EOS

Electrophoresis Operations in Space

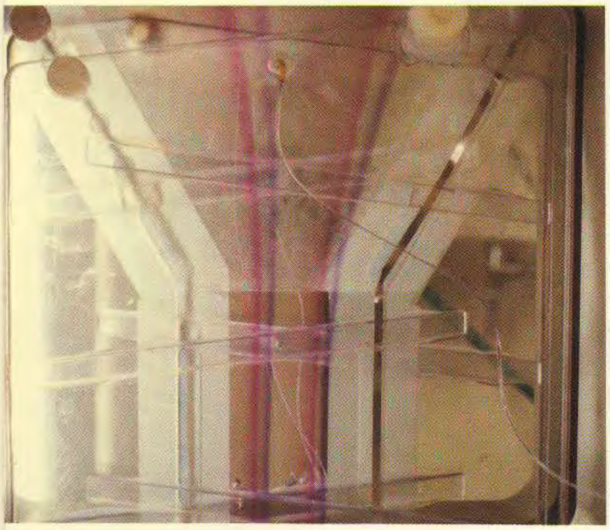
MCDONNELL DOUGLAS
CORPORATION

The Dawn of a New Era

The EOS.

Thanks to the McDonnell Douglas EOS Program, Electrophoresis Operations in Space, new and better treatments for illnesses such as diabetes and hemophilia may become available during the next decade. Because these illnesses and many others are caused by a lack of natural body substances, effective treatments depend on the ability to provide patients with the substances they require. These substances can be obtained by separating them from the biological mixtures in which they are produced. Until now, however, it has not been possible to separate enough pure substances to develop the necessary medicines. The EOS Program has changed all that.

Over the past seven years, McDonnell Douglas has developed a device that can separate cells, hormones, enzymes, and other proteins in the abundant quantities and in the exceptional purities needed by researchers and pharmaceutical companies. Based on a process called continuous flow electrophoresis, the EOS device has been working on Earth and in space to separate the materials that could lead to important breakthroughs in the world of medicine.



Ground-based separation of dyes ▲

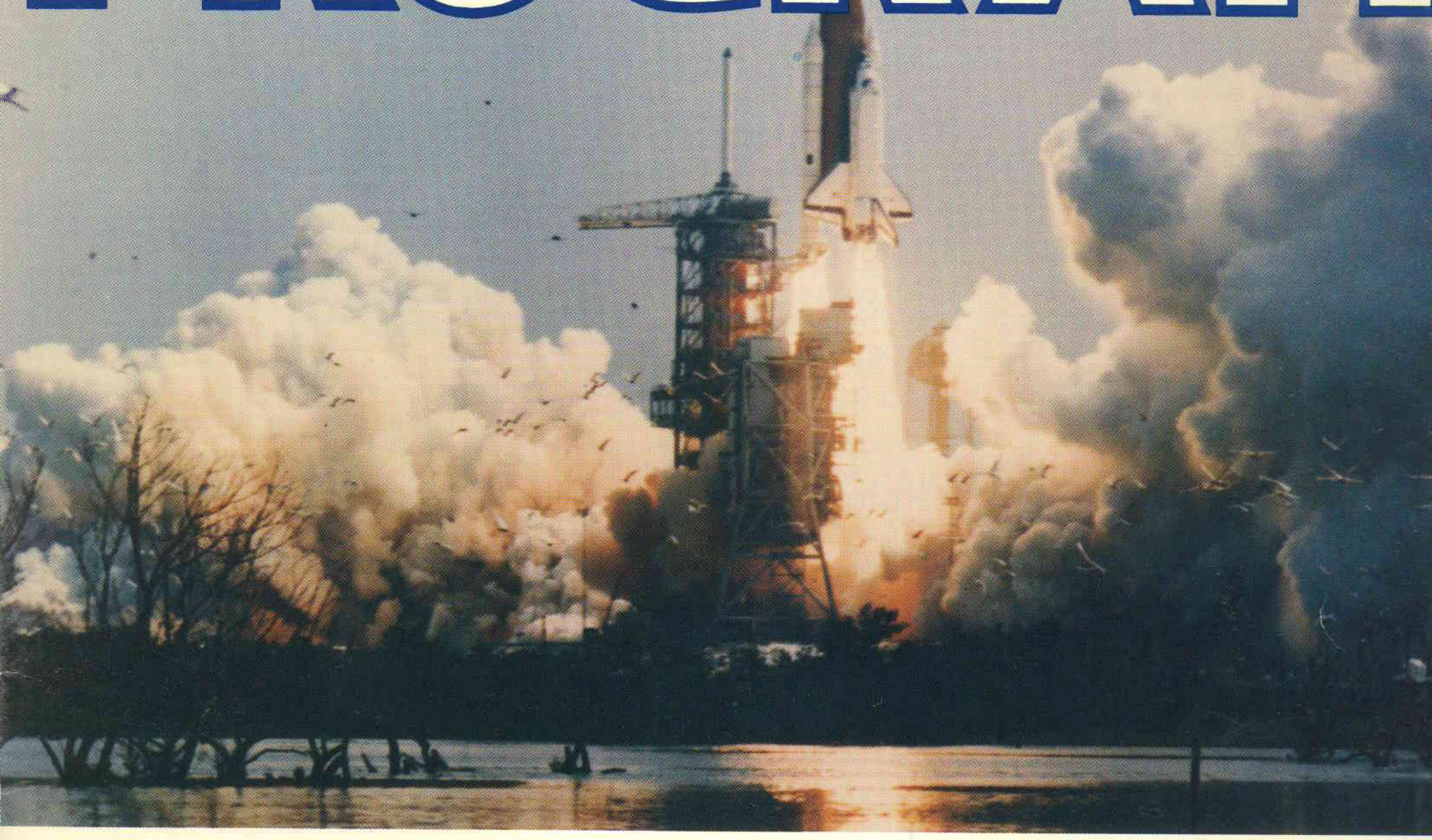
Astronaut Sally Ride checks the separation chamber ▼

