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'Grand Tour' Spacecraft Computer

By P. J. Parker.

Introduction

The best Solar System outer planet alignment in 179 years, occurring in the 1976 to 1980 time period, opens these planets to spacecraft exploration in an effective and timely manner. NASA's Jet Propulsion Laboratory is currently developing plans for two three-planet 'Grand Tours' for the late 1970's. One mission would send spacecraft on a fly-by of Jupiter, Saturn and Pluto while the other would reconnoitre Jupiter, Uranus and Neptune. Both missions would use the application and principle of gravity-assisted trajectories for spaceflight as proposed by Victor C. Clarke Jr., (Senior JPL engineer and Mission Analysis and Engineering Manager for the 1973 Mariner Venus-Mercury project) between 1960 and 1961. The huge mass and strong gravitational field of Jupiter (the pivotal planet for 'Grand Tours') and the other larger planets make large deflections and speed changes possible for fly-by spacecraft, cutting journey times to Pluto to 7-8 years as compared to a 41 years direct flight.

The technological challenges of a nine year plus spaceflight are formidable but not insurmountable. The basic Grand Tour spacecraft weighing about 544 kg. will carry scientific instruments for photography, atmospheric measurements in UV and IR and radiation detection. A nuclear isotope power source will be relied upon to operate on-board equipment. The Grand Tour spacecraft will also require the capability of replacing failed equipment automatically since it will take several hours for telemetry signals to reach Earth and then to return a corrective command to the spacecraft. At the NASA JPL such a self-repairing computer and data storage system is already under development for spacecraft use. The system, known as STAR (Self-Testing and Repairing), has passed preliminary tests and a 'breadboard' model underwent full-scale ground operation in September 1969.

Concept of STAR

The principle of the STAR system was conceived in 1961 by Dr Alvarez Avizienis, Ph.D., of the JPL Flight Computer and Sequencer Section, who visualized the computer as serving as the monitor and 'automatic repairman' for in-flight testing and maintenance of the entire spacecraft, whether the mission be to Jupiter, Pluto or even (ultimately) stellar destinations. Avizienis, also an Associate Professor teaching computer design at the University of California, designed the first experimental model in 1965-66, with the aid of Allen Weeks and David Rennels both of whom are involved in the hardware design effort for the flight-rated STAR. The ground operation 'breadboard' model of September 1969 filled three 1.8 metre racks but its parts can easily be miniaturized for spacecraft installation. The 1969 test model consisted of a 10-unit computer, using a coding system to detect errors, and a monitor unit to diagnose the cause and cure in 1/100th of a second. Two important contributions to STAR were the development of a magnetic power switch to disconnect faulty units (Stanford Research Institute) and a 'read-only' storage unit for permanent programs (Massachusetts Institute of Technology Instrumentation Laboratory).

STAR Operation

STAR belongs to the digital computer family. It operates using instruction words and numeric quantities represented in binary notation (0 and 1). Its instruction repertoire is carefully chosen such that a fault will alter a good word to an illegal one. When a faulty unit forwards a damaged word to another unit, the illegal word will be detected by the monitor and its source identified. The monitoring unit is termed the Test and Repair Processor (TARP). This unit, literally the 'brain and conscience' of the computer, receives status reports from all working units and decides whether all operations are normal. TARP also checks its own functioning to determine its own behaviour. The TARP has three active monitors which operate by majority vote. When two of these monitors indicate an anomaly, a decision is made by the computer to repair the malfunction. The suspected unit is tested once more and, if the error persists, it is replaced by disconnecting power from the faulty unit and 'powering-up' a back-up unit. Later, TARP may test the rejected device and, if the previous fault proved temporary, will arrange for it to be used again. The flight-rated STAR system will automatically handle most malfunctions, making spare-part substitution when required. Only in overwhelming fault conditions would Mission Control intervention be necessary. The flight-rated STAR will probably not exceed 0.057 cubic metres and not consume more than 50-watts of electrical power. Also, during interplanetary flights, the computer will have the unique capability of detecting external interference, ascertaining the undesirable changes it causes in internal spacecraft functions and then correcting these errors before the mission could be placed at risk.

