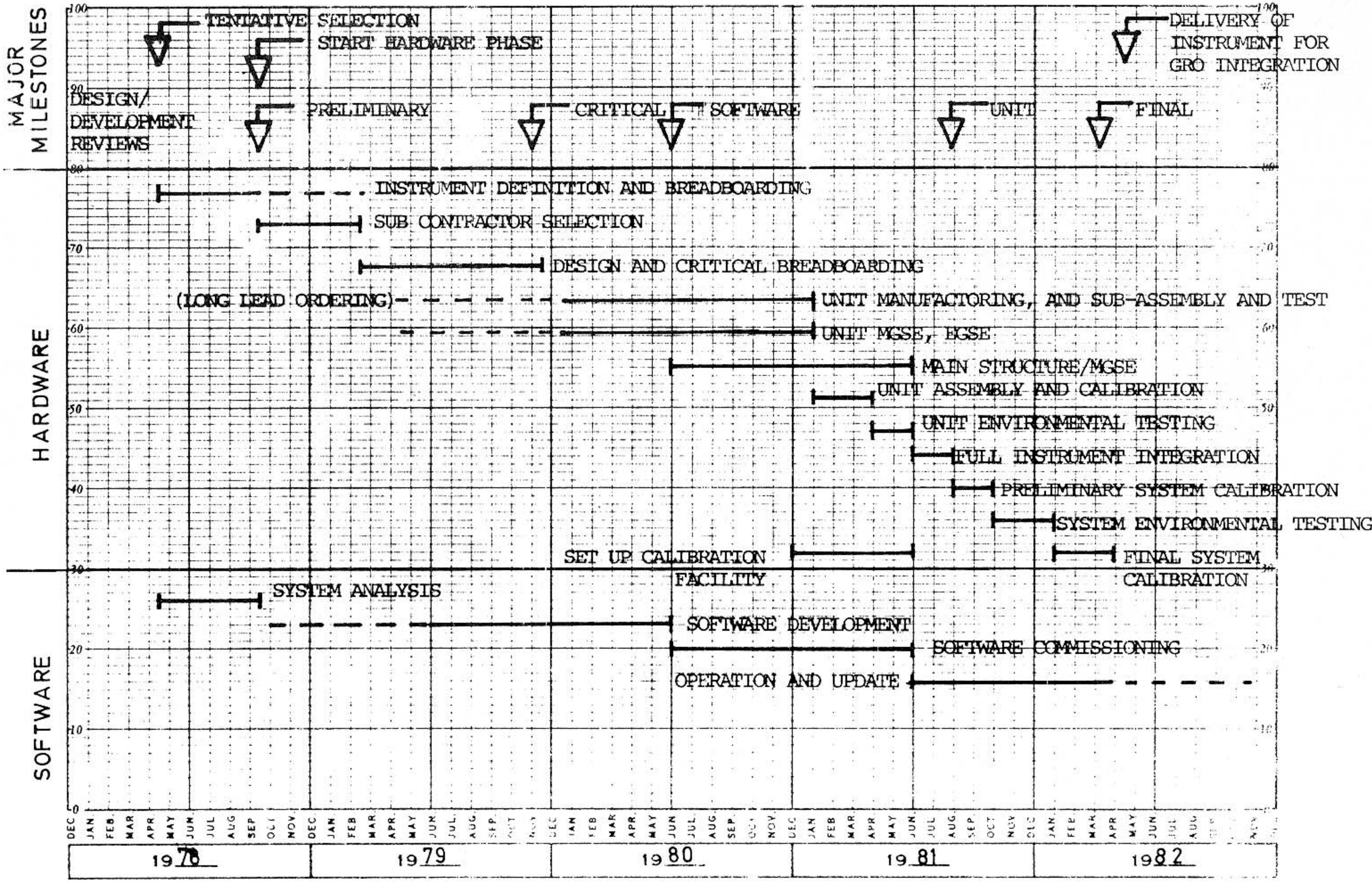


Table I: Biographical Data of Programme Participants

Institute; Max-Planck-Institut für extraterrestrische Physik

Table 1

Name, Age, Date of PhD, Awarding institute, No of publications	Present position, tenure to date, rôle, in this investigation, % time available	Applicable Experience											
		66	67	68	69	70	71	72	73	74	75	76	77
V. Schönfelder/37 1970/Physics Techn. Univ. München 35	Staff member 7 years PI 50%	MPE high energy neutron balloon expt. co-experimenter					MPE double compton telesc.: balloon expt.		2 flights	2 flights MPE-double compt. expt.-improved version			1 flight
F. Melzner/49 1967/Dr. ing. Techn. Univ. München 10	Staff member 15 years Exp. Manager 50%	Development of barium cloud technique for the measurement of electrical fields in the ionosphere. Design of special electron density probe (used in several rocket flights). Proposal and development of Electron Beam Experiment on GEOS (1977 launch). Technical support for various MPE projects.											
G. Kanbach/32 1974/Physics Techn. Univ. München 19	Staff member 3 years Exp. Scientist 50%				MPE high energy neutron balloon expt., co-experimenter					OSO-7 solar gamma ray lines (research associate at UNH)	COS-B, Data Reduction Officer		

