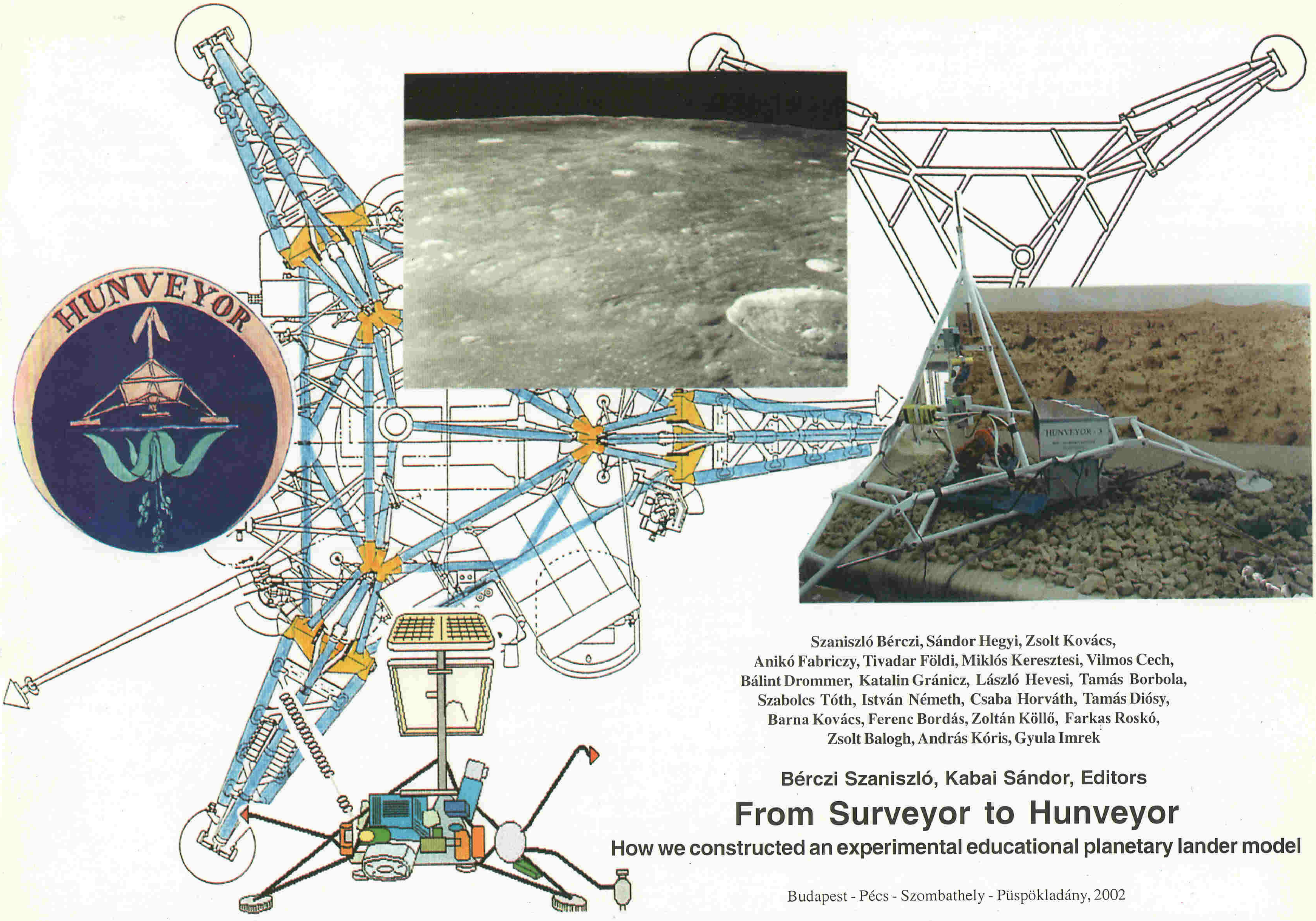

Szaniszló Bérczi, Sándor Hegyi, Zsolt Kovács,
Anikó Fabriczy, Tivadar Földi, Miklós Keresztesi, Vilmos Cech,
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From Surveyor to Hunveyor

How we constructed an experimental educational planetary lander model

Budapest - Pécs - Szombathely - Püspökladány, 2002

CONCISE ATLAS ON THE SOLAR SYSTEM (2) INVESTIGATING PLANETARY SURFACES BY MEANS OF THE EXPERIMENTAL EDUCATIONAL SPACE PROBE "HUNVEYOR" CONSTRUCTED ON THE BASIS OF "SURVEYOR"

One of the outstanding educational projects at the Cosmic Materials Research Group, working under the auspices of the Faculty of Natural Sciences of the Lóránd Eötvös University, includes the construction of an experimental educational space probe. The construction has a number of objectives. One objective is to show the relationship between the planetary geology and the construction of robots. It is also an important aim of the project to help undergraduate students learn the associated principles, such as measurements, technologies, instruments systems and computer technology. Whoever works through the construction of the electronic system will gather enough experiment which will be enough to understand the operation of an industrial plant, because a space probe consists of a series of assembled miniaturised technologies. By placing the space probe on a test terrain, yet another objective is served, i.e. to show the students how our measuring system merges with the surface processes of the alien planet. If a students learns how the measuring technologies select the predetermined details from the many interdependent processes, then he/she will be able to find fascinating analogies with the many problems encountered when trying to resolve the environmental issues on earth. In this way the students get acquainted with the complexity of the natural processes in addition to learning the complexity of a data processing system. During the measurements it will be possible for the students to have an understanding of how the many interwoven processes merge with the natural processes when establishing a technological facility. Working with the experimental space probe is always an interesting challenge because of its complexity. The many principles to be dealt with include analysis, designing, construction, measurement, and with this complexity of activities the experimental space probe is an outstanding teaching aid because of its ability to model many natural processes.

The reader can find characteristic and interesting information in a number of fields of natural sciences. In the above instruction it was already mentioned that the experimental space probe Hunveyor has relationship to many principles. Here is a list of scientific fields which are associated with Hunveyor.

Material sciences: An outlook is given on the materials, structures, complexity of materials, including the ordinary and special properties. Hunveyor is an aid to get acquainted with the materials used in establishing means of space research.

Processing technologies: Hunveyor provides an opportunity to accomplish a research and to establish models regarding the various manufacturing technologies, production methods, and the organisation of such processes and methods into industrial procedures. The measuring technologies used in Hunveyor are excellent examples for gathering knowledge in processing technologies.

Information technology: With Hunveyor it is possible to show how the signals are received, processed and transmitted, as well as how the electric circuits and systems handling the information are designed and constructed. The major fields of information technology encountered with the Hunveyor include control of instruments, collection of data and electronic data processing.

Power engineering: The power supply to the engineering systems is modelled. The systems are designed to have power supply either from the mains or from solar panels.

Environmental sciences: It is possible to study the processes and flows of the natural environment. One can also understand how the natural balance is interfered with by the human intervention. As a result of huge industrial facilities and the pollution generated by the human society can be extremely damaging to the natural environment. The experimental space probe (after a virtual landing on a planet) is a model of the interactions of technologies built into the space probe with the processes encountered on the surface of the planet.

Petrology: Morphology and formation of various rocks are investigated. The most important kinds of rocks constituting the Solar system are placed on the test terrain around Hunveyor for studying.

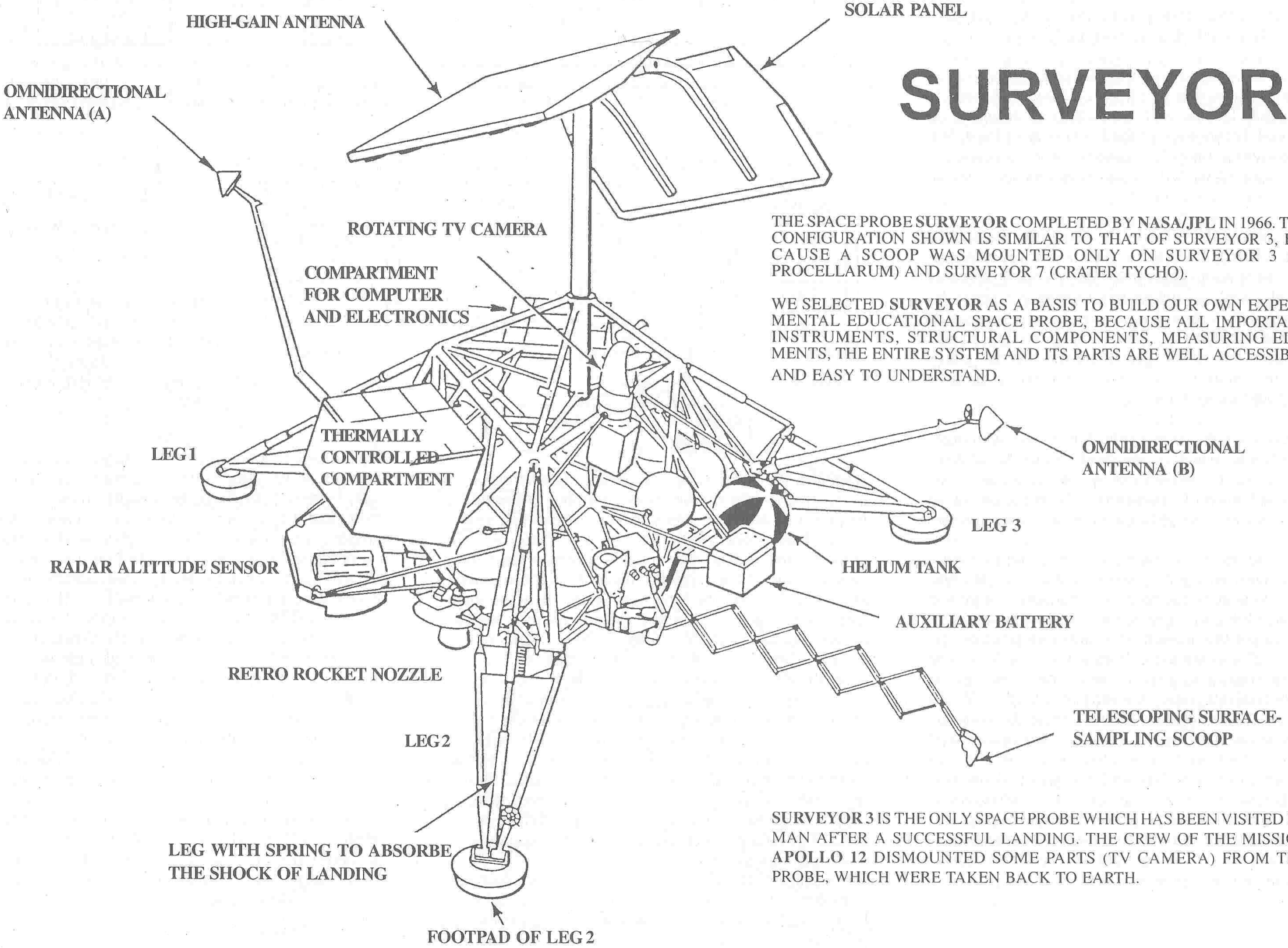
Planetology: This field of science deals with a comparative analysis of planets. The development, topography and geology of the planets are studied. The processes acting on planetary surface are studied with the help of space probes. So far the Moon, Mars, Venus and the planetoid Eros had been visited by spacecraft made by man. In the test terrain it is possible to model the condition encountered on the Moon, Mars and some outside planets of the Solar system.

Space research: This is the science which studies the cosmic space around the Earth with the help of spacecraft. Space research includes the construction and operation of space probes put on orbit around the Earth by means of space rockets, as well as the processing of data collected with local or remote detecting systems, and transmission of the relevant information back to Earth. While working on the Hunveyor the student are able to meet many tasks characteristic of space research.

Space technologies: This huge field of space research deals with the structures and technologies to be used in outer space. This is a complex engineering science facilitating the designing and construction of devices which are able to operate with extremely high reliability among cosmic conditions (very low temperature, strong sunshine, low pressure, weightlessness, long operating life). In the process of constructing Hunveyor the students primarily meet the complexity of the (miniaturised) technologies incorporated in the space device.

The concept of Hunveyor is based on the space probe Surveyor of NASA. The designers of Surveyor might be glad to learn that about 30 years after the successful mission of Surveyor spacecraft some active enthusiasts of space research selected Surveyor as a basis for keeping in touch with the development of space research and to highlight the magnificence of the associated activities to the interested students. Have a good work (Szaniszló Bérczi, editor).

SURVEYOR



THE SPACE PROBE **SURVEYOR** COMPLETED BY **NASA/JPL** IN 1966. THE CONFIGURATION SHOWN IS SIMILAR TO THAT OF SURVEYOR 3, BECAUSE A SCOOP WAS MOUNTED ONLY ON SURVEYOR 3 (O. PROCELLARUM) AND SURVEYOR 7 (CRATER TYCHO).

WE SELECTED **SURVEYOR** AS A BASIS TO BUILD OUR OWN EXPERIMENTAL EDUCATIONAL SPACE PROBE, BECAUSE ALL IMPORTANT INSTRUMENTS, STRUCTURAL COMPONENTS, MEASURING ELEMENTS, THE ENTIRE SYSTEM AND ITS PARTS ARE WELL ACCESSIBLE AND EASY TO UNDERSTAND.

SURVEYOR 3 IS THE ONLY SPACE PROBE WHICH HAS BEEN VISITED BY MAN AFTER A SUCCESSFUL LANDING. THE CREW OF THE MISSION **APOLLO 12** DISMOUNTED SOME PARTS (TV CAMERA) FROM THE PROBE, WHICH WERE TAKEN BACK TO EARTH.

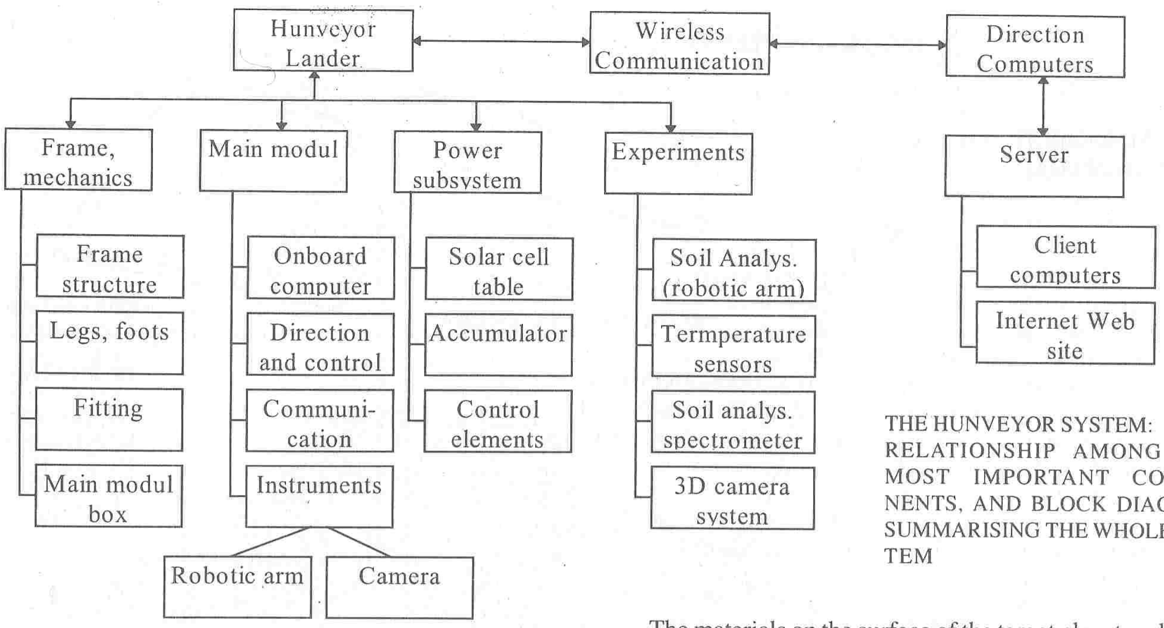
CONSTRUCTING THE EXPERIMENTAL EDUCATIONAL SPACE PROBE HUNVEYOR

Early in 1998 we started a new kind of educational project with the participation of Cosmic Material Research Group of ELTE TTK and the Faculty of Informatics and General Technology of the University of Pécs. We started to build a simplified space probe for educational purposes, and we named it Hunveyor, an experimental and educational space probe.

With its variety of instruments, autonomic measuring systems, robot devices the experimental space probe established a relationship between the technologies (earth bound and planetary) and the environmental science. In addition to that, it provides an opportunity to practice the way of miniaturising, assembling, modelling the technologies, and also to gain experience in designing for extreme conditions. It can also be used for demonstrating complex systems.

The experimental space probe Hunveyor was built around a frame, which is one third size of that of Surveyor. This was the reason why we named it Hunveyor (**H**ungarian **Un**iversity Sur**veyor**). The initial objective of the work was to establish a simplified space probe.

To be able to build the space probe the students need a basic education in natural sciences and technology. The space probe is constructed by the students in a period while they attend these basic courses. In this way they are able to put the learned principles into practice immediately. This is not the only educational value of the project of constructing the space probe. It has also a great power of integrating the various principles. While the students build, operate and assemble the continuously operating space probe, which accommodates very useful tests, they are in a position to gain an in depth knowledge of the involved technologies and practice the electronics in action. With such an experience students will surely be able to find their way around in life after graduation, because the knowledge of various technologies and the skill to organise and built facilities are indispensable in our modern world.



