Geographic Information System : A Global Technology

by Sayeed Ahmed

Geographic Information Systems (GIS), a technology that has evolved over the last three decades, has become an integral tool in many disciplines of today's world including agriculture, forestry, economics, demography, engineering, disaster management, environment and planning. Besides its use in a varied range of civil applications, GIS is being used in war planning and counter-insurgency activities as well. In the developed countries of the world, GIS is now an indispensable tool in natural resources management. The developing nations can also use this technology to manage and utilize their scarce resources. This article presents an overview of GIS and its fundamental concepts.

IN plain language, Geographic Information System (GIS) is a computer-based technology that involves maintenance and manipulation of data that are essentially spatial in nature. For example, alignment of a road over a terrain, location of wells in an area, administrative boundaries of a country, spot levels (elevation at some specified points) covering a certain area, location of homestead or cropping pattern; all may be the subject of a GIS. Additionally, for a GIS to be termed as GIS, it will not only store information on these elements, but also be able to carry out spatial analysis of these data to arrive at quantitative results.

With the aid of the GIS, one should be able to get answers to questions like what will be the length of the road if it is made to pass through certain points (constraints), how much land will need to be acquired rendering how many people homeless (analyzing both road alignment and settlement pattern), is there any relation between demographic characteristics and cropping pattern (analyzing demographic data and cropping pattern data together), how much earthworks (and therefore money) will be needed to cut or fill an undulating terrain (from elevation data) or how many homestead will be inundated under water as a result of 100 cm rise in the nearby river water level.

At one extreme, definitions have been postulated in narrow technological terms, while at the other, organizational and institutional perspective is considered more appropriate. In between, there are other process— or function-oriented approaches, application-oriented approaches, toolbox approaches and database approaches. Table 1 presents a set of definitions from different approaches.

In the definitions of GIS stated in Table 1, the common aspect is that they all deal with geographically referenced data. In GIS, the geographical features like administrative boundaries, physical features or locations of infrastructure are defined with geometric elements like areas, lines and points. These are called the geographically referenced data. Other information with are attribute to these, like statistical data, elevation along a road alignment or water table at well sites, are called the non-spatial or aspatial or statistical or attribute data.

Concept of Space and Spatial Data

The basic element of GIS is the issue of distance, and there are many ways to define distance.

Thus distance is the length of path a crow will fly from one point to another. However, there are some applications where a straight line distance measurement will not serve the purpose. Such cases may be illustrated by considering two points in a city area. Clearly it won't possible for someone to go from one point to another following a straight line as a crow will do. Distances are not always the physical length of a path. In a generalized sense, distance is the total amount of resistance one would have to overcome in going from one point to another.

Map Projection Systems

Spatial data, one of the basic elements of a GIS, are often derived from maps. Maps represent an area from the surface of the earth on a plane sheet of paper or in GIS, in a two dimensional coordinate system. But only a globe having the same shape as that of the earth can represent surface features correctly with reference to area, shape, scale, and direction. There are many ways of transforming earth's features on paper each having its own characteristics and limitations. Some tend to preserve distances, others areas and some others direction. One will get different measures of these parameters on two maps of different projection. That is, the coordinate system will very widely from one system to another. One of the first steps in setting up a GIS is to select an appropriate map projection system depending on its intended application.

Error in Spatial Data

Error is inherent and an important issue in any data gathering system although this is generally considered as an embarrassing issue. Reporting of error does not indicate any weakness of a data gathering system, but provides the crucial information needed in the interpretation of the data. The major concern of a GIS is the positional error of the database although errors in the attribute also exist. The general concept of positional error is that it is the deviation (or distance) between the measured and the 'true' value. In mapping sciences, accuracy (the opposite of error) refers to the closeness of an observation to a true value (or one accepted as true). Positional data are often gathered through the process of digitization from existing hardcopy maps. There is an important relation between the scale of the source map to be digitized and the positional error one would expect to be inherent in the GIS.

Data Structures

A typical GIS deals with a large amount of spatial data. The way how these data are preserved, retrieved, manipulated in often crucial in the performance of any GIS. There are several ways of organizing spatial data the most common of which is in the form of points, lines and areas. The objectives of organizing spatial data in a systematic manner are the following :

1. To process geometrical user queries and other geometrical operations for application programs, and
2. To implement these operations so that they are consistently, robustly, end efficiently executed in a computer system.

There are two major types of data structures; raster structure and vector structure.