The EOS ground unit, located in McDonnell Douglas laboratories in St. Louis, Missouri, offers an improved system for separating materials on Earth. The system can be used for basic research and development as well as for separating biological materials for small commercial markets.

The EOS space unit, carried in the Space Shuttle, offers an incomparable method for separating extremely large quantities of highly purified materials. In the four Shuttle flights on which the EOS space unit has flown, all mission objectives have been met. Freed of Earth's gravity, the unit separated over 700 times more material and achieved purity levels four times higher than those possible in similar operations on the ground. Backed by this success, McDonnell Douglas plans to begin flying a much larger unit on the Shuttle in 1985, one that can continuously separate large commercial quantities of material. By the early 1990s, we hope to have a number of full-scale production factories orbiting the Earth on manned or unmanned space vehicles.

EOS

PROGRAM

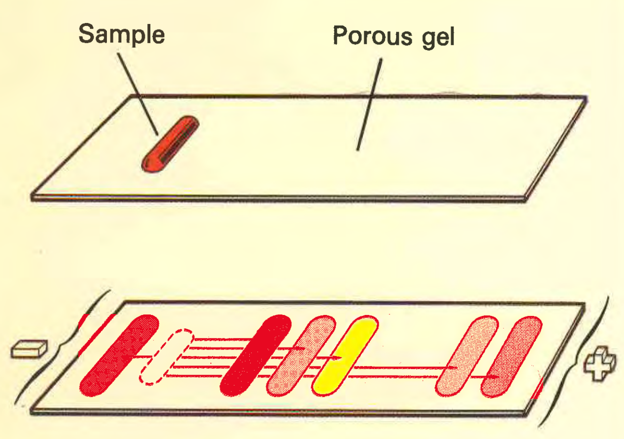


What is ELECTR

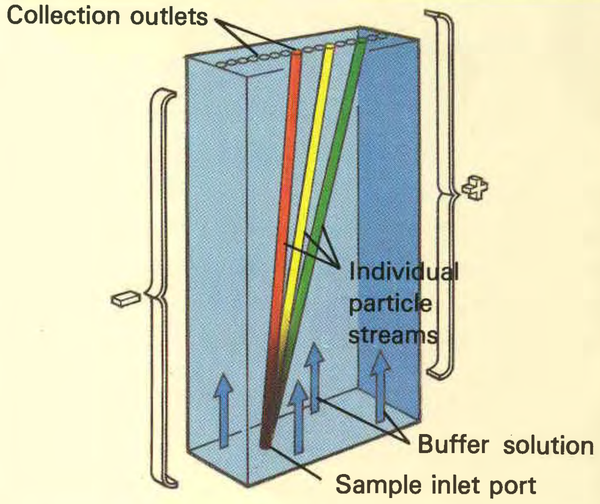
Electrophoresis is a separation process that takes advantage of the fact that every biological and chemical substance has an inherent electrical charge. A mixture of substances (called the sample) is placed in a buffer solution, which is then subjected to an electrical field. This field causes the differently charged substances in the sample to separate from each other.