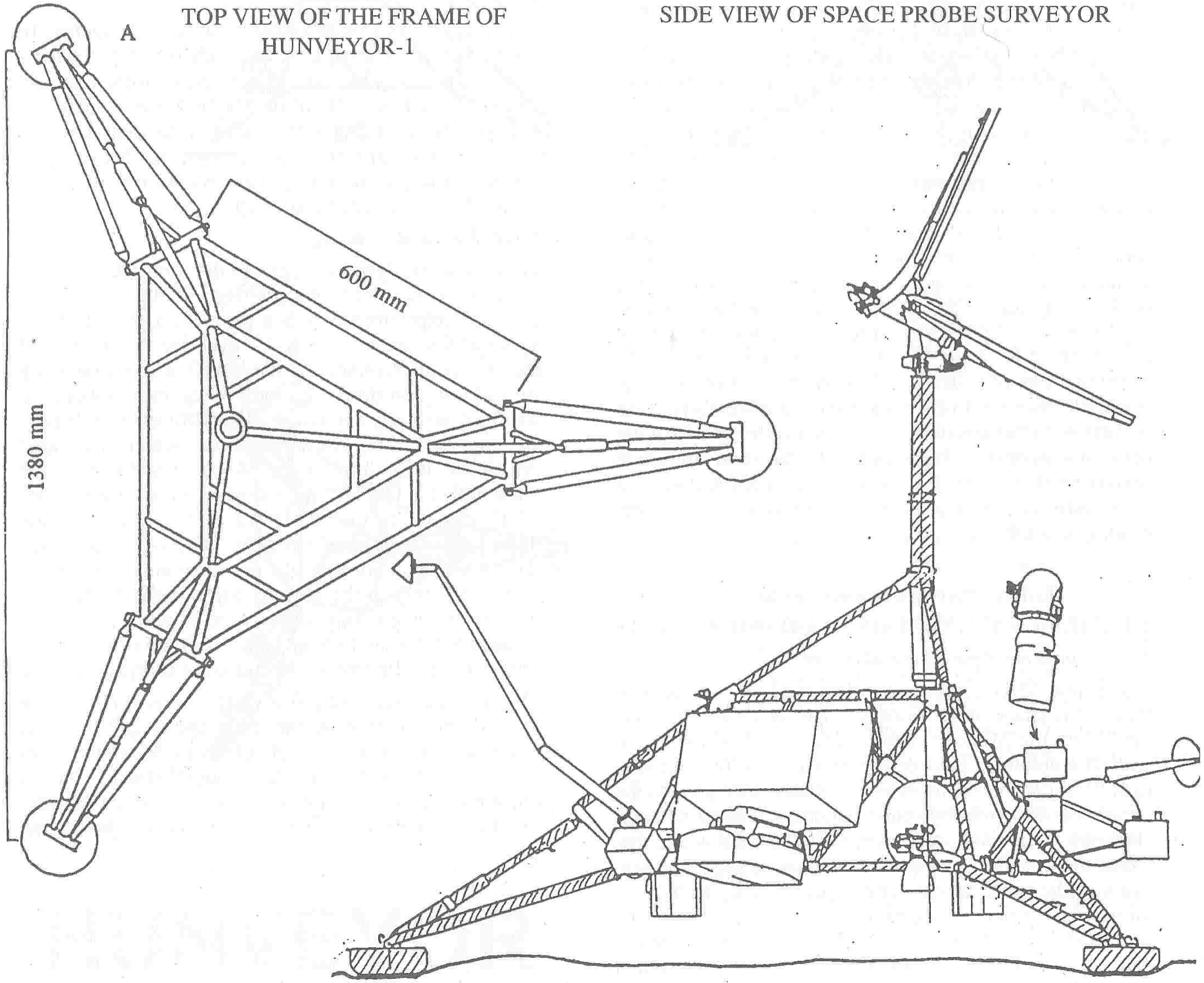
THE HUNVEYOR SYSTEM: RELATIONSHIP AMONG THE MOST IMPORTANT COMPONENTS, AND BLOCK DIAGRAM SUMMARISING THE WHOLE SYSTEM

Basically, the pace probe is a fabric of technologies. It is required to join the forces of a number of scientific fields for building an experimental educational space probe. This is one of the reasons why the project is attractive for students who intent to continue their education in one of the common fields of natural sciences and technology on the long run. In this way the joint teaching of space research and robotics presents a great attraction and possibilities. During the activities of the project many fields of the science appear to the student, the earth sciences and materials sciences being the primary ones in exploring the Solar system. But many other fields of science are also present, including geophysics, astronomy, spatial informatics, celestial mechanics, resource exploration, robotics, as well as the measuring technology to be conducted from orbit around the Earth, fast data processing, and many principles at the border areas of technologies. These fields are all parts of a leading science emerging at the beginning of a new millennium, the space research.
The versatility of activities associated with the construction of the space probe can also be efficiently utilised by researchers of natural sciences. Let us, for example, mention geology.

The materials on the surface of the target planetary body (e.g. soil of Moon or Mars) have been investigated by many kinds of instruments by the soft landing Surveyor, Viking and Pathfinder robot, as well as by crew of Apollo missions. For imitating the geological work on site we supplemented Hunveyor with a test terrain. On the test terrain we established models for various planetary landscapes. We established various terrain, including deserts of Moon and Mars, and even a river valley. With the use of a rover (small carriage), designed by Bálint Drommer, we transmitted pictures on the model terrain even to the internet. During the years 1999 and 2000 it was possible to manipulate the small carriage as well as the scoop by visitors of our home page at the internet. The scoop was able to dig into the sand of the desert, it could lift the soil, part of which dripped down. The major type of rocks constituting the Solar system had been placed on the desert terrain. We also set up a Martian desert, where boulders, similar to those photographed by Pathfinder, were deployed. The patterns of the desert planetary surfaces, caused by a variety of effect, can be studied here, such as dust sediment, impact crater and flow pattern.

With a brief review of the principles used in constructing the simplified space probe one can understand the future potentials of this complex scientific technology in the higher education, as well as in the organisation of science and scientific research. We applied the following major strategy of research-education-organisation:

1. The development and construction process was organised in a number of interdependent stages: initially a simplified space probe was completed, then it was gradually developed further in a way that in any completed stage it remained fully operational.



TOP VIEW OF THE FRAME OF HUNVEYOR-1

SIDE VIEW OF SPACE PROBE SURVEYOR

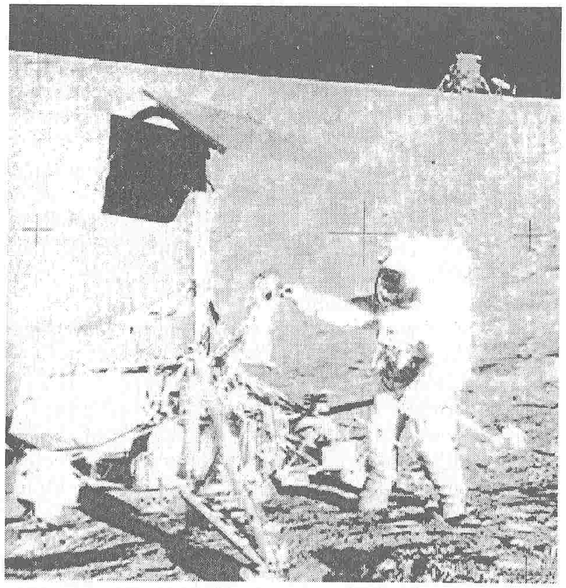
2. The space probe is assembled from self contained modules: independent units are established which are operable independently, then these units are joined and tuned to each other. One of the criteria of such tuning is the compatibility of the partial units.

3. By the incorporation of various development stages we gradually established a space probe version which is independent of the network and able to operate autonomously. The electronics is developed on PC base in view of the domestic availability of equipment and to keep the costs reasonably low.

4. A team work is organised. The project envisages a cooperation among groups of students as well as among various departments of the university. As soon as a department develops an adaptable instrument, it can be incorporated in the instrumentation of the experimental space probe. We intend to set up development groups which would have a task of developing new units on the basis of interconnecting border areas of science.

5. A two stage educational laboratory background has been established within the Department of General Technology of ELTE TTK. In the first stage the students build the equipment for performing the essential measurements (laboratory of Bálint Drommer), while in the second stage the systems consisting of essential measurements are coupled and attached to the Hunveyor (Laboratory of Hunveyor).

One of the long term objectives of the construction of the Hunveyor experimental education space probe is to establish a basis for the teaching of space research in Hungary at university and college level. Until now four high level educational institutions have joined the Hunveyor project, including the General Technology Department (then General Physics Department as of May 2000) of ELTE TTK (headed by Szaniszló Bérczi), Informatics and General Technology Department of PTE TTK (headed by Sándor Hegyi). The development of Hunveyor-3 is being pursued at the Technology Department of Dániel Berzsenyi College (under the supervision of Zsolt I. Kovács), and the construction of Hunveyor-4 has been initiated at the Kálmán Kandó Engineering College in Székesfehérvár (under the leadership of György Hudoba). The staffs of the four institutions have already joined forces in developing the Hunveyor experimental space probe.



Surveyor 7 of NASA landed on the Moon in February 1968. The location was special, because it was the first time when the landing site was chosen far from the lunar equator. The space probe Surveyor 7 landed on the northern slope of Crater Tycho amidst of large boulders. In addition to the usual mechanical, magnetic and optical tests, this probe performed X-ray fluorescent test as well to determine the soil composition. With the TV camera used already in previous missions an unusual rocky landscape was pictured around the probe, and because of the rocky surface the scoop was not easy to operate.

This Surveyor landing was the last in the series of probes exploring the Moon surface with instruments before the landing of manned Apollo spacecraft. In the Surveyor program No. 1, 3, 5 and 6 had been successfully completed prior to Surveyor 7. The success of Surveyor probes was greatly assisted by the simple framework and the well designed instrumentation in addition to the very careful preparation and the excellently operating control. We studies this exploration to be able to start the construction of the experimental space probe. The size was chosen as one third of the original size as we understood from the publications. The equipment were prepared completely by the first year students of the Technology Department.

Based on the Surveyor program, which has given rise to the idea, we named our university experimental educational space probe Hunveyor. The adverb "experimental" is a reference to a number of important functions.

1. The space probe has a laboratory nature, it can be inspected and accessed for assembling from all directions.
2. The basic configuration allows a further development in the future, thus incorporating always the latest technology and refined instrumentation.
3. It will be an educational space probe, because the conditions of various planetary surfaces could be modelled with the use of suitable programming and by replacing the soil in the vicinity of the space probe.
4. The instruments are mounted on the probe one by one after each completed stage of the development.

Two important objectives can be met with the Hunveyor. Partly, it is an educational tool, a complex robot. It contains a number of instruments which work simultaneously in a harmonised manner. The coupling of the operation of the various instruments are ensured by the on board electronic circuits, computer, interfaces, etc. On the other hand, it is a research tool, in which the existing range of instruments can be developed and supplemented further. In each stages of the development the on board instrumentation should be established as a cooperating system. This is probably the most important feature of Hunveyor. It appears to the student always as a complete unit. It is basically a chain or fabric of cooperating technologies.

1. The Hunveyor space probe

1.1. THE FRAME AND MAIN MECHANICAL PARTS

1.1.1. Surveyor type frame skeleton

The frame of Hunveyor was designed on the basis of that of the space probe Surveyor 7 of NASA which soft landed on the Moon in 1968. The sketch of the frame was obtained from Eugene Shoemaker in 1969. The success of Surveyor missions is essentially attributed to the simple but functionally sound structure. The tetrahedral structure is the most stable three dimensional shape, because the support at three point always ensures the stability of the space probe. The multiple level framework allows the optimum allocation and fastening of the various modules. The size of the Hunveyor experimental space probe is basically one third of that of the original size with minor differences.

1.1.2. The materials of the frame

We had to choose a light, but relative strong material. In the first attempt we chose copper pipe having a diameter of 12 mm and 15 mm mostly because it is readily available for anyone. Copper has, however, a major disadvantage, i.e. it is a good thermal conductor, which makes brazing rather difficult.

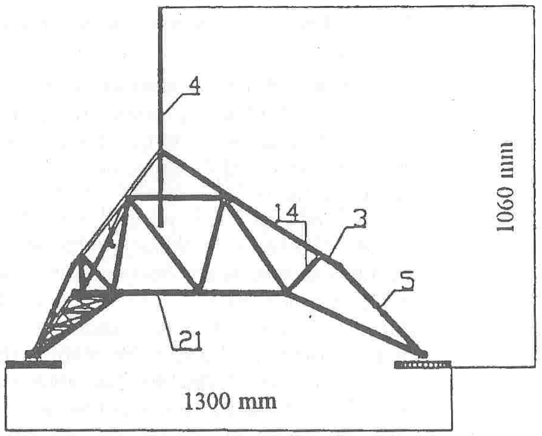
1.1.3. Joints

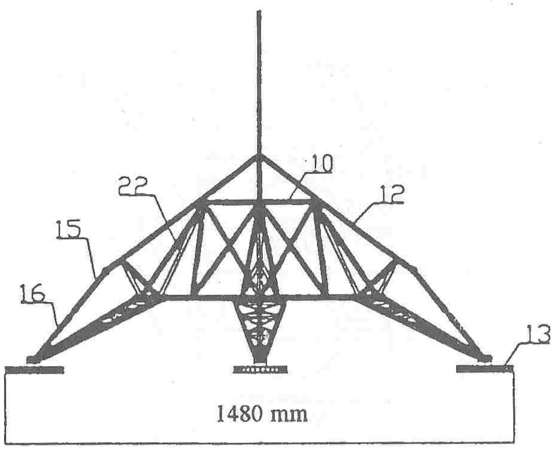
The copper pipes were joined by means of brazing. In order to ensure the required accuracy we prepared templates (jigs), to which the copper pipes were fixed by means of clamps after cutting to the proper length and chamfering according to the shape of the joint. Initially we used high capacity brazing iron, but because the copper transfers the heat quickly we started to use the more efficient petrol fired torch.

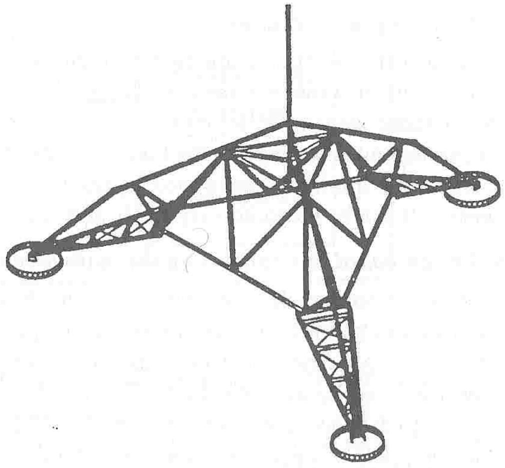
1.1.4. Footpads and legs

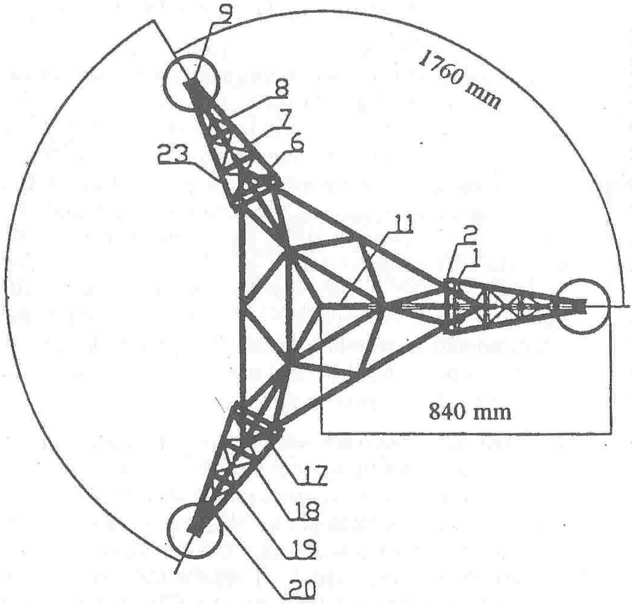
We tried to establish the legs and the footpads similarly to those of Surveyor. We prepared the legs from copper. The experimental space probe is a model of the successfully landed probe, for this reason we omitted the braces interconnecting the legs. For the time being we did not plan drop tests with the frame (however, it will be eventually necessary in the future). That is why we also omitted the telescope device, which attenuated the shock at landing on the Moon in addition to the retro rockets. The leg consisting of three copper pipes of 12 mm in diameter proved to be surpassing the expectations regarding strength! The solar panel and the various components of the instrumentation can be fastened firmly to the various parts of the frame. The legs of the original Surveyor were folded up until the preparation for landing was started. In this folded condition it could be easily fitted into the carrying rocket.

The footpads make sure that the probe is stable on the ground after landing. At the top of the plastic footpads a specially etched plastic structure joins the copper pipes together with the help of the threaded shank. This is required in case of an uneven landing surface in order to allow the rotation of the footpad around a horizontal axis.









1	Copper pipe dia. 15 mm, length 160 mm, quantity 3 pcs
2	Copper pipe dia. 16,5 mm, length 10 mm, quantity 13 pcs
3	Copper pipe dia. 16,5, length 20 mm, quantity 3 pcs
4	Copper pipe dia. 15 mm, length 660 mm, quantity 1 pcs
5	Copper pipe dia. 12 mm, length 100 mm, quantity 3 pcs
6	Copper bar dia. 3 mm, length 145 mm, quantity 6 pcs
7	Copper bar dia. 3 mm, length 120 mm, quantity 6 pcs
8	Copper bar dia. 3 mm, length 95 mm, quantity 6 pcs
9	Spacer ring dia. 20 mm, length 8 mm, quantity 12 pcs
10	Copper pipe dia. 15 mm, length 340 mm, quantity 3 pcs
11	Copper pipe dia. 15 mm, length 196 mm, quantity 3 pcs
12	Copper pipe with lug dia. 21 mm, length 645 mm, quantity 3 pcs
13	Pedestal dia. 166 mm, height 60 mm, quantity 3 pcs
14	Copper pipe dia. 15 mm, length 135 mm, quantity 6 pcs
15	Copper pipe with lug dia. 22 mm, length 155 mm, quantity 3 pcs
16	Copper pipe with lug dia. 22 mm, length 195 mm, quantity 3 pcs
17	Copper pipe dia. 15 mm, length 150 mm, quantity 3 pcs
18	Copper pipe dia. 15 mm, length 115 mm, quantity 3 pcs
19	Copper pipe dia. 15 mm, length 79 mm, quantity 3 pcs
20	Copper pipe dia. 15 mm, length 43 mm, quantity 3 pcs
21	Copper pipe dia. 15 mm, length 610 mm, quantity 3 pcs
22	Copper pipe dia. 15 mm, length 350 mm, quantity 12 pcs
23	Copper pipe dia. 22 mm, length 460 mm, quantity 6 pcs

DIMENSIONAL DETAILS OF THE FRAME OF THE EXPERIMENTAL SPACE PROBE HUNVEYOR 2 PREPARED IN PÉCS.

Interested readers may obtain detailed information on the Surveyor space probes, including structure, instrumentation, scientific data and results from the following document: NASA TECHNICAL REPORT NO. 32-103. JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY PASADENA, CALIFORNIA, USA, 10 SEPTEMBER 1966.

HUNVEYOR

1.1.5. Fastening unit, clamps

The various instruments and equipment should be fastened firmly and in a safe manner onto the space probe. For this purpose we use the solution shown in the figure. A plastic unit is fastened to the frame by means of four bolts, and a similar clamp is used for fastening the equipment. It can be prepared very easily and quickly.