STAR Applications

An early flight model may help to control a spacecraft on a 1½ year journey to Jupiter in 1974, with the full version operating on the 'Grand Tour' missions of 1976-1980. However, besides its space applications, STAR has very many terrestrial uses including aid in automating hospitals and controlling supersonic passenger aircraft. The STAR-type computer could monitor 100 to 200 bed patients, thereby helping to reduce routine work by doctors and nurses to a minimum. It could take routine measurements every second (heartbeat, pulse and breathing rates, etc.) look for abnormal readings, then ring an alarm and display the actual bed-patient position to monitoring staff. Failure of one of its own units would not cause STAR to forego its vigil. The faulty unit would be replaced by its back-up in less than 1/100th of a heartbeat. This type of split second action will also assist pilots of future supersonic aircraft during anxious moments such as encountering turbulence. STAR could also be used in real-time interactive computer complexes, industrial production line processes and automated railways.

The 1969 demonstration of the 'breadboard' STAR model climaxed seven years research and development by the Jet Propulsion Laboratory Flight Computer and Sequencer Section. Dr. Avizienis, a Lithuanian-born scientist-engineer, now heads the JPL teams developing the flight-rated STAR versions. The hardware design effort is led by Allen Weeks and David A. Rennels and software programming by John Rohr and Frank Mathur. Project administrator is John J. Wedel Jr, with William F. Scott as section manager. Other specialists at JPL are developing severe tests for the full-scale STAR model and in devising

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Phenomenon of Time Dilation

Sir, I was pleased to read Val Cleaver's *Some Comments on 'The Phenomenon of Time Dilation'*, September 1970 *Spaceflight*, for apart from its intrinsic merit, it indicates a steadily widening of astronautical interests from the mere skeletal basis of hardware. Indeed, I have long held that astronautics will ultimately become acknowledged as *the* all-embracing science. I regret not being able to add anything to the discussion, because, quite frankly, I don't understand Relativity very well, relatively speaking, and tend to disbelieve what I can't comprehend. For example, the only thing the classic 'clocks paradox' proves to *me* is the indisputable existence of clocks.

Clearly, therefore, I am an ignorant heretic: one, moreover, who thinks that Einstein carelessly dropped a number of spanners into Newton's superb synthesis which will give some super-Einstein a lot of trouble to extract from the works.

All this isn't surprising because master-mind Newton himself got into a shocking mess with wider aspects of his own cosmology ... Incidentally, would someone kindly explain to an enquiring idiot why light travels at 299,796 km/sec, in vacuo, and not at any other speed.

H. E. Ross

The Phenomenon of Time Dilation

Sir, I agree wholeheartedly with the views expressed by Mr A. V. Cleaver in his article 'Some comments on 'The Phenomenon of Time Dilation' (*Spaceflight*, 12, 378) and I should like to make a few additional comments on this interesting subject.

Firstly the phenomenon of *mind* may be described as the sum effect of the enormously complex nerve cell activity in the cerebral hemispheres. Thus mind would not reside exclusively in any particular part of the cerebral cortex nor would it be independent of the brain tissue. I therefore concur with Mr. Cleaver that if a human being could be converted to energy, transmitted to another part of the Universe, and reconstructed *perfectly* then this reconstructed person would undoubtedly have the same mental processes as the original. If the brain was not reconstructed perfectly then changes in thought patterns would be expected. For example memories may be stored in the cerebral cortex as permanent chemical changes in the ribonucleic acid of the nerve cells and consequently failure to reproduce these molecules exactly could give the reconstructed man distorted memories. He might then act, under certain circumstances, in a very different manner from the original man. A similar problem is already with us. A person who has damage to the cerebral cortex, particularly the frontal regions, may suffer dramatic change in personality, and close relatives may ask whether this is the same person they once knew.

In his article 'The Phenomenon of Time Dilation' (*Spaceflight* 12, 178) Professor D. F. Lawden discusses frozen astronauts and 'deep-freeze' burials, and states that if such a frozen body could be brought back to life the original 'stream of consciousness' would not return. I see no reason why the thawed person would not regenerate the same mind after x years in suspended animation provided the nerve cells could be restored to their normal structure and function. Perhaps Professor Lawden would rest more easily if, as was suggested recently (*Spaceflight* 12, 167), the metabolism of the astronauts travelling on prolonged flights may be slowed considerably but not stopped. In this situation the mental processes would not be interrupted.

I wonder if any B.I.S. members have more concrete ideas on a 'teleportation' system. I would be happy to correspond promptly on physiological aspects of this topic. It could make an intriguing article for the New Frontiers section in Spaceflight.

B. A. Gooden.

National Space Museum

Sir, I would like to support Mr. Carter's proposal for a National Space Museum (*Spaceflight*, October 1970) and I would like to suggest that a valuable additional item to the museum would be a comprehensive collection of 35 mm slides of various space programmes.