There are two major types of electrophoresis: static and continuous flow. In static electrophoresis, a sample is placed in an unmoving (or static) buffer, such as a gel plate. An electrical field is then applied across the plate long enough for the differently charged particles to migrate to distinctly separate areas. Good separation is possible with this method, but only a very small sample (about .01 milliliter) can be separated at one time. Because the sample is embedded in the gel, the separated substances cannot be effectively removed. These constraints make static electrophoresis useful for laboratory analysis but not for production.

Much larger quantities, however, can be separated by the continuous flow process, and the separated materials can be easily recovered. The sample is continuously injected into a flowing buffer solution that carries it from the bottom to the top of a long, rectangular chamber. As the sample flows through the chamber, an electrical field is applied across the flow. This causes the differently charged particles in the sample to move laterally at different rates, splitting the sample into separate particle streams that exit through an array of



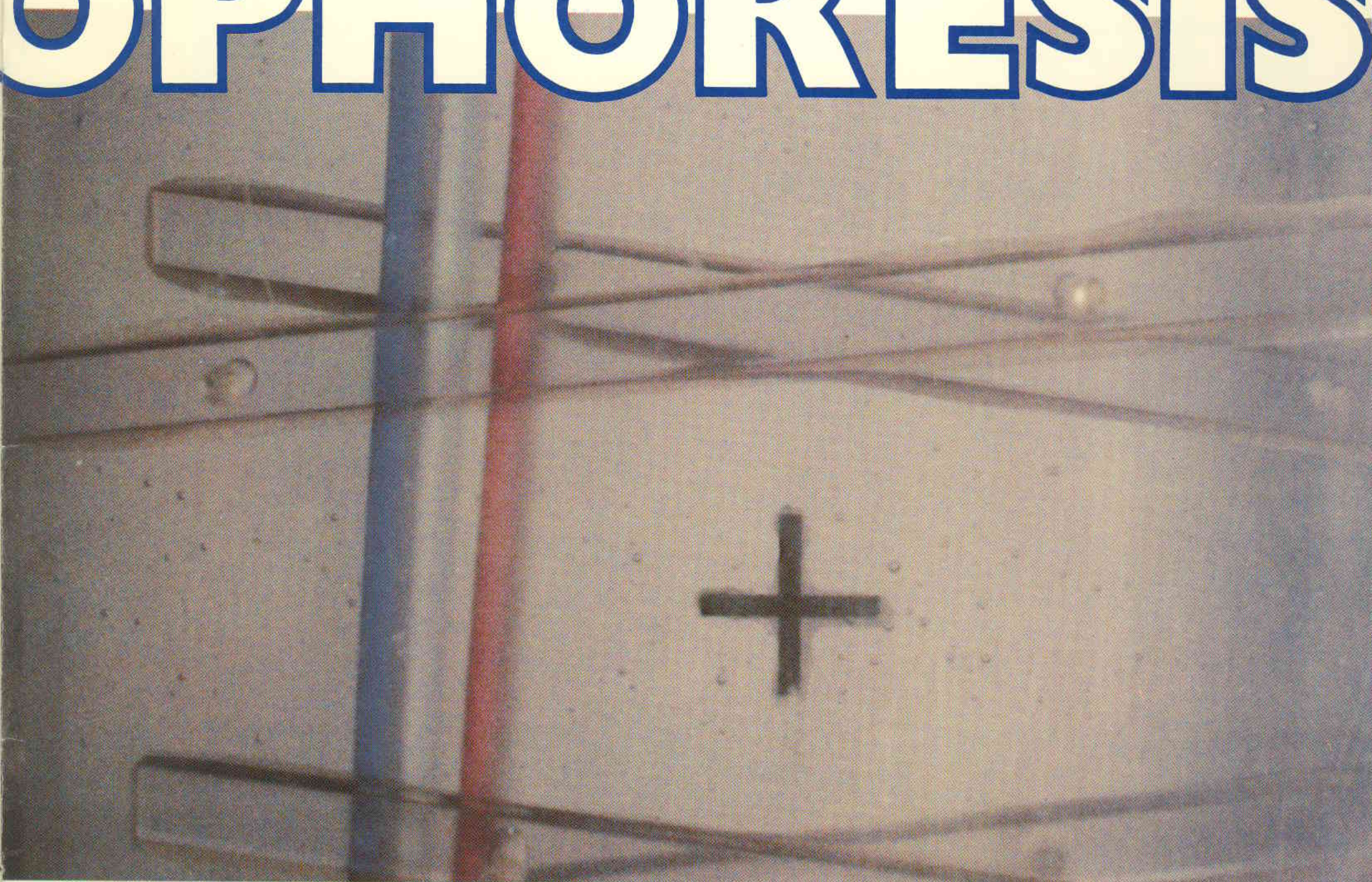
When the electrical field is applied, the sample separates into various components.