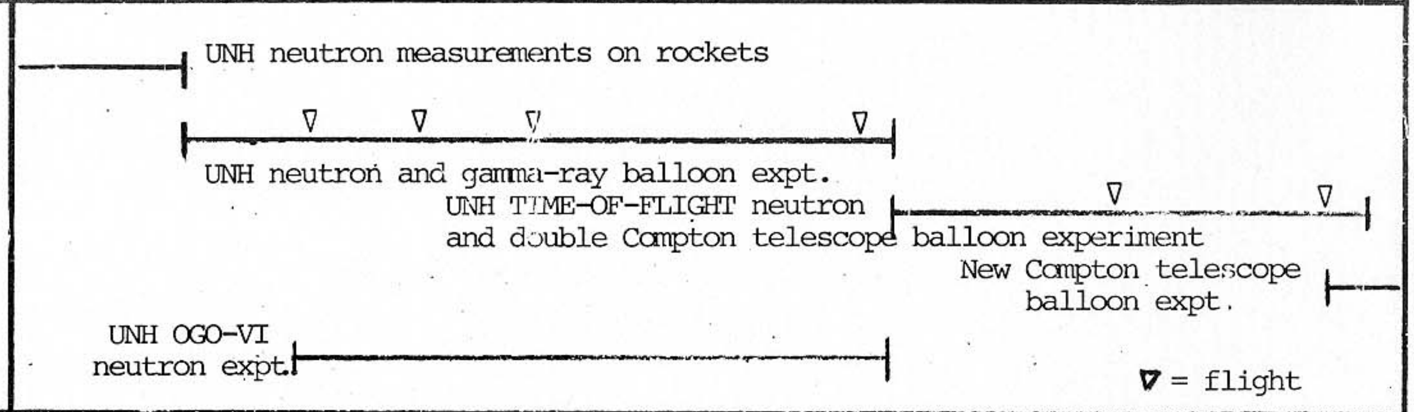
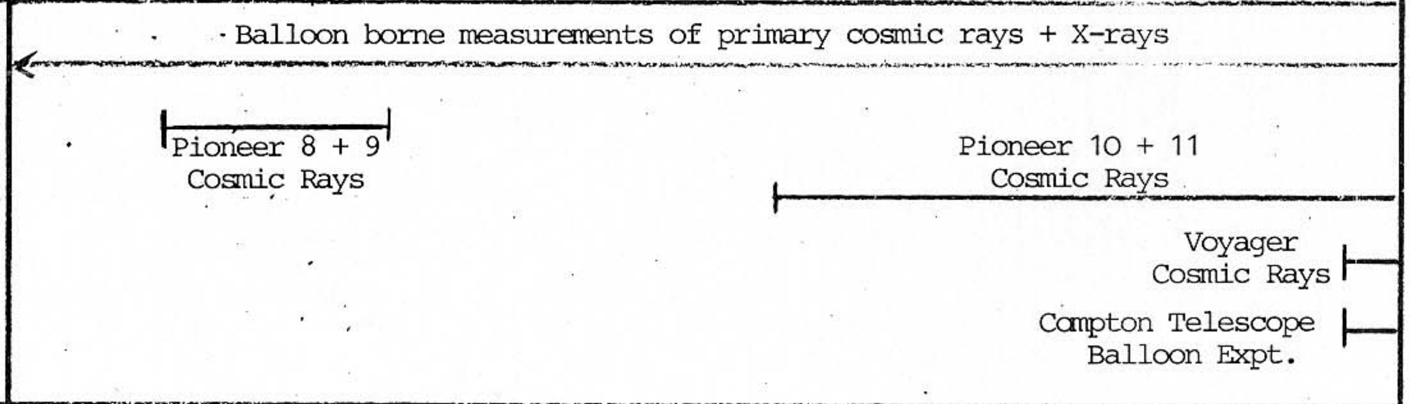
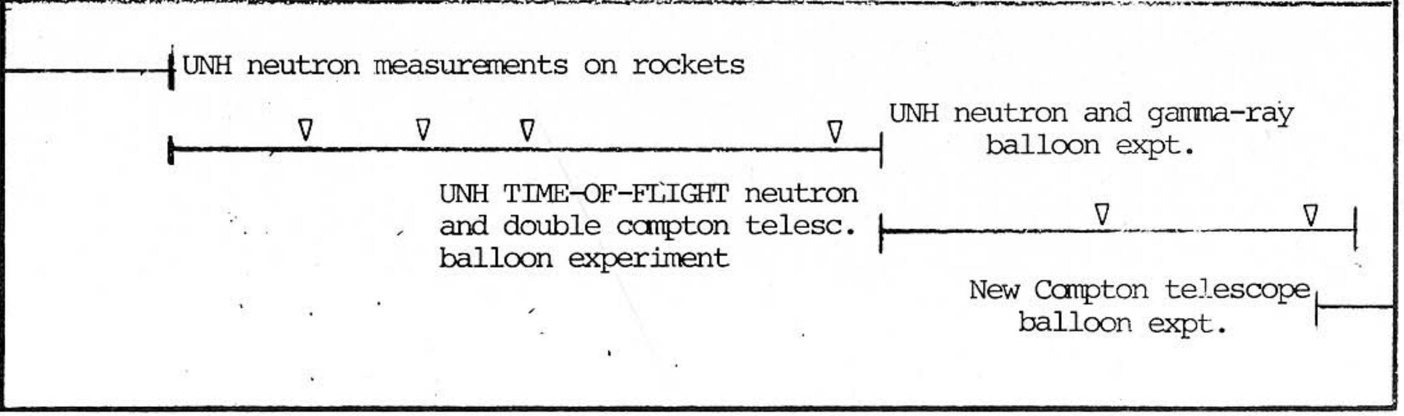
Institute; C.R.W.G. Leiden University