Such a collection would be a valuable asset especially if they were available on loan to any member of the public who might wish to borrow them. I recently required 35 mm slides to illustrate a talk I was giving and was most surprised to find that the United States Information Service did not possess such a collection on the American Space Programme.

Spaceflight has recently contained many excellent photographs of Soviet booster rockets and spacecraft, and a comprehensive collection of slides and photographs of Soviet hardware would compensate to some extent for the lack of actual models.

J. E. D. Davies

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applications for STAR in NASA's future programmes of planetary exploration.

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SOME COMMENTS ON 'THE PHENOMENON OF TIME DILATION–2

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We have still much yet to learn and there are, at present, so many unknowns, the answer to any of which could put an entirely different complexion on the whole problem. In the meantime, until more facts are established, we can but approach these questions with as much caution, reason and open-mindedness as possible.

REFERENCE

1. Cleaver, A. V., 'Some Comments on "The Phenomenon of Time Dilation",' *Spaceflight*, September 1970, pp. 378-388.

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COVER

TRACKS IN THE MOON DUST. The remote-controlled mobile laboratory Lunokhod 1 obtained a vast amount of information on the properties of the lunar soil in the Sea of Rains. It was soft-landed inside a shallow crater by the Luna 17 descent stage on 17 November 1970. An X-ray telescope scanned the celestial sphere, and successful experiments were made in conjunction with a French-built laser reflector on the vehicle. *Left* is a Soviet drawing of Lunokhod which can be seen in greater detail on page 90; *right* shows tracks left in the lunar soil during a communications session on 9 December; *below* are deeper impressions made by Lunokhod as it was being manoeuvred out of the crater at the landing site.

Novosti Press Agency

MILESTONES

December

10 Communications session with Lunokhod 1 begins at 4 p.m. (Moscow time) lasting for about nine hours. Vehicle covers distance of 244 metres, moving over 'rugged ground, first in the south-east and then in the westward direction, among boulders and hollows'. One crater encountered is 15 metres in diameter and about two metres deep. Lunokhod descends into crater, climbs its slope and emerges onto smooth surface. Mechanical properties of soil studied during vehicle's brief stops.

10 McDonnell Douglas Corporation confirms agreement whereby Hawker Siddeley Aviation and Dynamics will contribute to space shuttle Phase B design studies. Hawker Siddeley interest is defined as mission and systems analysis, aerodynamics, aerothermodynamics, structures, materials, controls, electronics and propulsion.

12 France launches 55 kg Peole (Preliminaire a Eole) satellite by Diamant B from Kourou, French Guiana. Equatorial orbit ranges between 750 and 820 km altitude.

14-17 Lunokhod 1 makes scientific measurements in parked position.

15 Venera 7 enters atmosphere of Venus at 8.02 hrs (Moscow time). After aerodynamic braking had slowed separated capsule to about 250 metres/sec, parachute and antennae opened and signals were received for about 35 min. When measurements began temperature was about 25°C and pressure 0.6 atmospheres; when signals ceased at about 19 km altitude values were 325°C and 27 atmospheres.

18-19 Ninety-third radio session with Lunokhod 1, begun at midnight (Moscow time), lasts 3 hr 41 min. Vehicle moves 197 metres in a south-easterly direction negotiating small hollows and boulders and descends into 50 metres diameter crater; total distance covered since 17 November is 1,022 metres.

20 Lunokhod moves out of crater and continues south across plain of small craters. Moves into crater of some 100 metres diameter with a slope gradient of 10°. Total distance travelled during this session is 337 metres. Periodically measured physical and mechanical properties of lunar soil; data transmitted from memory unit of X-ray telescope indicated no large increase in intensity of corpuscular cosmic radiation.

21 Lunokhod moves in a south-easterly direction on the inner slope of crater into which it moved the previous day, climbing slopes up to 23°, making turns and reverses, covering 78 metres. Temperature in instrument compartment 18°C; pressure 770 mm of mercury. Parked for second lunar night beginning 23 December.

29 European industrial consortium STAR (Satellites for Telecommunications, Applications and Research) formed by British Aircraft Corporation, Contraves (Switzerland), CGS-Fair and Montedel (Italy), Sabca (Belgium), Erriccson (Sweden), Fokker VFW (Netherlands), Dornier Systems (Germany) and Thomson CSF (France) to compete for future ESRO contracts. AEG-Telefunken (Germany) to contribute on communications satellite work.

January

8 Lunokhod begins third working day on Sea of Rains. Temperature in instrument compartment 18°C; pressure 755 mm of mercury.