Raster data structure tessalates (divides into small cells like a mosaic) space and assign each spatial element a unique value, thus providing explicit information for each location. Vector data structure represent spatial variations using lines located in continuous coordinate space. Lines in the original analog maps are stored as strings of coordinates, and the spatial relationship among map entities are stored explicitly or are computed when needed. Vector data structure is more complex than the raster structure.

Database Management Systems

The importance of database management systems (DBMS) in GIS has been growing since he early years and it has now become an integral part of the system. The requirements of a GIS interms of data storage and manipulation are these days viewed as a separate class of problem in DBMS. A DBMS generally refers to a computer system used for data storage, manipulation and retrieval from a database. A database is a collection of one or more data files or tables stored in a structured manner, such that interrelationships which exist between different items or sets of data can be utilized by the DBMS software for manipulation and retrieval purposes.

GIS and Remote Sensing

Remote sensing is a discipline dealing with the measurement of the electromagnetic properties (from a satellite or an aircraft) of a surface or object (generally the Earth) without being in contact with it. While most local environmental surveys still depend on manual interpretation of aerial photography, the use of digital imagery for regional analysis is now commonplace and will undoubtedly increase in the future. As a source of geographical information, digital remote sensing represents more than a simple extension of conventional aerial photography, requiring fundamentally different approaches to the analysis of the surface of the Earth.

GPS Technology in GIS

Global Positioning System (GPS) is a satellite based technology for determination of one's location anywhere on the surface of the earth. In this system, there are 24 satellites orbiting the earth in such a way that from any location, one will see at least 4 satellites at any time of the 24-hour clock. There are instruments called GPS receivers that receive signals from these satellites, measures the time taken by the signals to travel and knows the precise position of the satellites.

From these data, the GPS receivers calculate their own position in terms of latitude, longitude and altitude. GPS technology was initially developed for exclusive military use, particularly for making sure that the ICBMs launched from mobile units could home in on the appropriate target. The Gulf War saw a wide use of hand-held GPS receivers where it was dangerously easy to get lost in a open desert devoid of any permanent landmark.

Application of GIS

Many disciplines of today's world need the types of answers a GIS is able to provide. Cartographers can prepare maps accurately within a very short time from a GIS database. Economists can study the dynamics of regional development, demographic pattern, flow of resources and commodities and temporal and spatial variation of indices by using relevant spatial and aspatial data. In the monitoring and management of the environment, a GIS can be tremendously useful in the study of biodiversity, wildlife, ground and surface water levels, contamination of water bodies, soil erosion, spread of diseases and so on.

These are only some example of the wide application of GIS. It is being used to make valuable contributions to the understanding and solution of key socio-economic and environmental problems. Interest in this field and its application is expanding rapidly and it is reasonable to expect that over the next decade there will be a several fold increase in the activities related to geographical information systems. Many new disciplines are being added to the already long list of GIS beneficiaries.

Table 1 : Some definitions of GIS

Definition	*Approach*
A system for capturing, storing, checking, manipulating, analyzing and displaying data which are spatially referenced to the earth.	Process
Any manual or computer set of procedures used to store and manipulate geographically referenced data.	Toolbox
An institutional entity, reflecting an organizational structure that integrates technology with a database, expertise and continuing financial support over time.	Institutional
An information technology which stores, analyses and displays both spatial and non-spatial data.	Technological
A special case of information systems where the database consists of observations on spatially distributed features, activities, or events which are definable in space as points, lines or areas. A GIS manipulates data about these points, lines, and areas to retrieve data for ad hoc queries and analyses.	Database
A database system in which most of the data are spatially indexed, and upon which a set of procedures operated in order to answer queries about spatial entities in the database.	Database
An automated set of functions that provides professionals with advanced capabilities for the storage, retrieval, manipulation, and display of geographically located data.	Process
A powerful set of tolls for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world	Toolbox
A decision support system involving the integration of spatially referenced data in a problem-solving environment.	Database/Decision Support System
A system with advanced geo-modelling capabilities.	Application
A form of MIS (Management Information System) that allows map display of the general information.	Database/MIS

Table 2: Four basic elements of a GIS

Element	*Description/Remarks*
Computer	The hardware may be any type of platform beginning from
hardware	dedicated workstations and mini- or mainframe computer to today's powerful personal computers with or without specialized peripherals for data capture, storage, display and output.
Computer	There has been considerable development in GIS software
software	and now a powerful software may have several hundred commands and a wide variety of functionality. Three basic design for software have been evolved; processing, hybrid and extended. In the processing design, each data set and function is stored as a separate file and these are linked together during analytical operations. In the hybrid design, attribute data are stored in a conventional database management system (DBMS) and separate bespoke software is used for geographical data. In the extended design, both the geographical and the attribute data are stored in a DBMS which is extended to provide appropriate geographical analytical functions.
Data	Data is a crucial resource for any GIS. Large volume of data are common and cost of collection of such data are also quite high.
Liveware	The most significant element of a GIS. These are the people responsible for design, implementation and use of GIS.