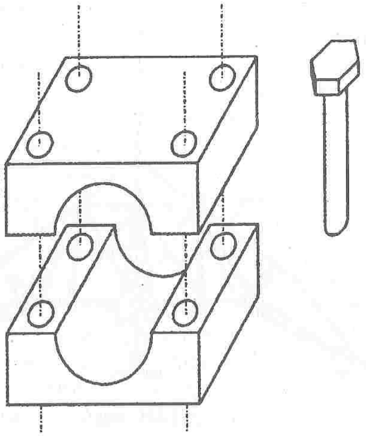
1.1.6. The on board box containing the main module

The instrument box, made of aluminium sheet, shown in an illustration below houses *the on board computer*, part of the *supply system electronics*, and the *batteries*, together with miscellaneous electronic circuitry. Preparation is very easy, because it is made from 6 wall panels, and each pair of opposites panels are identical in size. It can also be disassembled and mounted easily, the included electronics can be accessed simply after removing two bolts.

1.2. THE MAIN MODULE

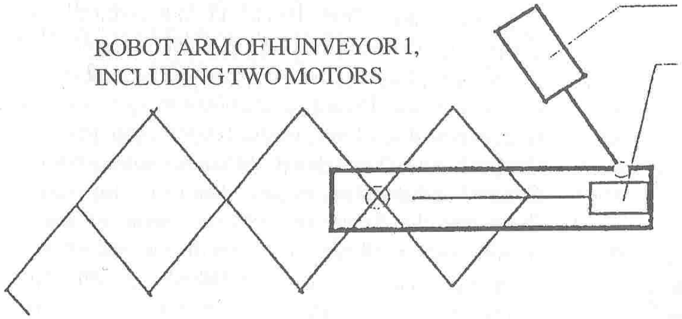
1.2.1. The structure of the main module

The main module controls the sub-modules, it summarises the received results, sends and receives data from the land based control panel. The main module presently is an Intel 386 computer. One of the benefits of the PC compatible programming is that the code can be developed also with high level languages. It is suitable for beginners to learn the programming, to understand the organisation of the system, however, it requires high power because of the many unnecessary functions, and as a result of its large size it is not very convenient. In the next development phase a low power note-book computer will be used. In addition to the low power consumption two important criteria would also be met by this solution. One of them is the compatibility, the other is the ease of software development. In the future, however, the best solution would be a purpose made microprocessor controlled circuit.

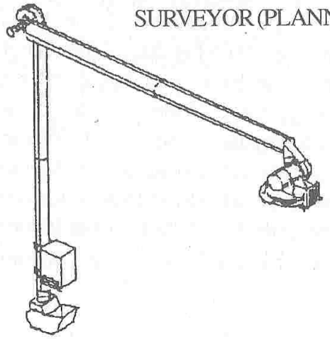


CLAMP USED FOR FASTENING EQUIPMENT TO THE HUNVEYOR FRAME

ROBOT ARM OF HUNVEYOR 1, INCLUDING TWO MOTORS



ROBOT ARM OF MARS SURVEYOR (PLANNED)



1.2.2. The sub-modules

1.2.2.1. The electronic and control structure of the sub-modules

The "brain" of the sub-modules can be μC (micro controller) or μP (micro processor) depending on the function. The actual selection is made on the basis of the required speed and the necessary space. In case of tasks involving many calculations, especially when the compression of data is a requirement, the application of μP together with the necessary purpose made electronic circuitry would be the best solution. Such equipment is for instance the CCD TV camera. The picture produced by the CCD camera should be compressed, so that it would not burden the main module too much, and would not hinder the data transmission of other modules. The μ program shall be intelligent enough to allow full completion of the required functions, unless critical error or disturbances are encountered. It means that a fully controlled instrument should be implemented with the μ program.

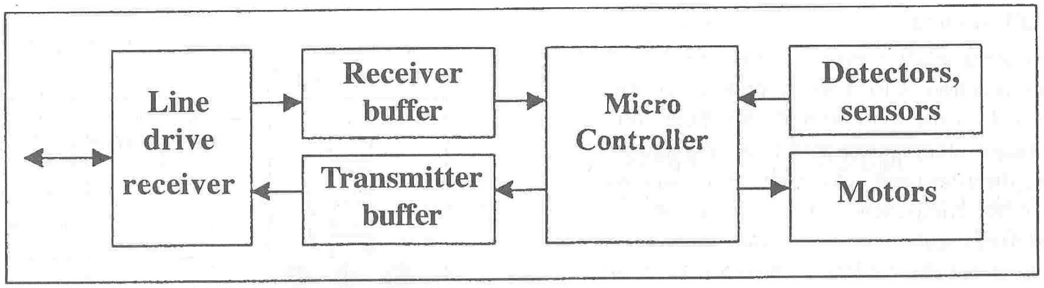
One of the most important instruments of Hunveyor (in its present configuration) is the robot arm. It was designed on the basis of the arm installed in Surveyor III. Its structure is amazingly ingenious. The arm occupies a small space only a few cm in size when retracted, but it can reach out to one and a half meter if extended. Its major function was to allow the determination of the strength and granular nature of the surface by means of scraping. The camera was located and adjusted for having a good view of the arm. In this respect, the instrumentation was arranged similarly on Hunveyor, i.e. the camera and the robot arm were installed at the same side of the space probe.

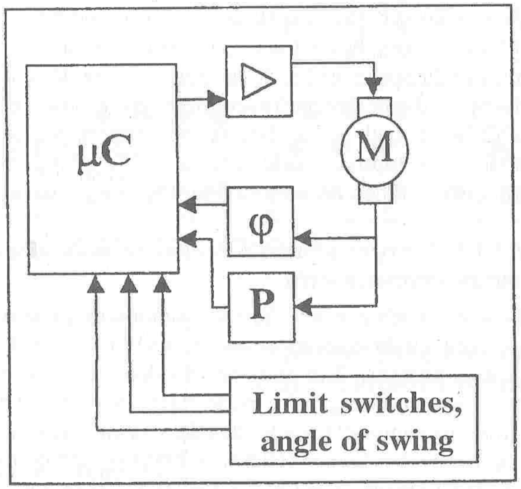
Two kinds of robot arm are used in practice. One of them has a retracting system (see the figure), while the other one consists of two parts joined at an elbow, which is the solution for present and planned space missions. This latter system was selected for the Mars Surveyor Lander 98' mission, which allows the extension of the two parts to a distance of 2 m. A CCD camera and a soil thermometer probe is mounted on the end of the arm. A temperature sensor system is also located at the elbow.

The first version of the arm was constructed from the elements of a metal construction toy, and the two motors were controlled by the Robot Evolution. The advantage of this configuration is that it can be assembled in a few hours, however, it is not very stable, and it can be used only for demonstration purposes. For this reason another unit will be constructed in the future, which is more similar to the original. For the ease of processing it will be made from copper. (Two such devices were prepared at the University of Pécs, and one of them was installed on Hunveyor).

The arm is driven by two motors. One of the motors extends and retracts the arm, while the other motor moves the arm up and down around a horizontal axis. This is how the arm is extended, lowered to the ground, then retracted. Later on a third and a fourth motor will also be necessary. One of them will be used to extend the area of movement by rotating the suspension around a vertical axis. A further small motor will drive the scoop. Servo motors will be used for this purpose, which are very strong.

Later on a sophisticated robot arm will be mounted on the Hunveyor which is no longer used just for demonstration. This will be provided with suitable devices for moving in two directions and to drive the scoop itself. Later we intend to extend the functions of the arm by installing a thermal sensor for measuring the ground temperature.

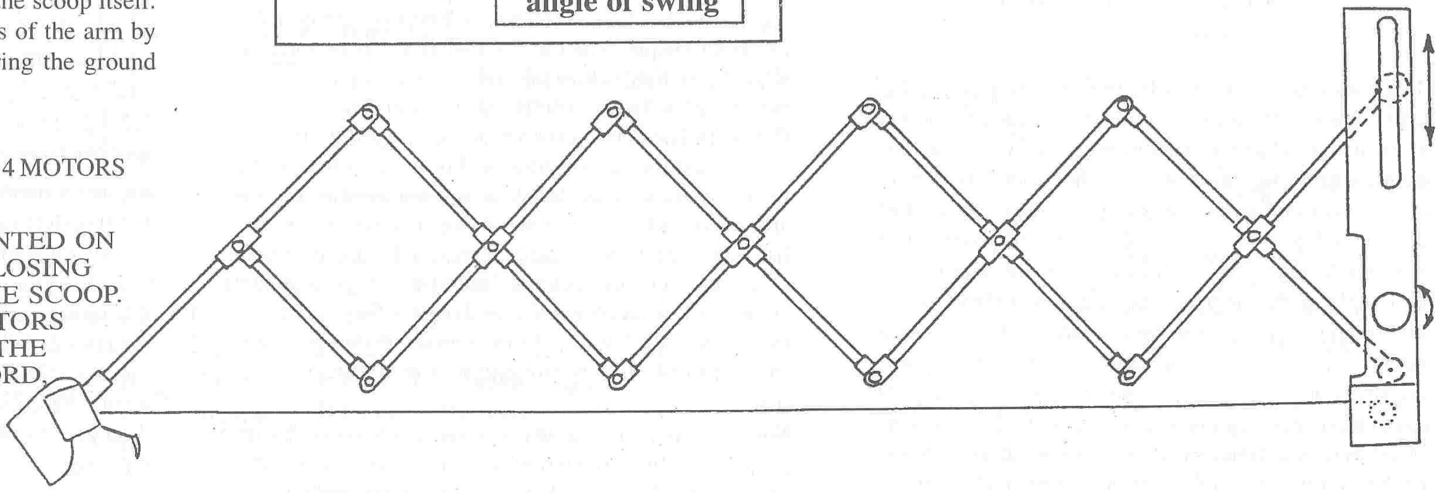




1. Moving one of the motors of the robot arm. The robot arm swings to the commended position while the motor speed, input power, the limit switches and the angle of swing are monitored. The motor will stop only if the arm is aligned to the commanded position, or if some critical fault occurs. If an overload occurs which is not critical, then the other motor tries to align the arm to the desired position without causing damage.

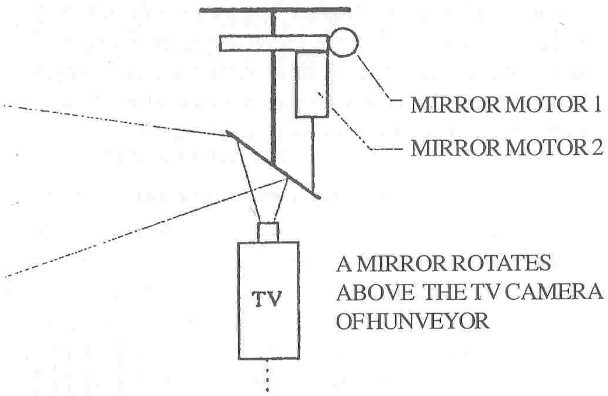
ROBOT ARM OF SURVEYOR WITH 4 MOTORS

THE FIRST MOTOR WAS MOUNTED ON THE END OF THE ARM FOR CLOSING AND OPENING THE LID OF THE SCOOP. THE SECOND AND THIRD MOTORS EXTENDED AND RETRACTED THE ARM WITH THE HELP OF A CORD, RESPECTIVELY. FINALLY, THE FOURTH MOTOR SWUNG THE EXTENDED ARM WITHIN A CERTAIN ANGLE.



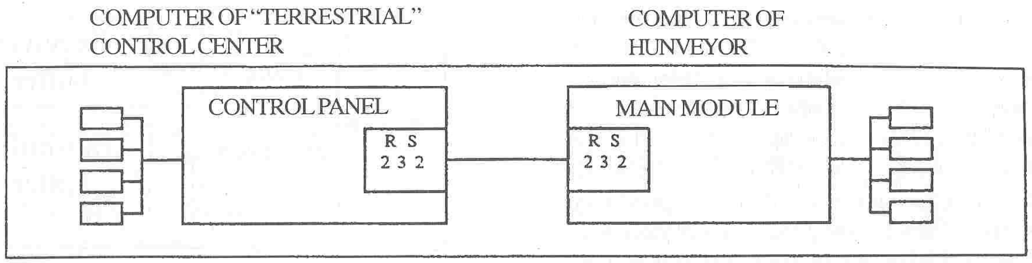
1.2.2.2. The TV camera

The camera system of Hunveyor is similar to that of Surveyor. Its function is to transmit pictures on the environment and on the robot arm. Its structure consists of two major components: one is the camera itself, including the associated optical devices and a mirror, and the other component is the moving mechanism. For ensuring a minimum power consumption the mirror located above the camera is moved instead of the heavy camera. The planar mirror reflects the picture into the optical system of the camera, from which a standard video signal is generated by the camera, which is easy to process and transmit.



A MIRROR ROTATES ABOVE THE TV CAMERA OF HUNVEYOR

The mirror is also moved by two motors (see the figure). One of the motors (1) rotates the mirror around a vertical axis, while the other motor (2) elevates and lowers the mirror, i.e. turns around a horizontal axis. In its initial position the mirror is aligned at an angle of 45 degrees relative to horizontal. With this system it is possible to get a view of the environment within a lateral angle of 180 degrees. For Hunveyor these motors were obtained from the *Robot Evolution* set. The bracket supporting the mirror may also be made from the metal construction set, but this is not very stable. It can be assembled very quickly and provides an efficient demonstration, and its mass is also proportional to the power of the motors included in the *Robot Evolution* set.



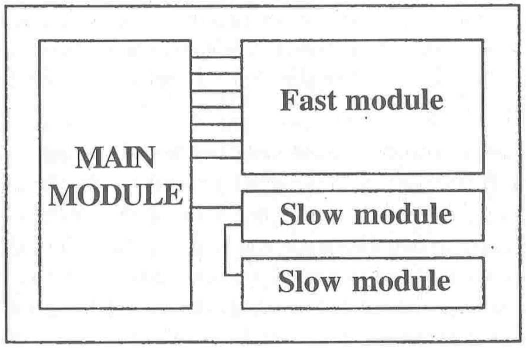
1.2.3. Transfer of data

As it is known, the data transmission should be established between the central control panel and the various units of the space probe. A multiple level modern intelligent hardware and software hierarchy should be established at both sides. The various structures meet at nodes, The topmost node consists of the central control unit and the ground based central control panel.

1.2.3.1. Transfer of data between the main module and subordinated units

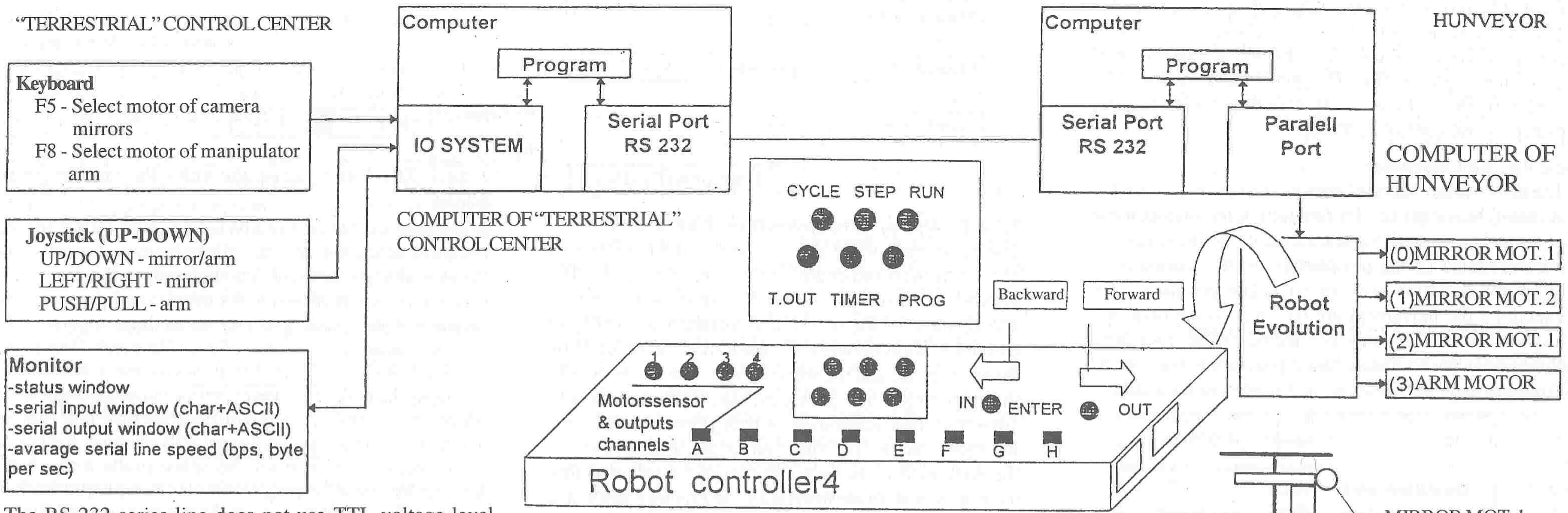
In order to achieve an efficient operation of the system we used a hybrid solution also instead of a single kind of data transfer. The units are divided into two main branches according to the mode of transfer. One branch (robot arm, mirror) has a limited data transmission need, while the other branch (CDD camera) has high demand for data transfer. The link for the former is established with series line, while the link for the latter is established with 8-16 bit parallel data transfer. There are further differences in the two branches regarding the bus request and the bus arbitration. For the parallel bus the better solution is the break controlled centralised bus arbitration, while for the serial line it is easier to establish a decentralised control. It means that the priorities of all the units are regarded identical, i.e. all units are authorised to receive and transfer data for a predetermined period of time. With the use of this predetermined priority it is possible to allocate indirect priorities.

For the time being the RS-323 and CAN buses are regarded suitable among the available buses. One of the reason why these standard equipment are preferred is that the associated purpose made circuits are commercially available, and also the relevant literature can be obtained easily.This is one of the important criteria of the compatibility.