Continuous flow electrophoresis separates the sample into individual particle streams.

EOS

OPHORESIS



▲ Separation of dyed latex beads for NASA on STS-7

outlet holes at the top of the chamber. McDonnell Douglas chose the continuous flow process for its EOS Program because it is much better suited for production purposes.

The Separation Process

To realize the production potential of continuous flow electrophoresis on Earth, we had to minimize several problems. These problems, all caused by gravity, can either disrupt the process entirely, seriously limit the amount of material that can be separated, or drastically reduce the purity levels that can be reached.

Two of these problems, sample stream collapse and bandspreading, occur because biological materials are typically heavier than the buffer. When they are much heavier, the stream simply collapses around the inlet port instead of flowing in a steady, continuous column. When they are only slightly heavier than the buffer, the streams flow but spread out and overlap. These phenomena lower the purity of the separation.

Collection tubes filling with separated materials ▼

▲ Analyzing separated materials

The other gravity-related problem is convection, which is caused by the uneven heating of the buffer when the electrical field is applied. Gravity causes the warmer buffer to rise and the cooler to sink, creating currents that make the separating streams waver back and forth. When this happens, the streams do not exit through their correct outlets but waver from one outlet to another, degrading purity.

On Earth, there is no perfect solution to these problems because it is impossible to escape the effects of gravity completely. An effective continuous flow system, such as the EOS ground unit, therefore represents a series of trade-offs among quantity, purity, reliability, and simplicity of operation. To overcome sample stream collapse and bandspreading, the sample must be diluted until its density is nearly the same as the buffer's, but this reduces the amount of material that can be separated. To minimize convection currents, the chamber must be kept shallow, but this also limits the amount that can be separated.

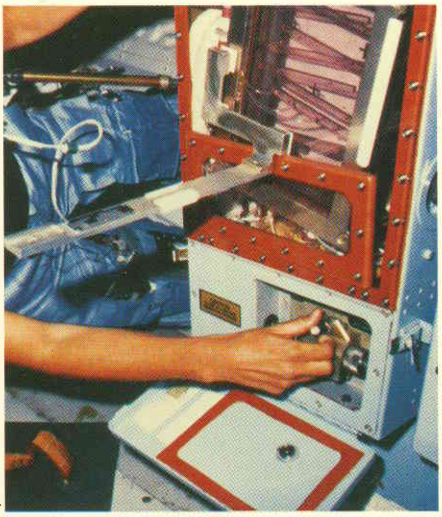
During more than four years of development work, McDonnell Douglas designed and built a series of increasingly efficient separation devices. While our biologists worked on the problems of sample stream collapse and bandspreading by experimenting with density levels, our engineers concentrated on designing a separation chamber and water cooling system that minimize convection currents. The result of this effort is a ground-based system that is reliable and easy to use and that can separate biological materials with exceptional purity.