A GIS would normally be expected to answer one or more of the following typical questions.

1.	Location	What is (say the population) at (a given location)?
2.	Condition	Where is (say all the districts) having (say population above a specified threshold)?
3.	Trend	What has changed (say in traffic volume through a road segment)?
4.	Routing	Which is the best way (to reach a particular point in terms of time, cost or any other criteria)?
5.	Pattern	What is the pattern (say, of distribution of a disease)?
6.	Modelling	What (say, will happen to crops) if (an area is flooded under 1m deep water)?

COLLISION EXPECTED JULY

Scientists Stand by to See Worlds Collide

by Peter Bond

ASTRONOMERS are buzzing with excitement at the prospect of observing the effects of the event of a lifetime: a collision between two worlds.

The big bang is expected in late July when the Comet Shoemaker-Levy 9 runs into the giant planet Jupiter.

"The most widely anticipated event in the history of modern astronomy" is how United States astronomer Clark Chapman describes the predicated crash.

Every available telescope and spacecraft will be turned towards the fifth planet from the Sun in order to capture as much information as possible for posterity.

Comets are mostly very small and made of dirty ice, the remains of the building blocks which formed into planets 4.5 billion years ago. Although there are billions of comets under the gravitational influence of the Sun, most are so far away that they cannot be seen. But on the fringes of the solar system their orbits are easily disturbed.

Each year, a small number are nudged off course by some passing star and sweep in towards the Sun. Occasionally, one of these intruders passes too close to Jupiter and is captured by the planet's immense gravitational pull. Shoemaker-Levy 9 is one of these.

The comet's discovery was a fortuitous accident. In March 1993, renowned comet hunter Carolyn Shoemaker noticed a "squashed comet" while taking pictures of the sky at the Mount Palmoar Observatory in California.

The newcomer was named after Carolyn, her husband Gene and colleague David Levy. Other astronomers using larger telescopes soon found that the comet had broken into many pieces which were strung out through space like a string of pearls.

Normally, such as small, dark, faint object would have passed unnoticed, but the elongated chain provided a larger surface area to reflect sun light.

Shattered comets are not unknown. Several have been to break apart when they pass too close to the Sun, but none has previously been fund around Jupiter. Within a couple of months, orbital calculations confirmed that SL-9 had broken up quite recently.

Tidal forces had torn it apart as it grazed past the planet's swirling cloud tops in July 1992. Then came the astonishing news. The cometary fragments were heading back towards Jupiter as if on a kamikaze suicide mission.

The latest photographs from the Hubble Space Telescope show more than 2 remnants surrounded by a dusty halo. It is impossible to directly measure their sizes, but the largest pieces are thought to measure 2-4 kilometres across. Current predictions suggest that they will plunge into Jupiter over a six day period between 18 and 24 July.