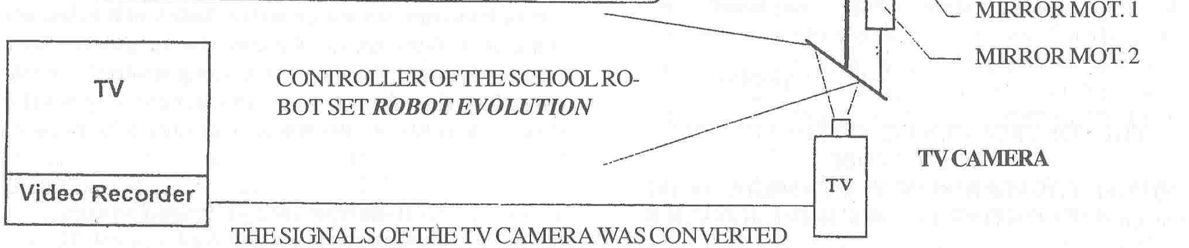


1.2.3.2. Transfer of data between the main module and the terrestrial direction and control computer

Presently standard RS-232 serial communication is used for transferring data between the two main modules, i.e. the on board computer of Hunveyor and the terrestrial direction and control computer. The capacity of this transfer can be set in the range 300-115200 bit/s. It operates in full duplex zero modem mode, which means that both parties are able to receive and transfer data simultaneously, and 3 cables are enough to link the two modules (Tx, Rx, GND) / Transmit Data, Receive Data, Ground).

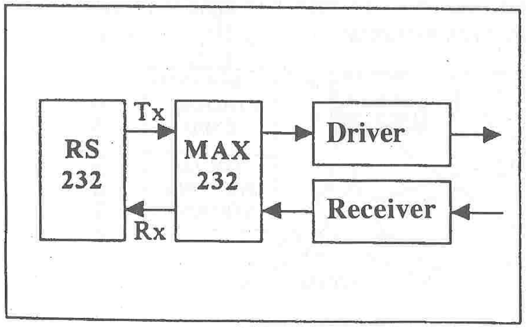


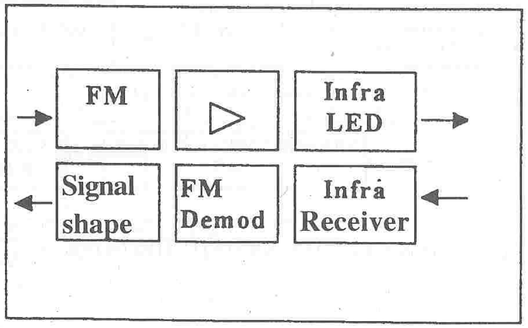
The RS-232 series line does not use TTL voltage level, but ± 12 V, where +12 V is the logical one, and -12 V is the logical zero. For this reason it is difficult to insert other circuits between the two modules. In order to connect infra or radio transceiver between the two points, it is required to use a line drives receiver circuit. This problem is resolved with a MAXC232 IC presently. For avoiding the information transmission through cables first an infrared transceiver is coupled. With this configuration the two partial systems are separate only to a distance of 3-5 m. Further improvement will be made later on by using radio transceiver, which will allow to locate the equipment outside the range of visibility.

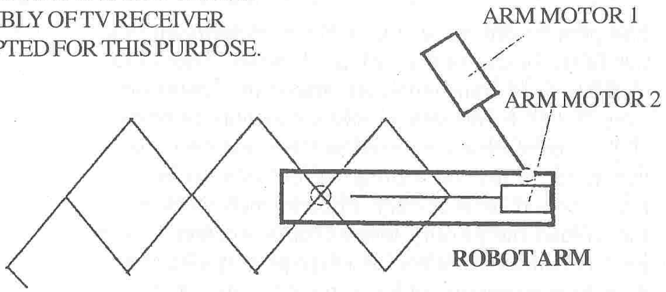


CONTROLLER OF THE SCHOOL ROBOT SET *ROBOT EVOLUTION*

THE SIGNALS OF THE TV CAMERA WAS CONVERTED TO AN IMAGE BY AN ASSEMBLY OF TV RECEIVER AND TAPE RECORDER ADAPTED FOR THIS PURPOSE.







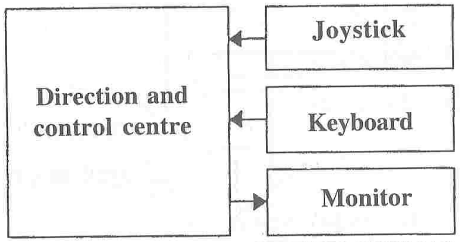
THE CONTROLLER OF THE SCHOOL ROBOT SET *ROBOT EVOLUTION* (ROBOT CONTROLLER 4) AND 4 SMALL MOTORS ARE APPLICABLE FOR CONTROLLING AND MANEUVERING THE ROBOT ARM (2 MOTORS) AND CAMERA MIRROR (2 MOTORS) OF HUNVEYOR MINIMUM SPACE PROBE.

1.2.4. The terrestrial direction and control computer

The main module represents the unit landing on a planet within the system used for introducing the experimental educational space probe. The main module is linked by cables to the computer representing the terrestrial direction and control computer.

1.2.4.1. The computer

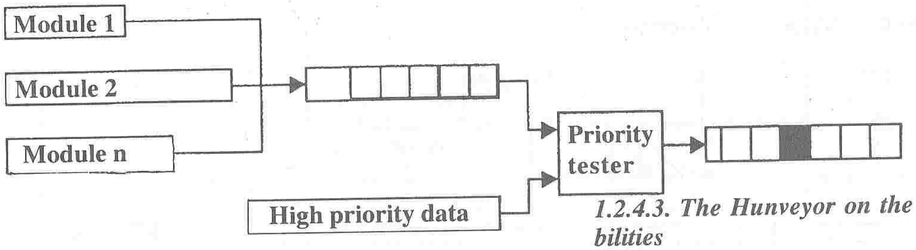
The direction and control centre consists of a single PC compatible computer. Its function is to maintain the communication with the main module. Various devices are connected to the peripherals of this computer to allow the direction and control. The commands for executing the movement are issued with the help of a keyboard and a joystick connected to the midi port. Presently a Turbo Pascal based program is used in the direction and control centre and in the main module.



THE CONTROL CENTRE OF THE MINIMAL SPACE PROBE

EITHER THE MIRROR OF THE CAMERA OR THE SCOOP IS CONTROLLED WITH THE JOYSTICK.

The priority can be set indirectly by determining the size of the blocks of the various modules. Data of the modules to be transmitted are placed in a transitional store (FIFO) by organising into the mentioned blocks. High priority data are joined to the system only after this store, so that no waiting for the store to become empty would be necessary. Prior to each block to be transmitted the priority tester checks whether a high priority data exists or not. If a high priority data exists, then the transmission of lower priority data is not initiated. Instead, all the high priority data are transmitted. Such high priority data include for instance an emergency shut down, joystick position, etc.

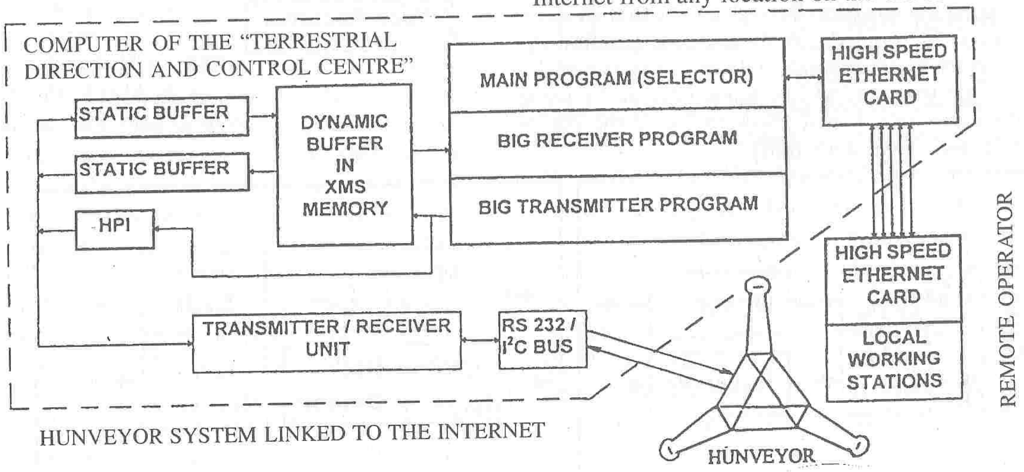


1.2.4.2. Steps of developments on Hunveyor-1

The major step of the development is the organisation of the direction and control centre into a network. The network consists of a server and some workstations. The function of the server is to maintain an intelligent communication between the main module mounted on the space probe and the workstations. The server divides the information into packages, blocks, then the blocks are transmitted, depending on their priorities, with time multiplex mode. The function of the workstations of the network is to monitor and control the sub-modules, as well as to evaluate the results. In this way one of the most important criteria are met at the side of the direction and control centre; i.e. the modular structure. This is very important, because each group dealing with the development of instrument can independently develop its own software by the use of standard network protocol.

1.2.4.3. The Hunveyor on the web - the internet possibilities

In our case the Internet can be used as a facilitator for our means of education. It is thought to be important to utilise the available possibilities. The Internet itself is less stable than the networks deployed for educational purposes, but its use is wide spread, and it is accessible for most of the educational institutions. Our Space Research Group and our Student Circle decided to publicise the achievements regarding the building of the experimental educational space probe. It means that we will provide not only descriptions and pictures on our work, but we will establish the conditions necessary to control the space probe through the Internet by anyone through their own computers. Various soils will be available to scoop up, samples could be taken with the arm, and this operation would be broadcasted with the help of the camera mirror or a camera mounted on a small carriage (rover) which is controlled by the remote operator. Later on, it would also be possible for the remote operator to carry out experiments through the Internet from any location on the Globe.



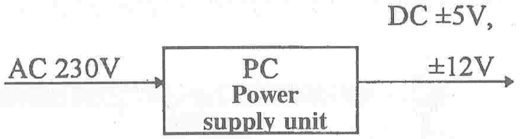
HUNVEYOR SYSTEM LINKED TO THE INTERNET

1.3. THE POWER SUPPLY SYSTEM

1.3.1. Tasks and functions served by the energetic system of the Hunveyor

The power required by the Hunveyor is provided by a power supply system. This is one of the most important part of the space probe, because this is one of the preconditions for the operation of all systems. It is not an easy task to design such a power supply system, because plenty of factors should be taken into consideration, including the orientation of the space probe relative to the Sun, and the time sequence of the operation of all electrical instruments. For this reason three designing stages are considered for establishing and constructing the system (see: steps of development).

1.3.2. The electronics of the power supply system



Presently a power supply unit of a PC is used for providing power to the Hunveyor. Because of its stable voltage and its relatively high capacity it is excellent for the electronic equipment, such as the on board computers, the *Robot Evolution* micro controller, as well as for the motors driving the arm and the mirror.

A PC power supply unit has a large size, but it can be easily and quickly integrated into the whole system. It provided stable output at levels ± 5 V and ± 12 V.

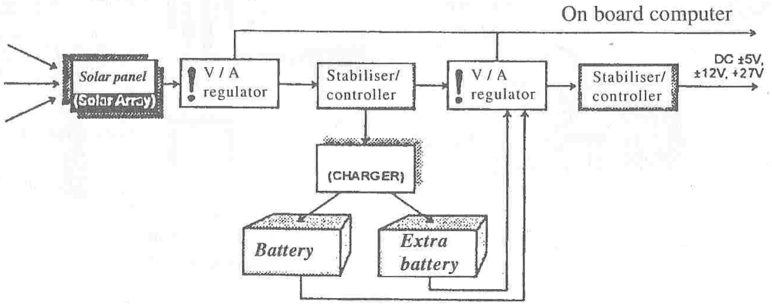
Such power supply unit is not connected to the electronic circuit initially, for this reason it will be described only later in the section dealing with the steps of development.

The primary output of the power supply unit is 27 V. This voltage is forwarded to the various electrical equipment, where it is stabilised and regulated at the required level. This solution has the benefit of a reduced loss.

1.3.3. The solar panel

One of the factors to be considered when dimensioning the electronic circuits is the maximum available output from the solar panel. For this reason it is very important to align the solar panel constantly at a proper angle, i.e. continuously following the direction of the Sun. For this reason an electronic instrument should be installed to measure the luminosity of the Sun. The solar panel is turned according to the result of this measurement. A mechanism is started to operate for rotating the solar panel as a result of the signals received from the luminosity meter. Two servo motors are necessary for this purpose, considering the weight of the solar panel. The motors are able to rotate the unit in two directions: around the vertical axis and around the horizontal axis.

Pictures available on Surveyor indicate that panels were installed above the equipment. Only one of these panels was actually a solar panel, the other panel was an antenna. No such antenna is necessary presently for the Hunveyor, because the communication between the space probe and the direction and control centre takes place through cables over a short distance only. The power of the solar panel is only 12 W (at 12 V), and it is evidently not able to provide power to all parts of the present system. This power is sufficient only for charging the battery, while all the instruments are switched off.



1.3.3.1. The connections between the on board computer and the power supply

Operations associated with the power supply of the various electronic equipment include regulation, switching on and off, as well as a constant monitoring. In addition to that, it is necessary to measure the voltage, current and temperature at well defined places, and the required measures should be taken as soon as some error is detected for eliminating the faulty condition. The electric power is essential for the space probe, for this reason this sub-system shall be in constant connection with the on board computer, which performs the above operations.

1.3.3.2. Steps of developments on Hunveyor-1

The first of the mentioned 3 steps of development includes the system which is presently based on a PC power supply unit. At the subsequent step of development (see the figure) no PC power supply unit will be needed any longer, because a purpose made power supply unit will be installed together with a battery, a battery charger and stabiliser/regulator circuit. We will still use the mains 220 V power in this step of development, but the purpose made charger and electronic circuit will mean a significant advance, establishing the base for the next step when solar panel, together with the battery and charger assembly will be used.

In the third step of development a complete supply system will be constructed (see the figure below). With the use of a solar panel the Hunveyor space probe will be provided with a self contained, independent power supply system. Two voltage/current controllers are included in the power supply unit, which is suitable to monitor the entire system. The data collected by the two supervisory components are transmitted to the on board computer. The first controller is used to monitor the solar panel, and the other is used to supervise the stabiliser/controller, as well as the battery charger and the battery. A spare battery might be required for two reasons:

1. If the primary battery fails.
2. If the solar panel is not able to provide enough power, and the primary battery has been discharged.

1.3.4. The solar panel of Hunveyor-2

The main component of the power supply system of Hunveyor-2 prepared in Pécs is the solar panel mounted on the top of the framework. The power provided by the solar panel is used for charging the batteries with the help of a charging circuit.

Commercially available solar panels, having an efficiency of 10-20 %, were used in the power supply system of Hunveyor-2. The solar battery is a 12 V Ni-Cd battery having maximum charging current of 1.7 A, and its preferred storing capacity is 16 Ah. In the conditions of the Moon and of the Mars the local coordinate system can be selected similarly to the horizontal coordinate system on the Earth. In this system the longitude measured on the horizon is the azimuth, while the latitude measured up to the zenith from circles of latitude above the horizon is the height (m).

The orientation of the solar panel is set by a moving mechanism having two degrees of freedom. One of the motors drives the horizontal rotating table (a rotating stool moved with a spindle as shown in the figure). This is basically a disk with cogs on its perimeter, and it rotated around a vertical axis for setting the horizontal coordinate. The height coordinate is set by the other motor, which rotates the solar panel around a horizontal axis.

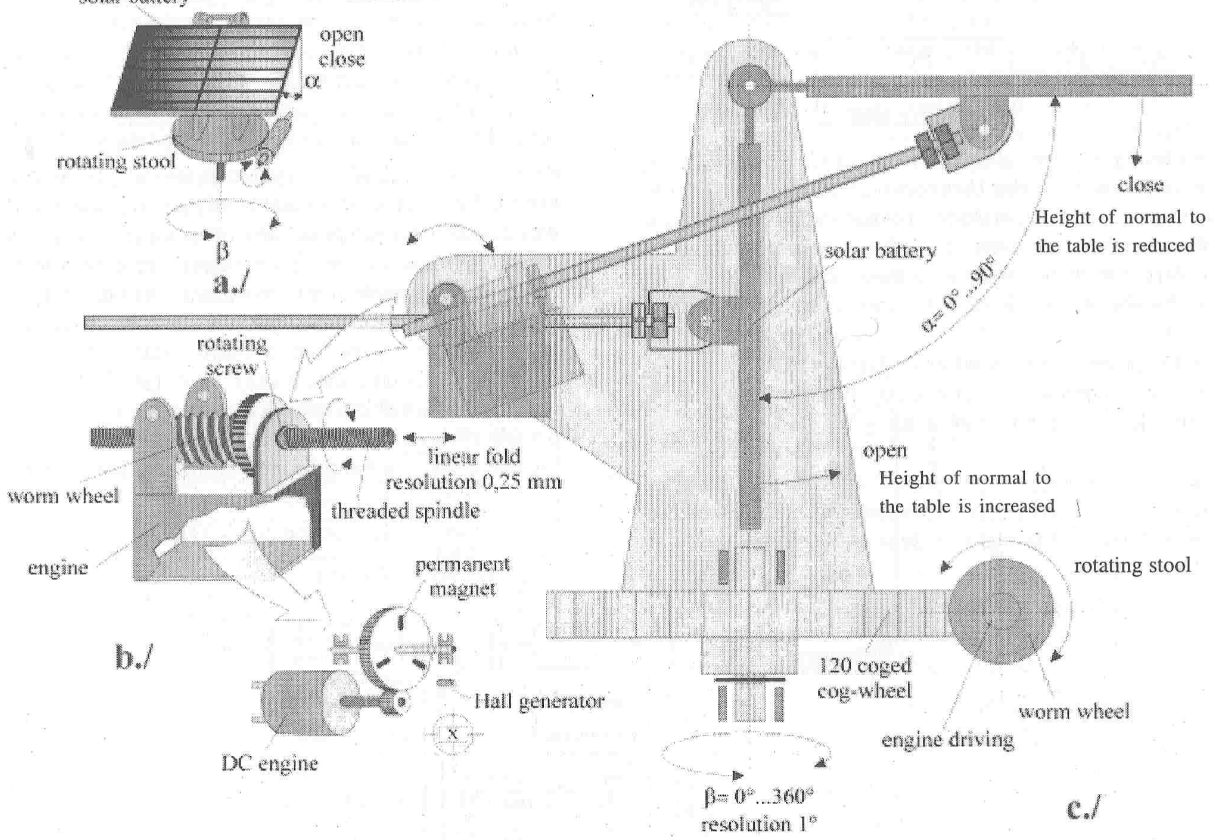
The positioning of the driving DC motors is allowed by the permanent magnets pressed into the cogwheel and the Hall generator. Each motor drives a threaded spindle. The rotating threaded spindle moves a nut in axial direction. The accuracy of this movement is 0.25 mm. For setting the horizontal coordinate the rotating threaded spindle (Fig. a) rotates the stool which has cogs on its perimeter. For setting the height coordinate (Fig. b) a nut is rotated. This rotated nut pushes (lifts) or pulls (lowers) the solar cell with the threaded spindle (Fig. c).