Table 1 cont.

Name, Age, Date of PhD, Awarding institute, No of publications	Present position, tenure to date, rôle, in this investigation, % time available	Applicable Experience 66 67 68 69 70 71 72 73 74 75 76 77
B.N.Swanenburg, 36 1971, Physics, Univ. Leiden, 30	Director Cosmic Ray Working Group, 2yrs Co-PI/Experiment Manager, 50%	Co-investigator OGO-V electron expt. Co-experimenter COS B COS-B Calorimeter Manager COS-B Steering committee EXOSAT Supervisory committee
W.Hermsen, 30 subm. 1978, Physics Univ. Leiden, 20	Staff Scientist, 5yrs Experiment Scientist, 80%	Nuclear Physics research Amsterdam Lab. research for electron expt. instrum. Co-experimenter COS-B COS-B Calorimeter hardware team member
J.A.M.Bleeker, 35 1971, Physics, Univ. Leiden, 25	Staff Scientist, 10yrs Support to E.M., 20%	PhD. research, balloon borne hard X-ray detectors Project scientist LEINAX Soft X-ray rocket programme. Co-experimenter, ESOSAT low energy X-ray expt. Member ESA Astronomy Working Group
A.J.M.Deerenberg, 42, 1973, Physics, Univ. of Leiden, 15	Staff scientist, 10yr Support to E.M., 40%	Balloon borne hard X-ray detectors Project Leader LEINAX rocket programme

Institute; Univ. of New Hampshire

Table 1 cont.

Name, Age, Date of PhD, Awarding institute, No of publications	Present position, tenure to date, rôle, in this investigation, % time available	Applicable Experience 66 67 68 69 70 71 72 73 74 75 76 77
J.A. Lockwood/58 1948/Physics Yale Univ. 90	Professor of Physics 30 years Co-PI 20%	 UNH neutron measurements on rockets UNH neutron and gamma-ray balloon expt. UNH TIME-OF-FLIGHT neutron and double Compton telescope balloon experiment New Compton telescope balloon expt. UNH OGO-VI neutron expt. ▽ = flight
W.R. Webber/48 1957/Physics Iowa Univ. 150	Professor of Physics 19 years Experiment Scientist 20%	 Balloon borne measurements of primary cosmic rays + X-rays Pioneer 8 + 9 Cosmic Rays Pioneer 10 + 11 Cosmic Rays Voyager Cosmic Rays Compton Telescope Balloon Expt.
L.A. Friling/36 1963/Physics (M.S.) Univ. N.H.	Physicist/Engineer 14 years Experiment Manager 50 - 100%	 UNH neutron measurements on rockets UNH neutron and gamma-ray balloon expt. UNH TIME-OF-FLIGHT neutron and double compton telesc. balloon experiment New Compton telescope balloon expt.