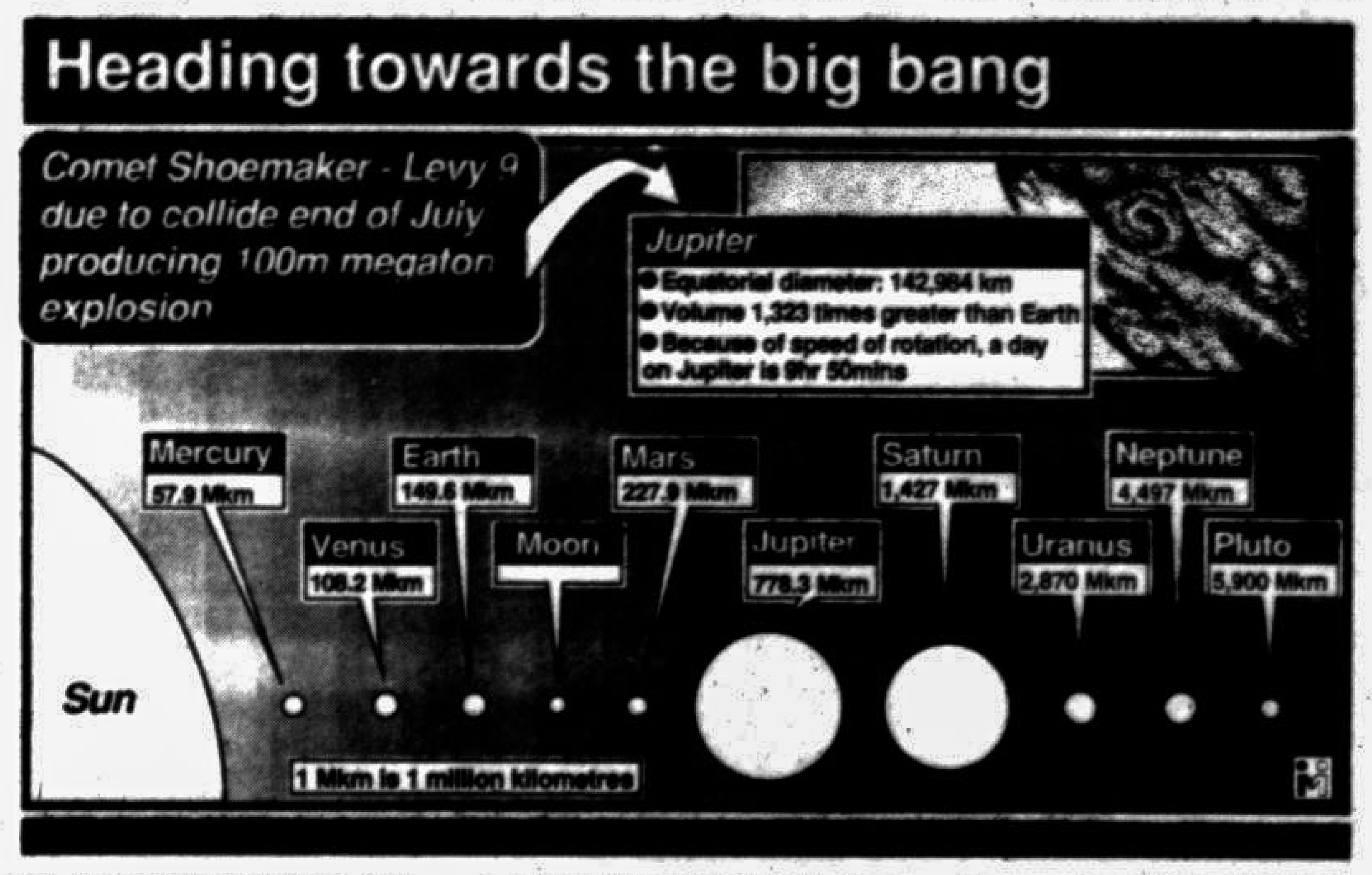
Unfortunately, the impacts will occur out of sight from Earth, about half an hour before sunrise in the planet's southern hemisphere. However, Jupiter rotates so rapidly, completing one turn in only 9 hours, 50 minutes, that the after-effects should still be clearly visible when the impact sites come into view.

One of the most intriguing aspects is that no-one really knows what will happen.

If the comet struck the Earth, it would produce craters in the solid surface, but Jupiter is a huge ball of hydrogen and helium gas. Even though they are tiny compared with their gaseous target, the icy fragments will pack quite a punch as they arrive at a speed of 60 kilometres per second.

Astronomers believe that they will explode, releasing energy equivalent to 100 million megatons, or 10,000 times the world's entire nuclear arsenal at the peak of the Cold War. The effects on Jupiter will be temporary but spectacular, rather like a wasp stinging a human.

One theory predicts that the fragments will be torn apart and vapourised as they plunge through the Jovian clouds. The result may be an enormous glowing fireball rising hundreds of kilometres above the planets' atmosphere.



This will not be visible from Earth, although astronomers may be able to see a sudden brightening of Jupiter's inner moons. Some direct observations should be available from the instruments on board the Galileo and Voyager 2 space probes, although neither will be close to the planet at the time.

Certainly, when the impact sites spin into view, ground-based astronomers should be able to detect the waves left over from the impacts, spreading out like ripples in a pond.

Other atmospheric effects may also be visible as billions of tons of gas are blasted out above the cloud tops. Giant auroral displays are one possibility.

One scientist has predicted that Jupiter may eventually gain a second ring as fine dust left behind by the comet is collected by the planet's powerful magnetic field.