1.3.4.1. Direction, movement and control of the solar panel of the Hunveyor-2

It is advisable to try to reach as much efficiency as possible with the daytime charging of the batteries with the solar panel,which provides power to the experimental space probe. The maximum efficiency can be reached if the radiation of Sun is perpendicular to the solar panel. Because of the orbital movement of the planets the location of the Sun relative to the horizon changes gradually. For this reason we established a system for the on board computer, which aligns the solar panel constantly in a position close to the perpendicular relative to the Sun.

The solar panel of Hunveyor-2 is mounted on a rotating table. It waits for the sunrise in horizontal position (default position). Two light sensors, fastened next to the solar panel, belong also to the Sun tracking system of the solar panel. The angle of vision is 90° for one of them, and 5° for the other. The sensor of 90° sends a signal to the on board computer as soon as it detects the sunrise. The setting (alignment) of the solar panel to the Sun is initiated immediately. The alignment of the solar panel is accomplished in two stages.

DIAGRAM FOR THE SOLAR PANEL ADJUSTING SYSTEM OF HUNVEYOR-2

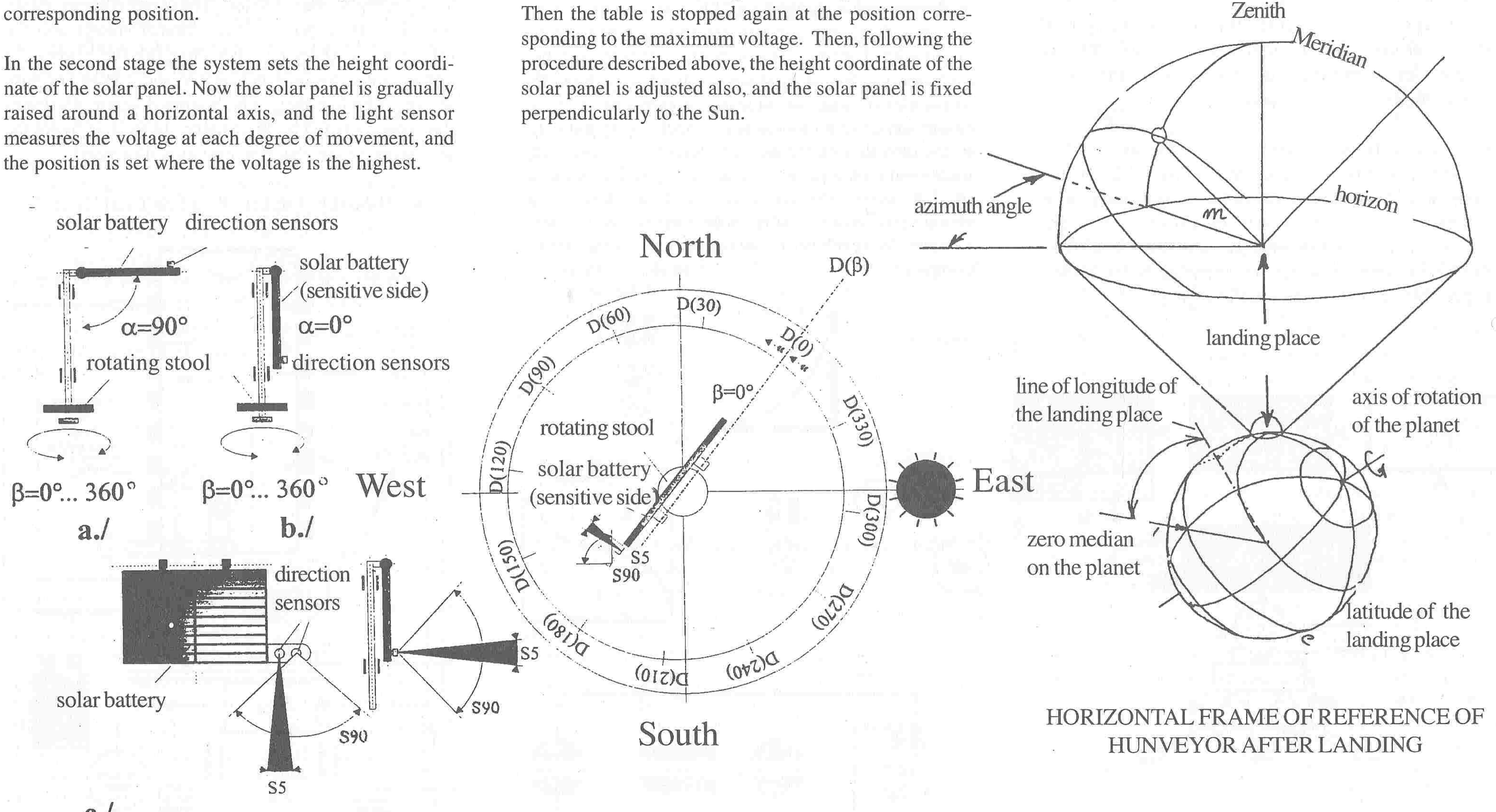


In the first stage the computer determines the horizontal coordinate of the Sun by rotating the horizontally aligned solar panel around the horizon, while measuring the voltage output of the light sensor having 5° angle of vision. The highest voltage is ensured when the horizontal coordinate of the longer edge of the solar panel is perpendicular relative to the horizontal coordinate of the Sun. The system stops the rotating table at the corresponding position.

In the second stage the system sets the height coordinate of the solar panel. Now the solar panel is gradually raised around a horizontal axis, and the light sensor measures the voltage at each degree of movement, and the position is set where the voltage is the highest.

The solar panel remains in this position as long as the produced voltage is above 90 % of the maximum value. When the voltage drops below this value, then the on board computer starts to find again the position perpendicular to the Sun. Again, the horizontal coordinate is set first, then the table of the solar panel is rotated around a vertical axis, and the sensor with 5° angle of vision measures the voltage in each degree of rotation. Then the table is stopped again at the position corresponding to the maximum voltage. Then, following the procedure described above, the height coordinate of the solar panel is adjusted also, and the solar panel is fixed perpendicularly to the Sun.

We have already completed the design, and started the construction of a Sun tracking system, which will no longer use processor time. With this new method it will be possible to keep the batteries constantly charged. In this way the risk of leaving the functional units of the probe without power is substantially reduced.

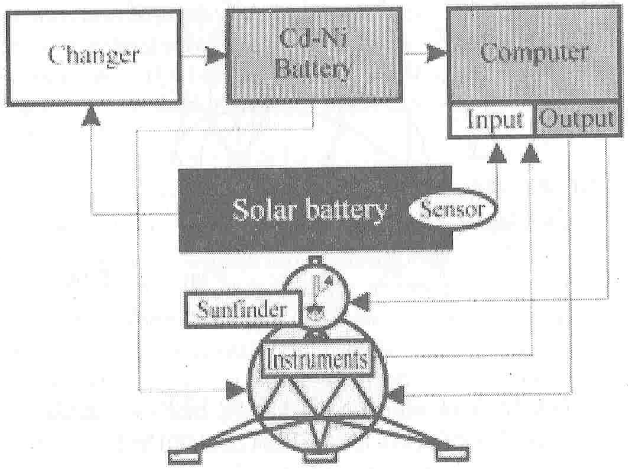


HORIZONTAL FRAME OF REFERENCE OF HUNVEYOR AFTER LANDING

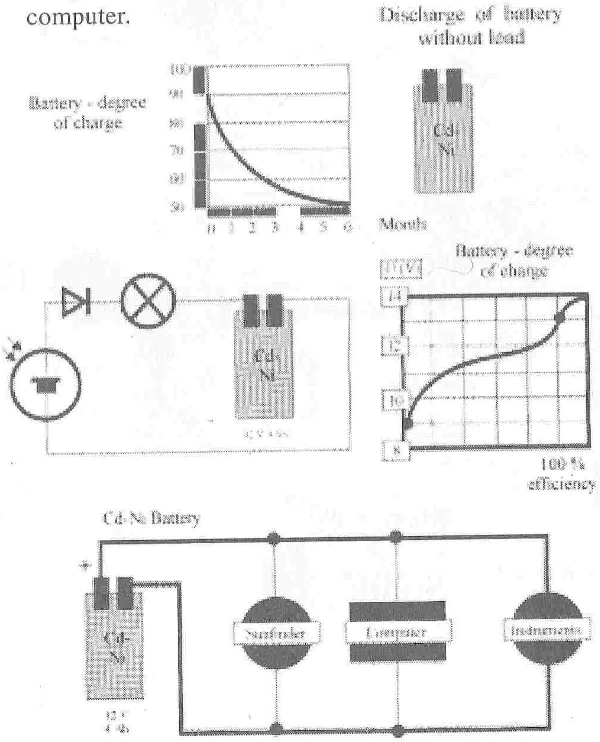
1.3.4.2. Energetics of Hunveyor-2: connection of the solar panel and the accumulator

The primary source of energy is the Sun. The radiation reaching the planet is converted to electric power by the solar battery for the Hunveyor. With the given voltage level the loadability of the solar battery is determined by the surface. This surface is limited for practical reasons, and the power produced by the solar battery is less than the power required for the operation of the instruments: the current output of the solar battery is much less than the current necessary for the operation of the system of the landing unit.

In the experimental model completed the solar battery is capable of producing a current output of 0.5 A, but the electrical systems need 2 A for the operation. This difference can be eliminated by the use of a Cd-Ni battery which has a minimum capacity of 4 Ah. Considering the efficiency, a useful operation lasting for 2 hours is possible after 12 hours long charging.



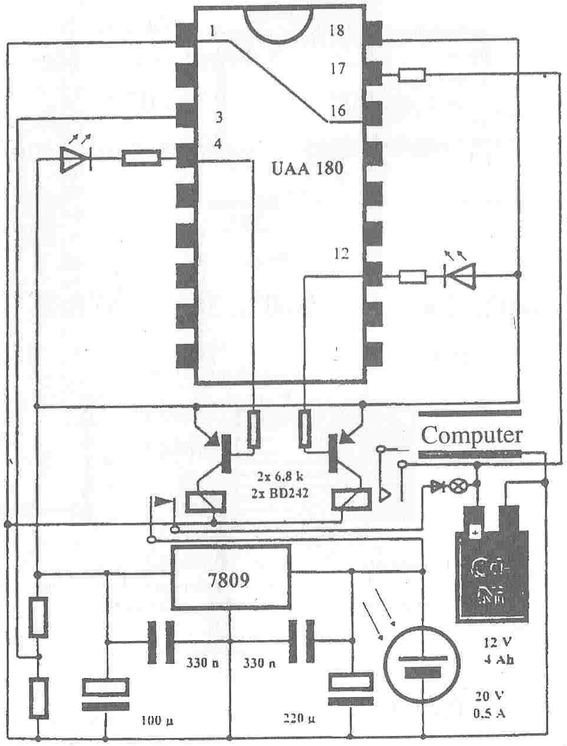
In the first figure, introducing the power supply system of Hunveyor-2, the functional setup of the system is shown. As can be seen in this diagram, the solar battery forwards the electric power through an automatic charger to the Ca-Ni battery. The initial 9 V of the nine-cell battery is increased to 13.68 V within about 12 hours. A higher voltage would mean an overcharging that damages the battery. The battery voltage is monitored by the automatic charger, and it also takes care of turning on and off the on board electronics when not engaged with charging. The on board computer is turned on as soon as 9 V is reached, and it starts to direct the sun finder having two degrees of freedom. The sun finder makes sure that the solar panel is perpendicular to the direction of radiation by tracking the Sun. The instruments of Hunveyor-2 are energised as soon as the battery is fully charged (C=100%). The actual charging status of the battery is detected by the automatic charger and the relevant information is sent to the control computer.



It is advisable to turn on the active measuring period already in the producing (charging) stage, because in such case the battery supports the "drip charging" mode also.

At the top part of the figure a diagram shows the self discharging process of the battery if it is left alone. For this reason it is necessary to recharge the battery during a long interplanetary mission. The centre diagram shows the relationship between the terminal voltage and the efficiency of charging. For charging the battery the voltage must not drop below 9 V, and it must not raise above 13.68 V either. The bottom diagram illustrates the consumers fed by the battery. In the last figure the schematic of the charging circuit is illustrated.

SCHEMATIC OF THE BATTERY CHARGER



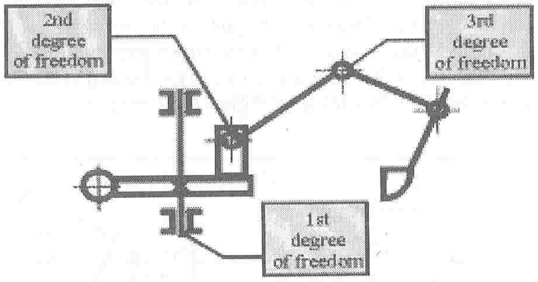
1.4. EXPERIMENTS, MEASUREMENTS ON HUNVEYOR

1.4.1. The robotic arm and the TV camera as system for soil measurements

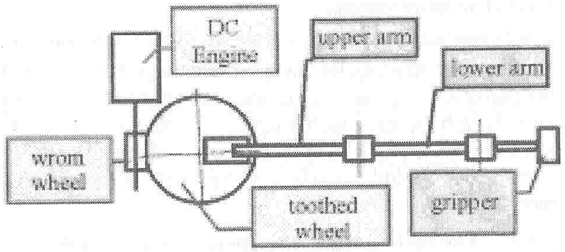
Two robotic arms have been developed for mounting on Hunveyor-2 in order to perform two different functions. One of the functions is the soil investigating work already introduced for Hunveyor-1, which is supplemented with a scoop up movement. The other function to be performed is the measurement of hardness.

1.4.1.1 Design of the soil sampling robotic arm

The robotic arm is mounted on the space probe (on a stand). With the help of rigid parts (1) and movable joints (2) the moving mechanism (drivers, motors) (3) this can performs mechanical operations on the soil and rocks of the desert around the space probe with the instruments (effector) (4) mounted on the end of the arm. If we want to reach any point within the outreach, then it is necessary to establish the possibility of moving in three directions independently. For this reason the robotic arm of Hunveyor-2 has 3 degree of freedom.

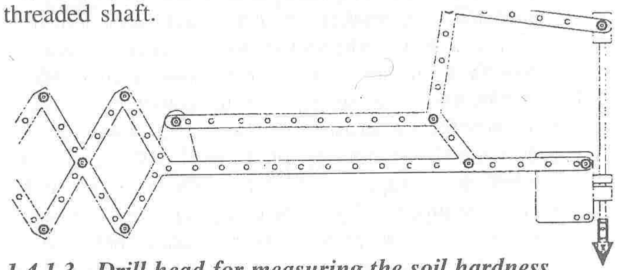


A small motor (7 V, 200 mA) is used for driving each robotic arm. Various mechanical links are installed between the driver motors and the driven units. These are the components of the drive chain, which couple the rotating movement of the motor (speed, torque) to the nature of the driven unit. The small motors of the robotic arm drive worm gear or threaded spindle through reduction gear. The soil is tested with a scoop mounted on the end of the arm.



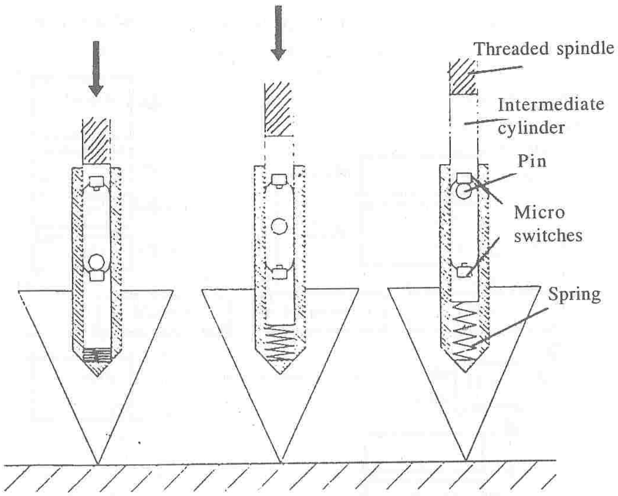
1.4.1.2 Arm and instrument for measuring the soil hardness

A stronger arm is used for measuring the hardness of ground. On the Surveyor this is a scissors (telescoping) arm, which is supplemented with the framework at its end for receiving the special drilling device. The arm is made of copper pipe, it has a relative large mass, and it is driven (extended or retracted) by a 12 V 700 mA motor through a worm gear. Thus the arm has only one degree of freedom. The instrument (drill) mounted on the end of the horizontal arm has also one degree of freedom. A 7 V 200 mA DC motor drives the measuring drill head located at the end of the vertically aligned threaded shaft.



1.4.1.3. Drill head for measuring the soil hardness

The configuration of the drill and the drill head allows the measurement of three of hardness ranges. The threaded spindle driving the drill head is able to move within a specified range in vertical direction. A spring is installed within the drill head to the end of the spindle, which is pressed by the spindle through a spacer cylinder. A pin protrudes from the small cylinder through a hole on the side of the cylinder. This pin operates as a three -position switch: a micro-switch at the top and at the bottom can close a signalling circuit, while in the third position the circuit is open, and this is the indication of the central range.



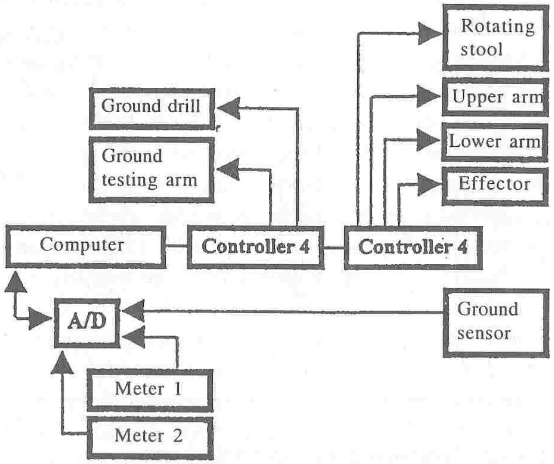
1.4.1.3 Measuring with the drill head

In the initial condition the pin is pressed to the upper micro-switch by the spring located within the drill head. When the drilling takes police in **soft soil**, then the advance of the drill require a smaller force then the force required for compressing the spring in the drill head. In this period the circuit remains closed through the upper micro switch. A higher force is required when drilling in a **firm soil**, and the spring is somewhat compressed as a result. The circuit is broken at the top switch, but not closed yet by the bottom switch. This is the indication that the soil hardness is in the medium range. When drilling takes place in **hard soil**, the spring is compressed fully, the pin closes the circuit through the bottom micro switch, and this is the indication of the hard soil range. With this configurationit is possible to distinguish three different soil hardness ranges with the help of two contractors on the drill head.