Institute; Space Science Department of ESA

Table 1 cont.

Name, Age, Date of PhD, Awarding institute, No of publications	Present position, tenure to date, rôle, in this investigation, % time available	Applicable Experience 66 67 68 69 70 71 72 73 74 75 76 77
B.G. Taylor/37 1967/Physics Univ. Southampton (UK) 30	Head, High Energy Astrophys 7 years Co-PI 20%	OGO-5, Co-experimenter, cosmic γ-ray experiment Project scientist HEOS 1/2 Co-experimenter S 204/HEOS 2 Proj.Sci. COS-B/Telescope Manager Co-experimenter COS-B Payload Manager for EXOSAT X-ray experiments Co-experimenter Spacelab I X-ray spectroscopy Co-experimenter EXOSAT X-ray spectroscopy
K. Bennett/30 1973/Physics Univ. London 25	Staff Scientist 3 years Experiment Manager 50%	PhD. Research γ-ray Astronomy (Balloon expts.) COS-B Telescope hardware & software team member COS-B Telescope Data Reduction Officer Lab. research for high energy astrophysics instrumentation
R.D. Wills/41 1961/Physics Univ. London (UK) 40	Staff Scientist 7 years Experiment Scientist 30%	Co-experimenter 090-5 cosmic γ-ray experiment Co-experimenter COS-B COS-B Telescope Exp. Officer COS-B Telescope Data Reductn. Officer COS-B Data Reduction Coordinator COS-B Project Scientist

TABLE IIb

CRWG

Vehicle	Launch Date	Investigations
OGO-V	1968	High energy cosmic ray electrons
COS-B	1975	Gamma-ray astronomy
EXOSAT	1981	X-ray astronomy

Between 1964 and 1977 the Cosmic Ray Working Group was involved in 4 rocket experiments, together with the University of Nagoya, Japan, and in about 25 balloon experiments.

TABLE IIc

UNH

Vehicle	Launch Date	Investigations
USAF/Discover	1960/1961	Neutron flux measurements
PIONEER 8	1967	Cosmic ray investigations
PIONEER 9	1968	Cosmic ray investigations
OGO-VI	1970	Neutron flux measurements
OSO-7	1971	Solar gamma rays
ATS-F	1973	Low energy electrons
Voyager 1	1977	Cosmic ray studies
Voyager 2	1977	Cosmic ray studies
SMM	1979	Solar gamma rays and neutrons.

TABLE IId

SSD/ESA

Vehicles	Launch Date	Investigations
HEOS 2	1972	Magnetospheric and interplanetary energetic particles (S-204)
COS-B	1975	Cosmic gamma rays
GEOS I/II	1977/78	Magnetospheric DC electric fields (S-300)
ISEE A	1977	AC/DC electric fields, electron gun (MOM)
ISEE C	1978	Solar protons (DFH)
SPACELAB 1	1980	Gas scintillator for X-ray spectroscopy (1 ES 023)
		Solar constant measurement (1 E 021)
		Phenomena induced by chraged particle beams (1 E 020)
EXOSAT	1981	Gas scintillator for X-ray spectroscopy
JOP	1982	Spacecraft potential control
OEE	1983	Cosmic ray and solar charged particles (proposal 32)

Table III (a)

General Facilities and Resources: MPI

1) Mechanical and electronics design offices and workshops
2) Vacuum chamber, temperature chambers, clean-rooms and vibration test installations
3) In house computing facilites and connection to the IPP computers IBM 360/91 and Amdahl 470

Table III (b)

General Facilities and Resources: CRWG

1) Mechanical and electronics workshop
2) Vacuum and temperature chambers
3) In house computing facilities and connection to the two IBM 370/58 computers of the Computer Centre of the Leiden University

Table III (c)

(UNH)

1) Machine shop and design facilities
2) Electronic fabrication shop
3) Computer facilities including DEC-10
4) Management and technical personnel in Space Science Center

Table III (d)

Availability of General Facilities and Resources SSD/ESTEC

1) Mechanical design office and workshop
2) Electronic design and circuit layout shop
3) Electronic manufactoring (thick-film)
4) Electronic wiring and integration workshop
5) In-house computers HP 21MX (2), ICL/4
6) Full range of environmental test facilities including vibration, acoustic, thermal vacuum, solar-simulation EMI/EMC