Although this will be the first time that astronomers have been able to predict and observe such as major cosmic catastrophe, the solar system is full of roaming debris. It ranges in size from dust particles to mountains. Most are likely to be swept up by the massive outer planets. Estimates suggest that a comet is likely to plunge into Jupiter once every 80 years.

The likelihood of such a large object striking Earth is quite small, perhaps once every 25,000 years. The most recent event was in 1908 when an incoming object perhaps 50 metres across broke up and exploded above uninhabited Tunguska in Siberia. Pine trees were flattened over thousands of square kilometres. Had such a blast occurred over a large city, the death toll would have been horredous.

Perhaps the events of late July which are happening millions of miles away in space have an important message. Just as an asteroid impact may have wiped out the dinosaurs 65 million years ago, so our civilisation could be brought to a sudden end by an interplanetary intruder. Shoemaker-Levy 9 reminds us how vulnerable we really are.

Some astronomers argue that we should be prepared to spend a few hundred million dollars to construct an early warning system, not against human missiles, but against natural ones. — GEMINI NEWS

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Why Russian Space Projects are in Peril

by Andreimartov

HOPES of bringing Russia into the North American and European space programmes may have to be revised because of the virtual breakdown of the Baikonur cosmodrome in Kazakhstan.

Conditions reached a new low in June. Poorly-paid Kazakh construction troops went on a rampage, burning three headquarters buildings, several clubs, a hospital and a library containing 12,000 books.

In the past year, Leninsk, the city where Baikonur is located, has seen the departure of 21,000 inhabitants, one-fifth of its population. Cinemas and other cultural buildings have close. Shelves in shops are bare. Empty apartments have been taken over by outsiders.

The police force, reduced to one-third its size, faces a rising tide of robbery, Molestation and drug-abuse. Entry to the closed military city can be had for a 400-rouble bribe at the gate.

After the break-up of the Soviet Union, the cosmodrome was designated the property of Kazakhstan, despite the state's lack of technical resources and specialised personnel to run it. Only 200 Kazakh officers serve on the technical side of the operation.

Attempts by the Russian and Kazakhstan governments to agree on rules for running the space centre have not progressed beyond paper. Last year Russia announced the formation of special "military rocket forces" to take over the operations of Baikonur and other installations. Unwisely, it failed to consult other Commonwealth of Independent States members on their deployment.

Also, the Kazakhstan constitution forbids the basing of foreign troops on its soil. Russia, too, has a problem, in that only volunteer soldiers may now be posted abroad. With a volunteer costing 50,000 roubles per month in pay alone, sending them to Baikonur is outside the Defence Ministry budget.

The Kazakhstan government explored the possibility of inviting Western countries to launch their rockets from a privatised cosmodrome. When the Russian Defence Minister, General Pavel Grachev, hared of that plan he pointed out that the second stage of any rocket launched from Baikonur must pass over Russian territory.

Having invested huge sums of money in the centre, and with further space launches planned, Russia cannot simply write off Baikonur an concentrate on its other two space bases — in Kapustin Yar and Plesetsk.

Baikonur contains the only ramps suitable for launching the heavy rockets Proton and Energia.

A solution to the dispute looked near last summer when Russian and Kazakhstan ministerial delegations discussed setting up a joint organisation to run and develop the centre. Under the plan, Russia would pay 94 per cent of the costs and provide up to 6,000 conscript troops to guard it.

Kazakhstan agreed to receive up to 20,000 Russian soldiers on its territory in exchange for 500 additional places for Kazakhstan students at Russian military institutes.

Those agreements now seem unlikely to be honoured. New construction has been halted an existing buildings are falling apart because of Russia's unwillingness to spend money on another country's property.

Huge temperature swings — from minus 40 degrees Celsius in the winter to plus 50 degrees Celsius in the summer — mean most of the centre's communication equipment must be changed twice a year. Systems of all kinds need constant attention, but precautionary maintenance is kept to a bare minimum, with dangerous implications.