1.4.1.4. Controlling the robotic arms of Hunveyor-2

The two robotic arms of Hunveyor-2 are controlled with the help of Controller 4 unit obtained from the Robot Evolution set. Controller 4 is a small special purpose computer, which is composed of a micro controller, a memory, I/O circuits and power stages. In the Controller 4 unit there are 4 equivalent programmable channels.

(One channel can handle 6 contractors.) By linking two controllers, it is possible to program 8 channels for the robotic arm unit shown in the diagram.



1.4.1.5 The robot arm and camera as a cooperating set of soil testing instrument

The essential mechanical properties of the soil can be tested and observed with the help of operations made with the arm and on the basis of pictures transmitted by the camera. The features which can be observed include the granular nature and colour of the soil, dust accumulated on rocks and colour of the soil beneath the rocks. Conclusions can be drawn from the observations on any wind driven dust, as well as on composition of rock and soil. While the arm is being manipulated, it is possible to assess the thickness of the dust laying on the firm soil. The thickness of the dust can also be determined from the scale mounted on the leg of the space probe, or from the sinking of the leg into the soil. Thermometer probes are mounted on the end of the arm.

1.4.2. Measurements on the temperature of the soil and atmosphere

The measurement of the temperature of the atmosphere is a simple operation, for this reason is has been included in the minimal space probe. The value shown by the thermometer can also be read with the camera. The measurement is made while the arm is in extended position in order to reduce the interference from the various equipment. By measuring the temperature of the planetary (Martian) atmosphere we do not only obtain information on the changes of the atmosphere, but also we can make assumption regarding the thermal properties of the rocks close to the surface.

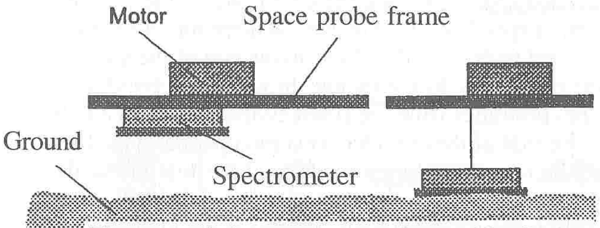
1.4.3. The spectrometer

The figure below shows a piece of equipment which is suitable for investigating the composition and the structure of the material of the soil. A diode emits light with various wave length values, which is reflected from the ground into a photo-transistor. After processing the obtained string of signals it is possible to assess the material of the soil surface.

1.4.3.1. The main units of the spectrometer system

The spectrometer of the Hunveyor experimental space probe consists of five main components. A **central computer** (a PC in this case) performs the tasks of controlling and data processing. The **light source control unit** switches on the light source having the colour required for the testing. An **analogue-digital converter** receives the signal from the **light sensing units** and generates signals in the form necessary for the computer. The light sources have different colours in order to provide the light with various wave lengths as necessary for the measurements.

The spectroscope itself has four main parts. The so called head unit (1) houses the photoelectric devices; 5 LEDs and 1 phototransistor. The light sources are controlled by a control unit (2); it makes sure that always the suitable light source will be on. The various light sources produce different light intensity as a result of identical currents, for this reason a balancing resistor is to be applied in order to make sure that the measurements are comparable. The analogue-digital converter (3) produces digital signals from the analogous output signal of the photo-transistor so that it could be processed with the computer. A power supply unit (4) is used to provide the necessary energy to the equipment. This unit provides a stable voltage at 5 V and 12 V levels.



The suspended spectrometer is lowered by the space probe to the ground by an electric motor.

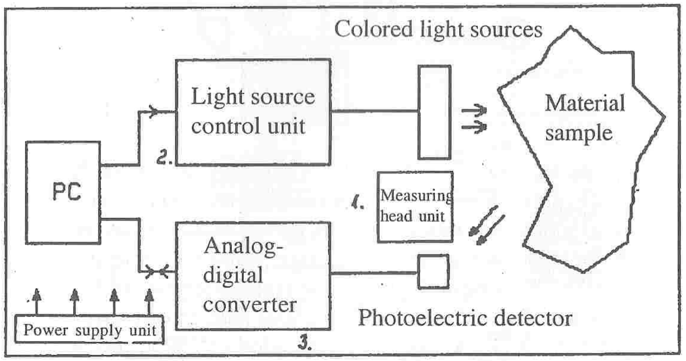
The spectrometer is able to operate as an independent instrument, and also as part of the space probe. With its properties (ensured by semi-conductors, as well as by the omission of moving parts, and the use of digital I/O devices) this measuring unit complies with the criteria of modern sensor based instruments.

For the duration of the measurement the spectrometer shall be kept in an environment free of light, so that external light would not interfere with the result of measurement. This can be accomplished with suitable cover, and the light protecting sheet.

1.4.3.2. The principles of the measurements

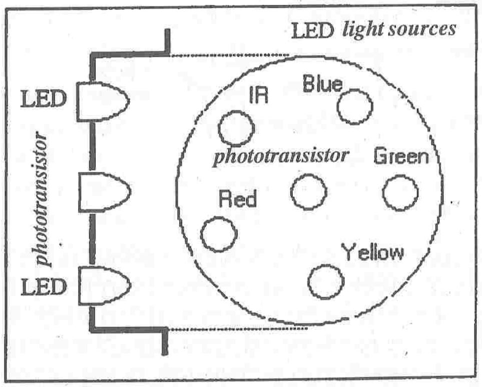
The principle of the measurement is based on the phenomena that the light of various wavelengths is reflected with different intensity by the various materials depending on their composition. If a chart is available that shows the reflecting curves of the various materials, then it is possible to identify the material from the measuring results.

The light with various wavelengths is produced by light emitting diodes (LED) from the infrared range to the blue colour in five steps. The LEDs are controlled by a counting circuit. Because of the discrete wavelengths the equipment has limited capabilities, but it is still excellent for taking comparative measurements. The reflected light is detected by a light sensing component (phototransistor). This phototransistor produces an electric signal on the basis of the detected light. Electric signal is forwarded to the computer through an analogue-digital converter.



1.4.3.3. The structure of the measuring head

The measuring head has twofold function. It houses the light sources and the light detector unit, and it ensures that no external light reaches the inside of the equipment, because any external light would falsify the measuring results. The head is designed in a way that the light sources are located along a circle, and the light detector is at the middle. In this way the distance between any light source and the detector is always the same. The measuring head is also to be provided with a non-transparent flexible boot, which closes the space around the head when placed on the material to be tested in order to prevent external light from getting in.



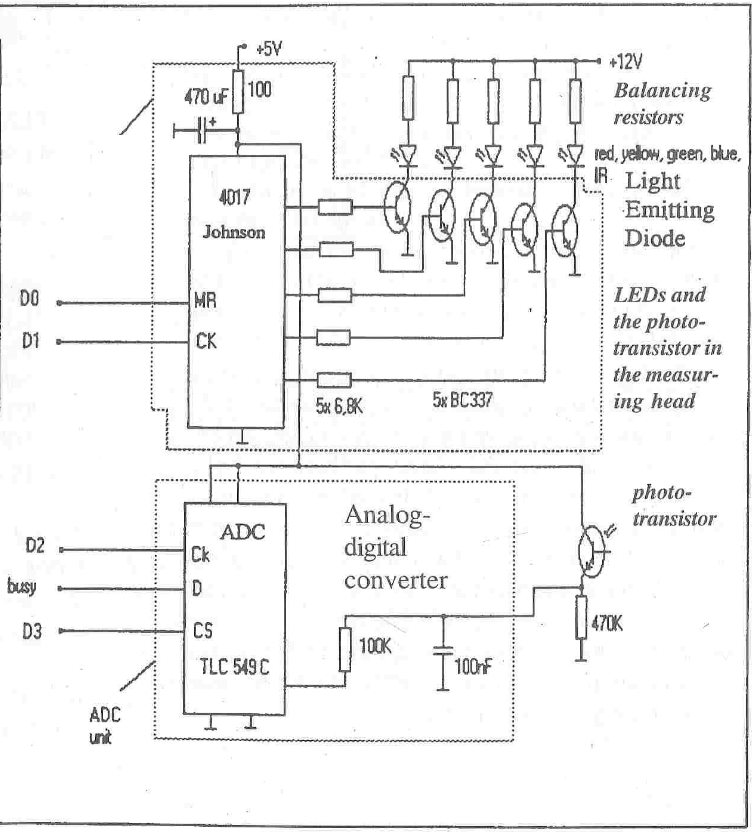
MEASURING HEAD OF SPECTROSCOPE:

THE SIMPLEST VERSION CONTAINING 5 LEDS

Yet another robotic arm of the space probe (having a simpler structure) will be used to move the measuring head, including the placing the head on the specimen.

Later on the entire measurement will be configured for the purpose of integrating into the interface system of the space probe. This will be provided with a microcontroller, which will also carry out a preliminary data processing.

SCHEMATIC FOR THE MEASURING HEAD AND CONTROL UNIT OF THE SPECTROSCOPE



1.4.4. Measuring the levitating dust cloud above the lunar surface

Surveyor space probes took some pictures even after the Sun has set at the place of the landing on the Moon. In the direction of the Sun setting it had been observed that a narrow bright zone is shining about 1 m above the lunar surface. Some time later the instrument deployed by the Apollo mission also detected this phenomenon appearing above the surface. According to our interpretation, this is a multiple component ionised dust cloud. The measurement of this dust cloud has also been envisaged with the Hunveyor experimental educational space probe. For this purpose we developed an instrument package for executing three different measurements under the direction of Mr. Tivadar Földi. In the following paragraphs these measurements will be introduced briefly.

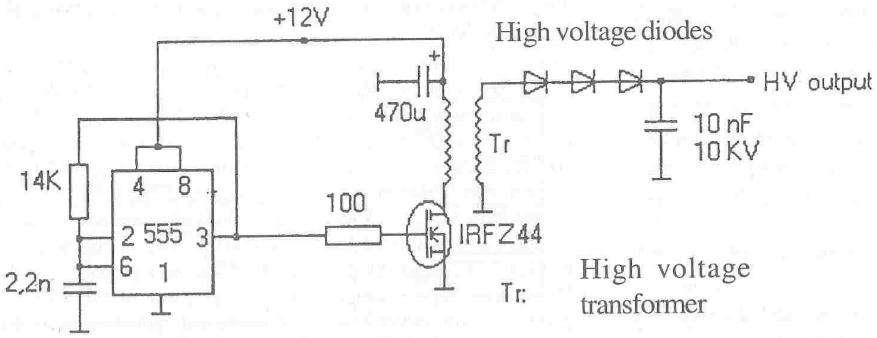
1.4.4.1. Measuring the strength of the electric field above the lunar surface

The following experiment had been carried out on the flagship Saint Steven of the Austrian-Hungarian Monarchy. With the conductor bar (which corresponds to an antenna of today) the strength of the electric field was measured between the deck and the clouds. Later on this experiment was improved by mounting a weak radioactive material on the end of the antenna. The radioactive material has the function of emitting charge to its environment, which enhances the flow of ions, and a dynamic equilibrium is established faster between the layer above the surface and the active part of the grounded measuring system.

1.4.4.2. Measuring the changes of the strength of the electric field

The ion cloud is gradually generated by the ultraviolet light of the Sun above the lunar surface. As a result of photoelectric effect the UV radiation ejects electrons from the molecules of the rocks on the surface. The electrons escape the Moon in the very thin "atmosphere". The UV radiation also hits dust particles frequently. In this way the dust particles become positively charged as a result of photoelectric effect. This rather thin atmospheric feature is called an ion cloud, which is levitated by the electric expelling force above the surface, and it consists mainly of dust.

The space mill (rotating field meter) modulates the static electric field by mechanical means, thus producing a varying signal, which can already be amplified, and the sensitivity of the measurement can be increased by several orders of magnitude.

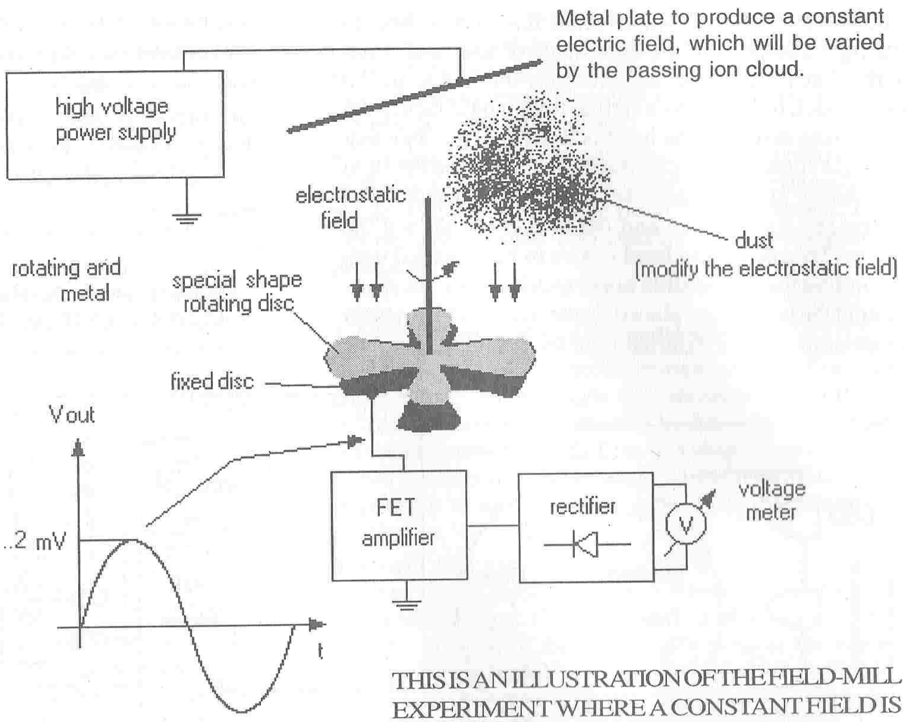


SCHEMATIC FOR A SIMPLE HIGH VOLTAGE POWER SUPPLY UNIT

1.4.4.3. Measurements of the levitating ionised cloud by a field-mill

The field-mill device can be used in two situations for detecting the ion cloud. The first situation occurs when the ion cloud is being generated from an arbitrary point of the daytime. The second situation is encountered when the ion cloud floats above the Hunveyor experimental space probe after sunset or prior to sunrise. The configurations used for these two measurements are introduced here for the first and the second situation, respectively.

When the fixed Maltese cross is free (not covered by the four rotating and grounded fan blades), then a charge accumulates on this fixed Maltese cross as a result of the field produced by the ion cloud. When the four blades of the rotating fan hides (shields) the Maltese cross, then the charge departs to the ground through a resistor, thus producing a voltage on the resistor. This is an alternating voltage because of the cyclic shielding, which can be amplified, and it follows the gradually increasing field strength of the ion cloud in a sensitive way.



The field-mill measuring configuration can also be used in another measuring position. A plate is mounted on the Hunveyor and charged with high voltage. An equilibrium static electric field is developed between the high voltage plate and the ground. If the ion cloud passes through the terminator at the sunset, the change in this static field can be measured with the field mill described above. This is a somewhat more complex equipment, which is shown in the figure. (The simpler experiment described in the previous paragraph can be derived from this diagram if the high voltage plate and the associated power supply unit is removed.)

THIS IS AN ILLUSTRATION OF THE FIELD-MILL EXPERIMENT WHERE A CONSTANT FIELD IS PRODUCED BY A CHARGED PLATE. THE EQUIPMENT IN THIS CONFIGURATION MEASURES THE CHANGES IN THE ELECTRIC FIELD WHILE THE ION CLOUD PASSES BENEATH THE METAL PLATE.

1.4.4.4. Measuring the dust content of the lunar levitating ionic cloud above the surface

The ion cloud is gradually generated above the lunar surface and it contains dust particles too. With the help of a special dust collecting system operated for a prolonged time the integrated dust content of the ion cloud can be measured (FOELDIX-1).

1.4.5. The rover of Hunveyor-1

The Surveyor space probes were not accompanied by a rover, but the Pathfinder, which made a successful soft landing on Mars, already included such a device. This gave us the idea to include an off road vehicle in the equipment of Hunveyor.

1.4.5.1. The rover of Hunveyor-1 on the test field

The mobile unit of Hunveyor is the rover, which can be moved around the test terrain freely. A **camera** is mounted on the rover, which can be used to explore the surface. Additionally, two import auxiliary units belong to the system, but these are not directly placed on the test terrain. One of them is a **server computer** which keeps contact with the environment, and the other is the small capacity **on board computer** of Hunveyor.

1.4.5.2. The rover of Hunveyor-1 on the web

A web surface has been established to allow transmitting command for the rover of Hunveyor, as well as to the other movable component, such as the robotic arm, from a station connected to the Internet. It is possible to move the rover forward, backward, left and right, while the arm can be moved up, down, forward and backward. As a result of the commands, the corresponding movements are accomplished on the test terrain, and the user has a feedback in the form of picture transmitted by the camera. The picture of the camera of the rover shows the actual view of the equipment on the test terrain.

1.4.5.3. The subunits of the system of Hunveyor-1 rover on the web

1. **The web-surface of the user:**

The user starts a browser with its own computer to find the user surface of Hunveyor (URL). The user is able to issue commands to the rover and to the arm of the lander of Hunveyor by clicking on various buttons. The result of the operation can be checked on the monitor.

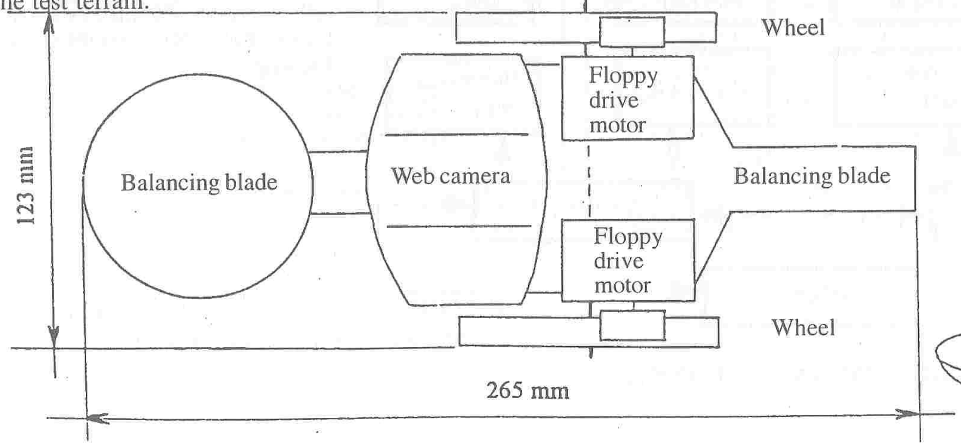
2. **The server:**

The command coming through the Internet from a user computer is processed by the server computer, which sends the relevant information to the on board computer of Hunveyor. The server also receives the picture of the camera of the rover. The server forwards the camera picture to the Internet. The server is a PC working with WindowNT operating system. It has an average configuration, and it keeps contact with the environment, with the on board computer and using a communication protocol.

3. **A The role of the on board computer of the Hunveyor (Hunvok):**

The on board computer processes the commands received from the server, and starts the operation of the mobile units. The on board computer has a DOS operating system, and it has a very simple configuration.

CONFIGURATION OF THE ROVER OF HUNVEYOR-1. THE TWO WHEEL ARE DRIVEN BY A FLOPPY MOTOR. THE CAMERA IS MOUNTED IN FRONT OF THE WHEELS.



4. **The TV camera of the rover:**

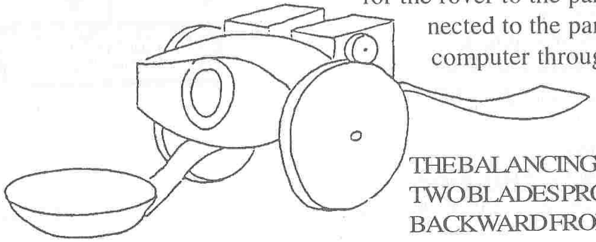
The camera carried by the rover transmits a picture to the server. This is a standard web camera.

5. **The rover of Hunveyor-1**:

This is a small carriage constructed from the elements of metal construction toy and Lego units. The operation of the carriage is controlled by the on board computer. Each of the two wheels is driven by the stepping motor. The motors can be controlled separately for the turning operation of the rover. Because of the allocation of the weight it is necessary to use a balancing blade in front.

1.4.5.4. Communications between the subunits of the rover-web system

The communication and transfer of data among the subunits are made through standard buses and with the help of corresponding protocols. The server receives packages forwarded by TCP/IP protocol from the Internet, which are served by CGI scripts. The home page (i.e. the user surface) has been prepared with a home page editor software. This processes the commands received from the remote user, and sends the relevant information to the on board computer. The server also communicates with the environment by the use of TCP/IP protocol through the Internet, including the transmission of the camera picture. The camera uses the parallel port of the server, and it has its own image processing software. The server also communicates with the on board computer of Hunveyor through the serial port via an RS232 cable. It writes the processing commands to the serial port. The on board computer receives the commands, and starts the operation of the mobile components accordingly. It writes the commands for the rover to the parallel port. The rover is connected to the parallel port of the on board computer through an interface.



THE BALANCING OF THE ROVER IS MADE BY TWO BLADES PROTRUDING FORWARD AND BACKWARD FROM THE AXLE

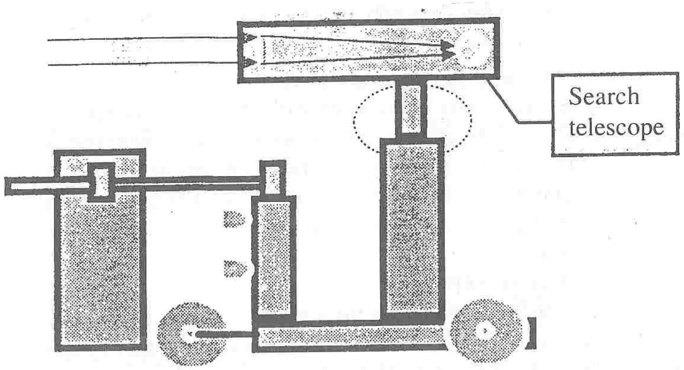
1.4.6. The rover units of Hunveyor-2

Two small rovers were provided for Hunveyor-2 constructed in Pécs. The earlier model is larger and has three wheels (Rover-1). One of its characteristic feature is a grabbing scissors, which extends in forward direction and is suitable to grab a cylindrical instrument container. Yet another experimental unit mounted on the rover is a light finder telescope. Lamps and optical sensors are also installed in the rover.

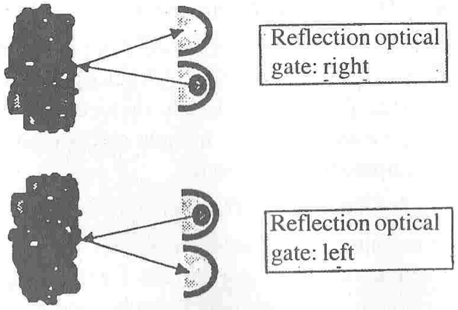
1.4.6.1. Direction and control units of the Hunveyor-2 Rover-1

The Rover-1 model has been constructed with the objective of deploying instrument container, and to allow to develop and demonstrate the mechanical, kinematics and control functions of the robot. The planned series of operation is as follows: the rover departs from the lander of Hunveyor-2, fetches the instrument contained from the lander in order to deploy it on the planetary surface. The rover bypasses any obstacle detected in its way, then it finds its targeting lamps, measures the angle and steers itself to the target. It deploys the container at the target point, and backs up from the container in reverse mode.
Functional units:
Main movement of rover: forward, backward. Steering: left, right. Scissors type arm for grabbing and deploying instrument container. Mechanism for lifting and lowering the instrument container. Optical reflection sensor, right side. Optical reflection sensor, left side. Drive motor of the rotating light finder telescope. The sensor of the light finder telescope provides an input signal. Control unit of the rover.

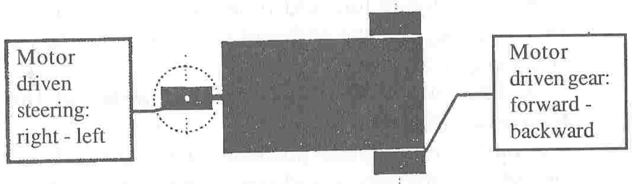
The on board control of Rover-1 is accomplished through two controllers of the Robot Evolution set. The following functions are connected to the 8 control channels of these controllers:
1. Scissors for grabbing and deploying the instrument cylinder
2. Lifting and lowering the instrument cylinder
3. Main movement of Rover-1: forward and backward
4. Main movement of Rover-1: steering right and left
5. Optical reflection sensor: right side
6. Optical reflection sensor: left side
7. Light finder telescope (input), whistle signal (output)
8. Left and right rotation of the drive motor of the light finder telescope



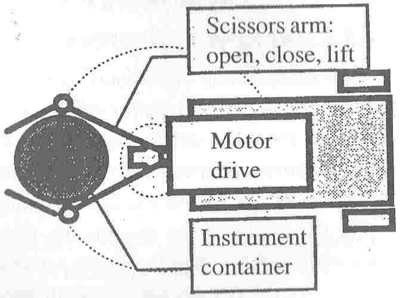
ROTATING MOTOR OF THE LIGHT FINDER TELESCOPE. THE SENSOR OF THE TELESCOPE PROVIDES AN INPUT SIGNAL.



REFLECTION OPTICAL SENSOR, RIGHT SIDE
REFLECTION OPTICAL SENSOR, LEFT SIDE
THE REFLECTOR CAN BE SWITCHED SEPARATELY

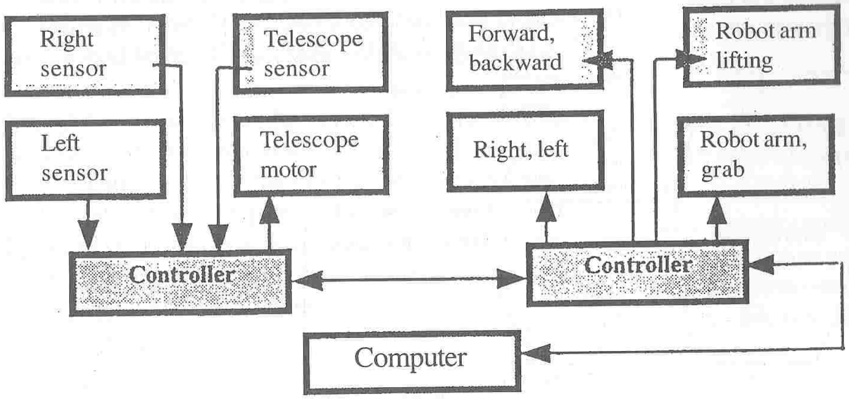


MAIN MOVEMENT OF ROVER: FORWARD, BACKWARD
STEERING: LEFT, RIGHT



SCISSORS ARM FOR GRABBING, DEPLOYING

MECHANISM FOR LIFTING AND LOWERING INSTRUMENT CONTAINER



CONTROL SYSTEM OF THE MODEL

1.4.7. Optical-chemical sensors on Hunveyor-2

For medical applications - such as blood gas analysis - sensitive optical chemical sensor devices have been developed. They also can be used for environmental monitoring of dissolved gases, ions or other chemical substances.

Fibre optic devices sensors have small mass, low energy consumption and great variability, therefore multiple number of specific sensors can be mounted on a rover. We focused on gases, such as carbon-dioxide (CO_2), ammonia (NH_3), oxygen (O_2), sulphur-dioxide (SO_2) or hydrogen-sulphide (H_2S). The listed compounds are present in the atmosphere of Earth and Mars. Some of them also may indicate remnants of fossil living tissue.

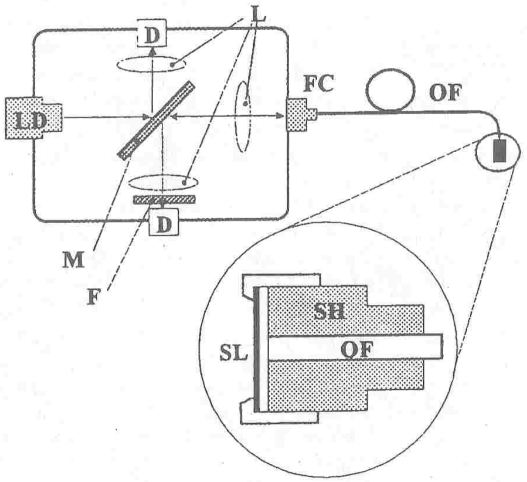


DIAGRAM FOR THE FIBRE OPTIC CHEMICAL SENSOR AND THE PHOTOMETER UNIT

1.4.7.1. Measuring principles with the fibre-optical chemical sensor

A fibre optic chemical sensor device consists of a selective sensing layer placed on one end of an optical fibre and of a small instrument, which measures the changes of the optical property of the sensing layer at a given wavelength. Among the variety of optical properties (and methods) available for the detection, the measurement of the reflection or fluorescence of the sensing layer is fairly simple and therefore frequently used.

The sensing layer of the sensor contains carrier and dye molecules. The carrier molecule catches selectively the compound of interest, while the dye molecule acts as a transducer: it converts the chemical signal (the presence of the analyte) to optically detectable information (e.g. its colour or fluorescence will be changed).

1.4.7.2. The fibre-optical chemical sensor unit

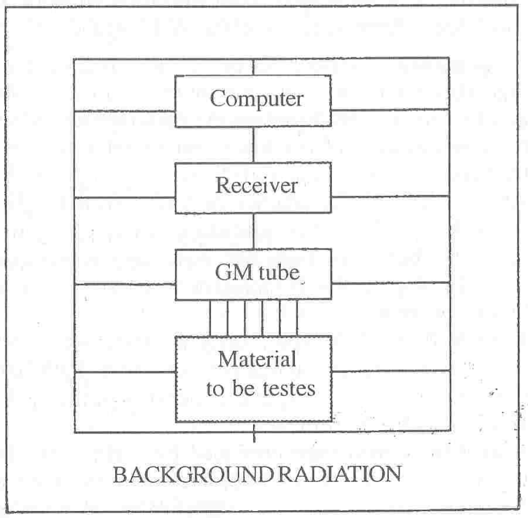
The construction of a fibre optic photo/fluorometer can be made very simply. A light emitting diode or a laser diode (LD) serves as light source. The incident beam passes through a splitter (M) and is coupled into the optical fibre (OF) via lenses (L). The light reaches the sensing layer (SL) at the sensor head (SH) through the fibre and is partially absorbed by the dye molecules. By using an absorption/reflection type sensor the reflected light comes back on the same way and is reflected to the primary silicon photodiode detector (D). A second detector is used to monitor the energy of the light source. In fluorescence mode the beam splitter is replaced by a dichroic- mirror and a filter (F) is placed between the detector and the mirror for complete separation of the exciting and fluorescent light. This fibre optic chemical sensor system has been developed by Dr. Barna Kovács for the Hunveyor-2 experimental space probe.

1.4.8. Measuring the natural radiation of the soil and the rocks

In the opinion of the research group working in Szombathely the first measurement to be done by the space probe landing on a planet should be the measurement of the radiation. If a strong radioactive radiation is present in the environment, then it might detrimentally influence other measurements. For this reason the first instrument developed for Hunveyor-3 was a radiation tester unit.

The radiation tester consists of three main components: one GM tube (Geiger-Müller counter) for detecting the hits, one receiver for counting the hits, and a computer for evaluating data.

The radiation to be measured might come from two sources: one is the material actually tested, and the other is the background. First the background radiation is determined, then the radiation of the rocks on the test terrain is measured. For the purpose of radiation measurements we selected rocks, which are similar in composition to those of the Moon and Mars (e.g. vesicular basalt, because on all planets the basalt is the most important effusive rock).



2. The test terrain of the Hunveyor experimental lander

2.1. THE MAIN PARTS OF THE TEST TERRAIN

2.1.1. The Hunveyor-1 after landing

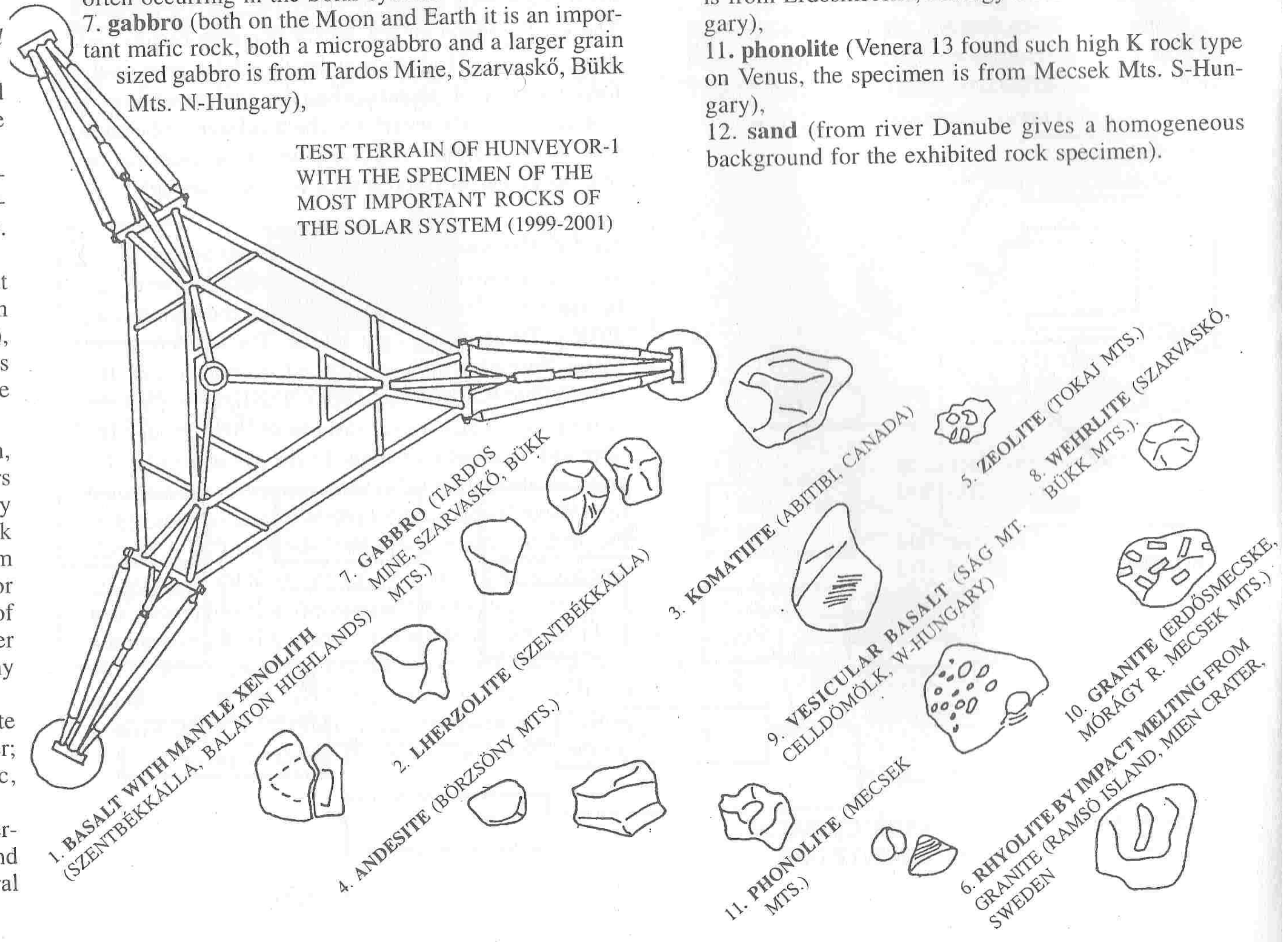
Until now we studied Hunveyor experimental space probe as a robot and as an engineering-measuring-communication system. Yet another important educational aspect of the experimental space probe is the test terrain established around the space probe where the operation can be shown in terrain conditions. It is possible to study the operation of the space probe in a realistic environment as if it has landed on a planet.

2.1.2. Rock types of the desert landscape arranged around Hunveyor-1

Students are able to gather important petrologic and geological knowledge in association with the space probe.