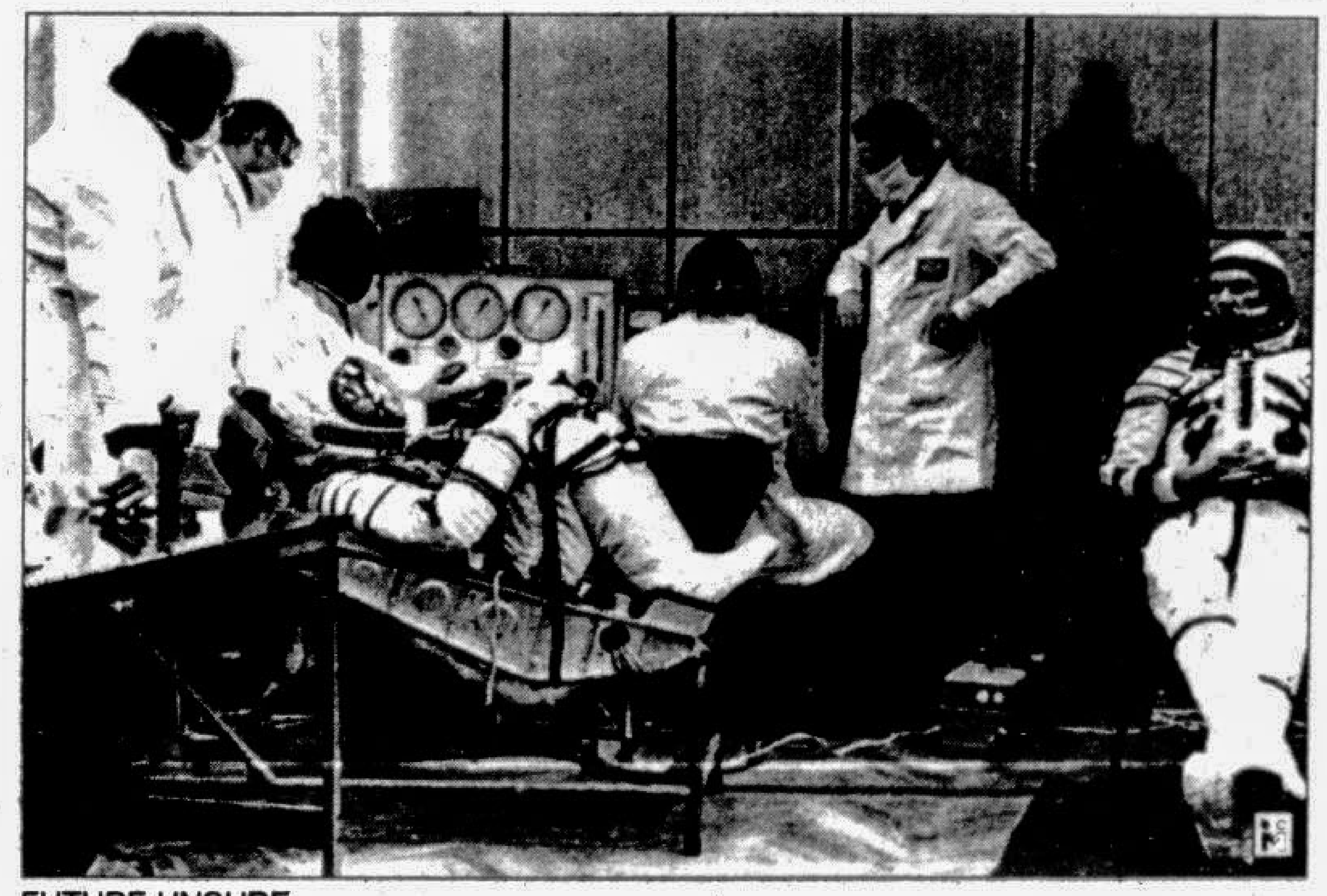
In an apparent warning of the consequences of neglect, the Russian army newspaper Krasnaya Zvezda in October referred for the first time publicly to a 1960 disaster when a long-range R-16 rocket exploded, killing 92 people.

Earlier this year, a Proton launcher carrying a Horizon communication satellite fell into the Pacific Ocean because unauthorised metal additives had entered the second and third stage fuel workings (it has not been established how). The launching of Protons, Russia's most promising rocket design, is now being moved to another base.

Meanwhile, the roof of the test-assembly building has become so leaky that during preparation of the launcher for a Franco-Russian space mission, rainwater poured into the rocket.

Just before it was sent to the launch pad, there was an electricity cut and an emergency circuit had to be activated.

Cessation of ownership has affected the attitude of Russian staff formerly responsible for security. No piece of equipment is safe from theft, including underground copper cables. At the same time, a rule forbidding the shipment of items abroad — including to Russia — for repair has led to a scarcity of working television sets and refrigerators.



FUTURE UNSURE
Spacemen at the Russian base in Baikonur face uncertain days