We arranged Hunveyor as if it were landed on a planetary surface and arranged around it the most important rock types from the Solar System rocky bodies. The list of rocky actors around is as follows:

1. **basalt with mantle xenolith** (basalt is the most common rock type in the Solar System, the specimen is from Szentbékkálla, Balaton highlands, W-Hungary),
2. **lherzolite** (over mantle xenoliths Martian meteorites represent this rock type from the Solar System, the specimen is from Szentbékkálla, W-Hungary),
3. **komatiite** (it represents early volcanism on Earth, high Mg content, probably present in volcanism of Mars and Io, (on Galileo, based on the measurement of very high temperature of outflow), and found similar rock by Venera 14 on Venus, too) Specimen originate from Abitibi complex, Canada, we borrowed from Dr. Tibor Szederkényi. The other spacemen is from Yilgarn of Australia, borrowed from Ms. Éva Papp, a researcher in the Geological Research Institute of Canberra; many thanks are due to them.)
4. **andesite** (a rock type mostly in island arc in plate tectonics, but present on Mars recognised by Pathfinder; the specimen is from the Inner-Carpathian Arc, Börzsöny Mts. N-Hungary),
5. **zeolite** (a rock type produced by surface weathering on Mars and also by hydrothermal volcanism and metamorphism on Earth. It significance as a mineral was revealed by Dr. Ernő Mátyás in Hungary, the specimen was collected in Rátka, Tokaj Mts. E-Hungary while visiting the area to study the silicate industry, the help from Dr. Ernő Mátyás is very much appreciated.
6. **rhyolite by impact melting** from granite (a larger piece from Ramsö island, Mien crater, Skone Province, Sweden, which exhibits clasts and fragments from the precursor rocks), The cosmic object hitting the granite had melted the rock, and the subsequent rapid cooling produced the effusive variety of granite. This specimen is a representative of the impact (converted) materials often occurring in the Solar system.
7. **gabbro** (both on the Moon and Earth it is an important mafic rock, both a microgabbro and a larger grain sized gabbro is from Tardos Mine, Szarvaskő, Bükk Mts. N-Hungary),
8. **wehrlite with high titanium content** (at Szarvaskő, both some gabbros and wehrlite ore peridotite has this unusual characteristic making them relatives to the famous high Ti basalt collected by Apollo 11 and 17 missions).
9. **vesicular basalt** (sometimes found by Apollo astronauts on the Moon, the specimen is from Ság Mt. Celldömölk, W-Hungary),
10. **granite** (we know it from the Earth in large block and as small fragments they occur on the Moon, probably Venus may have this rock type, too; the specimen is from Erdősmecske, Mórágy r. Mecsek Mts. S-Hungary),
11. **phonolite** (Venera 13 found such high K rock type on Venus, the specimen is from Mecsek Mts. S-Hungary),
12. **sand** (from river Danube gives a homogeneous background for the exhibited rock specimen).



TEST TERRAIN OF HUNVEYOR-1 WITH THE SPECIMEN OF THE MOST IMPORTANT ROCKS OF THE SOLAR SYSTEM (1999-2001)

2.1.3. Modelling planetary landscapes

The best known planetary landscapes include the Lunar and Martian surfaces where space probes have already landed. The Lunar surface is covered with fragmentation material, regolith, and many boulders. The Martian surface is also characterised by boulders, but the allocation of the rocks is the result of complex processes taking place on the surface. Viking 2 photographed some kind of white precipitation as well. Planetary landscapes arranged on the test terrain around the Hunveyor are not only characterising the materials of the rocks, but also the patterns of the fragmentary materials.

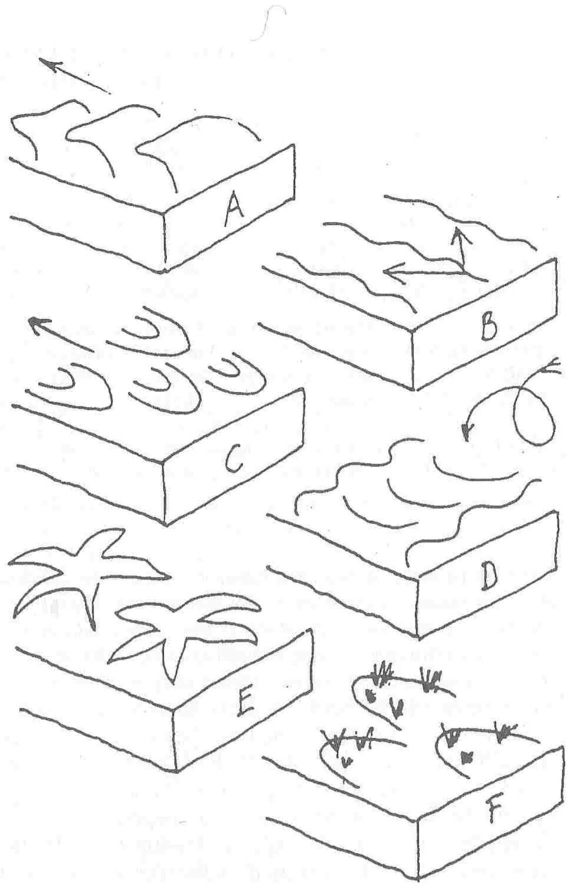
2.1.3.1. Lunar landscape

Among the Surveyor missions it was the No. 7 which found the most heterogeneous rock desert around itself. Such a landscape could be modelled by placing large pieces of rock on the test terrain. Surveyor-3 landed in a small Lunar crater, where the ground sloped in about 12 degrees. This can be modelled easily also, and at the same time in this model interesting challenges are encountered with the adjustment and operation of the robot arm, the camera and the solar panel.

2.1.3.2. Martian landscape

The landscape, where Pathfinder landed on Mars, is characterised by flow patters. The location of landing is within the "estuary" of Ares Vallis. For this reason some researches think that the arrangement of the rocks is the result of flowing water. The landing location of Pathfinder was also formed by the wind after the Chryse Bay had dried out: large dune like shapes were formed by the wind, which have been identified on MGS photographs.

Small scale landscapes were established on the test terrain to imitate the landscape of the landing location on Mars. The structures recognised on the Martian landscape are as follows: Erosion, caused by windblown fragmentation material and dust, can be observed on the rocks. Sand formations with various shapes, such as tails, flags and crescents can be observed in front or behind the rocks depending on the direction of the wind. In the windblown desert the surface of the sand also exhibits interesting patterns established by the wind. Some of such patterns are also demonstrated. The shape of the various barchanes and series of dunes also depends on the prevailing wind, on the firm rocks of the surface (as well as on vegetation in Earth), and on many other factors (e.g. particle size of sand). Such patterns can be found in Earth in hot and frozen regions alike (Sahara, Antarctica). If the sand desert on the test terrain is established according to the sand shapes observed on Mars, then we can get an insight into yet another interesting chapter of planetary geology.



VARIOUS ROCK SPECIMEN WERE PLACED ON THE SAND DESERT ESTABLISHED AROUND HUNVEYOR, WHICH CAN BE FOUND IN CERTAIN PLANETS OF THE SOLAR SYSTEM. IT IS ALSO POSSIBLE TO ARRANGE THE SAND USED FOR IMITATING THE DESERT SURFACE IN VARIOUS WINDBLOWN PATTERNS, SUCH AS DUNES, TAILS, BARCHANES. 6 OF SUCH FORMATIONS ARE DEMONSTRATED HERE. THE WIND IS SHOWN WITH ARROWS WHERE THE SHAPES ARE ESTABLISHED BY A PREVAILING WIND. ON THE OTHER HAND, STAR DUNES ARE FORMED BY WIND WHICH CHANGES DIRECTION FROM TIME TO TIME. THE INTRODUCED WINDBLOWN SHAPES APPEAR NOT ONLY ON SAND DESERT, BUT ALSO IN SNOW COVERED LANDS OF ICY DESERTS (E.G. ANTARCTICA).

Hunveyor-1
Lóránd Eötvös University of Sciences, TTK Department of General Physics, Cosmic Materials Research Group, Budapest
Minimal space probe: Autumn 1997
Frame: brazed copper pipes. Pipe diameter: 12 mm
Size (between centres of footpads): 1380 mm
Minimal space probe: camera + mirror, telescoping robot arm, PC based electronics. Assembler and Turbo Pascal programming languages.
Power source: Mains
Test terrain: sand and rock desert with rocks representing the Solar system.
Carriage (rover): Completed in autumn 1998, connected to Internet in spring 1999.
Accessories: one web camera. Information transfer with cables.
Special instruments: spectroscope, electrostatic dust collector
http://emc.elte.hu/~hargitai/hunveyor/

Hunveyor-2
University of Sciences, TTK Department of Inforamtics and General Technology, Pécs
Minimal space probe: Spring 1998
Frame: brazed copper pipes. Pipe diameter: 12, 15, 16.6 22 mm
Size (between centres of footpads): 1320 mm
Minimal space probe: camera + mirror, telescoping robot arm, PC based electronics. Logo, Turbo Pascal programming languages.
Power source: Mains, and also solar panel
Test terrain: under development
Carriage (rover 1) Three wheels, scissors grab for instrument container, light sources and optical reflection sensors (spring 1999).
Carriage (rover 2): 6 wheels, powered by solar panel (spring 2000)
http://davinci.jpte.hu/ami/urkutato/index.htm

Hunveyor-3
Dániel Berzsenyi College, Department of Technology, Szombathely
Minimal space probe: Spring 2001
Frame: brazed copper pipes. Pipe diameter: 18 mm
Size (between centres of footpads): 1250 mm
Minimal space probe: camera + mirror, telescoping robot arm, PC based electronics. Turbo Pascal 7.0 + Visual Basic 6.0 programming languages.
Power source: Mains
Test terrain: rock desert (Martian model).
Carriage: Under development
Special instrument: GM counter to measure the radioactive radiation of the environment and rocks.
http:/www.bdtf.hu/hunveyor3/

HUNVEYOR EXPERIMENTAL SPACE PROBES UNDER CONSTRUCTION IN SEPTEMBER 2001

2.2. ENVIRONMENTAL-ROBOTICS INTERACTIONS STUDIED ON THE HUNVEYOR AND ITS TEST TERRAIN

2.2.1. The interaction matrix of the Hunveyor

The environmental science requires the joint studying of technologies and natural processes. The relationship among the environmental processes and the technologies is rather complicated. To be able to identify the interactions and cross effects between the two types of processes we can compare the processes after describing them in a simplified manner.

In earlier works (Bérczi, Cech, Hegyi, 1992) we have already summarised the possible simplest way of describing the technologies. In this description of technology we use a principle known in physics: i.e. the principle of movement along a constraint path. The technology is described with three processes occurring simultaneously. These three threads are associated with MATERIAL, MEANS and OPERATION. Technological descriptions are often provided only as a list of sequential operations. The curriculum dealing with technology of materials (e.g. Bérczi, 1985) focuses on the sequence of changes in the conditions of materials. The curricula introducing the mechanical systems deals with the series of means used for processing the materials.

Our description deals with the three threads simultaneously. In the technological description *the major actor of the technological process is material*: the ***material*** is passed through a constraint path represented by the processing ***machines*** (referred to earlier as series of means of production). At the same time, the machines divide the production process into a ***sequence of operations***. The series of ***changes of conditions*** suffered at the various machines also characterise the process. Each of the three characteristics of process, i.e. operations, series of material conditions and machines, provides a certain picture of the production process separately, but in order to have a full qualitative and quantitative description of technologies it is necessary to treat these three characteristics simultaneously. The same kind of process description can be also applied for describing the environmental streams. For the proper description the "riverbed" of the natural stream is to be identified, which corresponds to the constraint path mentioned above. The counterparts of the operations will be scenarios of condition change (environments), in which the stream of material is being converted. For demonstration imagine a simple example: the flow of water at a section of its path. Rainwater falling on a karst area is swallowed by dolines. The limestone is partly dissolved, and caverns are formed as a result, while flowing in the direction of the fall.

HUNVEYOR'S MEASURING UNITS AND SUBSYSTEMS / ENVIRONMENTAL STREAMS: MATRIX OF INTERACTIONS

Streams on the planetary surface Hunveyor Structural Units	WIND, STREAMS OF GASES	SOIL, DUST ON THE SURFACE	COLORS, INCIDENT LIGHT FROM SUN	HEAT, THERMAL CONDITION	ELECTRIC CHARGES, CHARGED PARTICLES	MAGNETIC GRAINS
FRAME, SKELETON AND SURFACES	Great wind pressure is dangerous	Dust may sediment on free surfaces	Scattered sunshine is disadvantageous	Thermal dilatation, insulation, conduction	Charged particles can charge up frame of Hunveyor	Magnetic grains may sediment on the frame
SENSORS, INSTRUMENTS, THEIR ELECTRONICS	Measurements on wind-speed, chemical components, etc.	Filtering in, taking in soil for analyses in the instruments of Hunveyor	Reflectance spectroscopy, textures, images by spectroscope and camera	Measurements by thermometers, dilatation-stamps, etc.	Measuring the levitating charged dust cloud above lunar/ Martian surface	Selection of magnetic grains by special pattern of magnets
ENERGETICS: SOLAR PANEL	Dust-clouds may shadow the Sun	Sediment dust is disadvantageous	Basic energy production is supported by solar panel	Mirror+lens can focus solar light to heat up some materials		

The path of water in the limestone caverns can be divided into two stages: the one when the limestone is dissolved, and the one when the limestone is built (stalactite cave). Once water flows to the open it will assume additional destroying and building stages. Rapid stream of water can move rocks, and the boulders in the stream get "milled". When the water reaches plane land then sandy meanders are built, and so on. At locations close to towns the water flows into water intake stations, where it is cleaned. From here on the flow of water is included in operations which already belong to the category of technologies. If, for instance, water is used in a sugar mill, then it is utilised as an auxiliary material in the processing operations; the water takes up other materials, which are filtered in subsequent operations, but to some degree it remains contaminated by the materials introduced by the technology. This contamination will be carried further for the rest of its path. In this way the concentration of the contamination is changed in the materials detoured from the natural processes to the technological processing (industrial plants, or consumption by the population).

Now, the environmental streams utilised in industrial plants (or utilities) and the material flows of technologies can be regarded as *streams that intersect each other*. The technological "paths" depicted in horizontal direction are "intersected" by environmental streams running perpendicularly. In our matrix, simultaneously showing the technologies and the environmental streams, each water intake, utilisation and discharging of water by various industrial plants occupies one cell in this matrix. The water intakes of various plants are aligned in the same column. Similarly, the data of the air circulation occupies the cells of a single column. **The major role of the matrix is to provide a single map to show simultaneously and in a understandable and convenient manner the material circulation of the important plants of settlements relative to the important environmental streams.**

This kind of arrangement of series of operation into a matrix can also be applied for describing the processes of measuring and information technologies. By using the matrix for the description of a space probe, **we obtain a map of interconnected measuring and information technologies.** Basically, a space probe is a fabric of many measuring, information and data processing technologies. In our matrix of space probes the measuring technologies are aligned in horizontal rows, which are intersected by columns representing the environmental streams. The columns of the matrix include various measuring operations (or only their effects) of the corresponding stream on the surface. E.g. one of the columns is occupied by streams of wind and dusts. Various sensors are placed into the streams of air and materials. In the matrix of the measurements of the space probe we are able to see simultaneously the important instruments of the measuring technology, as well as the streams of the environment considered for the measuring technologies.

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This work has been dedicated to Eugene Shoemaker

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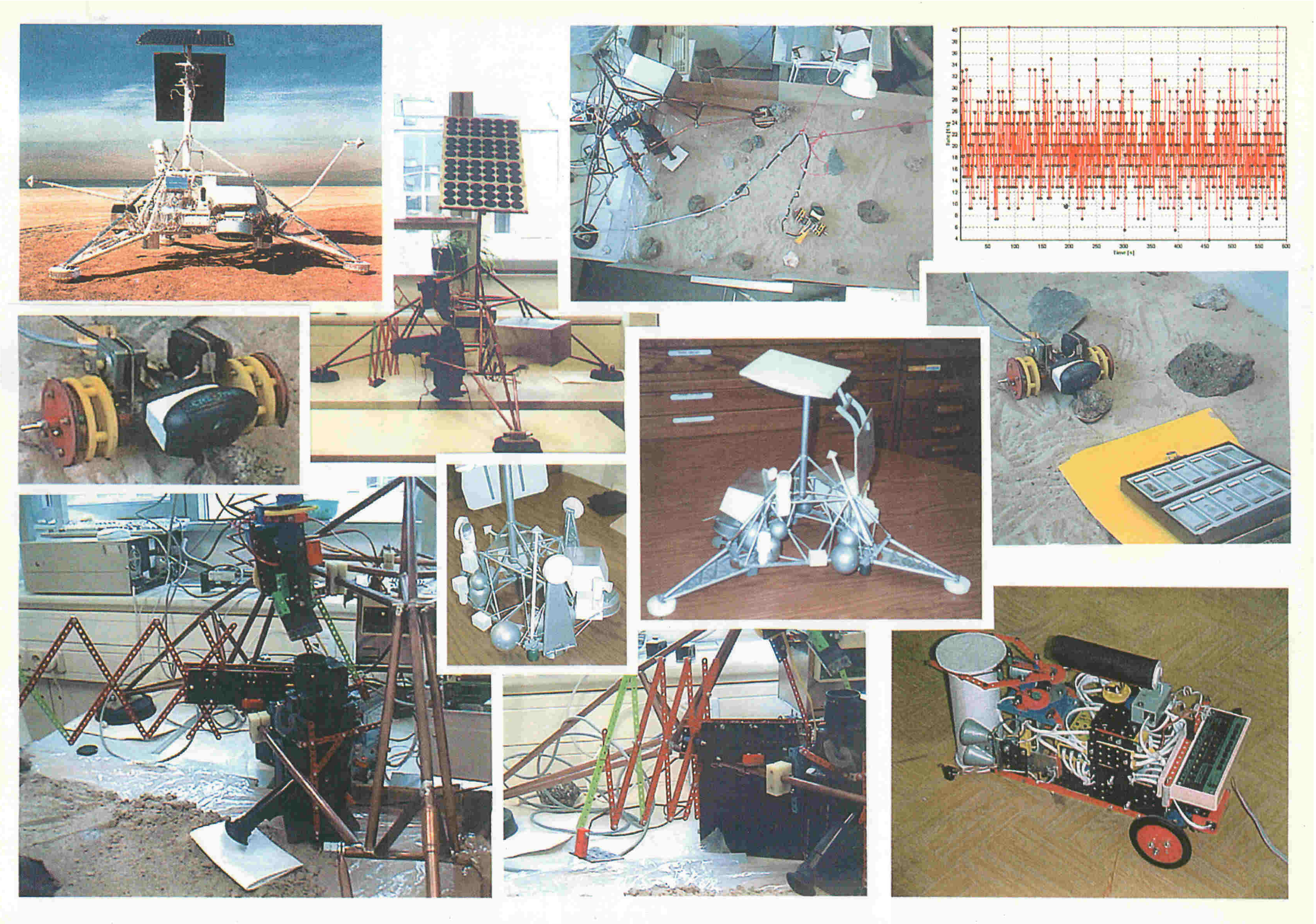
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