ON EARTH

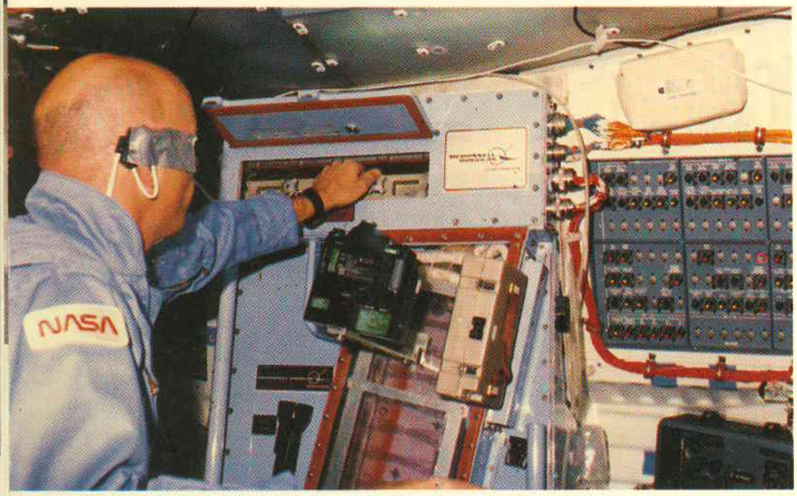
These advantages make the EOS ground-based system ideal for research and development projects as well as for small-quantity commercial markets.

EOS ground equipment separating materials ▲

The Separation Process



An astronaut injects raw materials for separation ▶



Astronaut Story Musgrave removes the tray of separated materials ▲

Because the problems associated with gravity disappear in space, a number of changes can be made to the ground-based EOS system that lead to dramatic increases in both the quantity and purity of separation in space. Sample concentrations can be increased 100 times over ground concentrations without causing sample stream collapse. Bandspreading no longer occurs, so there is no need to dilute samples to equalize the density of the sample and the buffer. Also, because convection currents virtually disappear, a deeper chamber with bigger inlet ports can be used to quadruple the amount of sample material processed. Finally, the amount of voltage applied across the chamber can be increased, which improves the purity of the separation.

These changes are the major reasons the space-based EOS system has achieved phenomenal separation records. In less than two years of testing in space, it has demonstrated that it can separate over 700 times more material and achieve purity levels four times higher than is possible in similar operations on Earth. With such quantities of purified materials available to them, pharmaceutical companies, for example, will now be able to produce new medicines for large commercial markets at an affordable cost.

The early success of the space-based EOS system has given McDonnell Douglas the impetus to push ahead with its plan to develop a full-scale, commercial production system in space. This plan calls for the EOS system to fly in three separate space situations: the middeck unit of the Shuttle, the payload bay of the Shuttle, and in a space station or free flyer.

The heart of the middeck unit is a 580-pound separation chamber that rides in the Shuttle's middeck crew compartment. This unit is semiautomated but requires the support of an astronaut or payload specialist.

The payload bay unit will ride in the large area behind the middeck where the Shuttle carries large payloads like commercial satellites and the Spacelab. The EOS payload unit will be considerably larger than the middeck device and have 24 times more production capacity. It will be completely automated and can run continuously the entire time the Shuttle is in orbit.

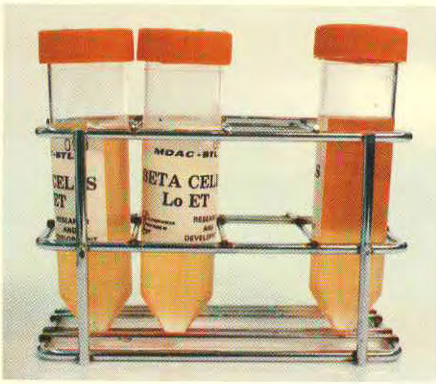
IN SPACE

The space station or free flyer would hold one or two EOS production units, each the same size as the payload bay unit. These automated units would run continuously for much longer periods, needing only to be visited every three months or so by Shuttle crews for pickup and resupply of materials.

Operating in the

The middeck unit, which has already flown on four Shuttle flights and is scheduled for two more, is a six-foot-high separation chamber that runs on a semiautomatic basis supported by an astronaut. On its first four flights, the unit met all its test objectives. This success set the standard for the more ambitious objective of separating even larger amounts of material on upcoming flights.

The first EOS middeck flight took place in June of 1982 (STS-4) and proved that continuous flow electrophoresis works better in space than on the ground. A mixture of albumins and a mixture of proteins were separated at varying concentrations, and even the most dense of these mixtures was separated with a high degree of purity. The quantity of material we processed in two six-hour runs was even better than predicted. Four hundred sixty-three times more material moved through our space unit than is possible in our ground unit. Even at the highest levels of concentration, the quality of separation was not affected.



▲Beta cells separated on STS-8

◀Payload specialist Charles Walker checks the EOS equipment

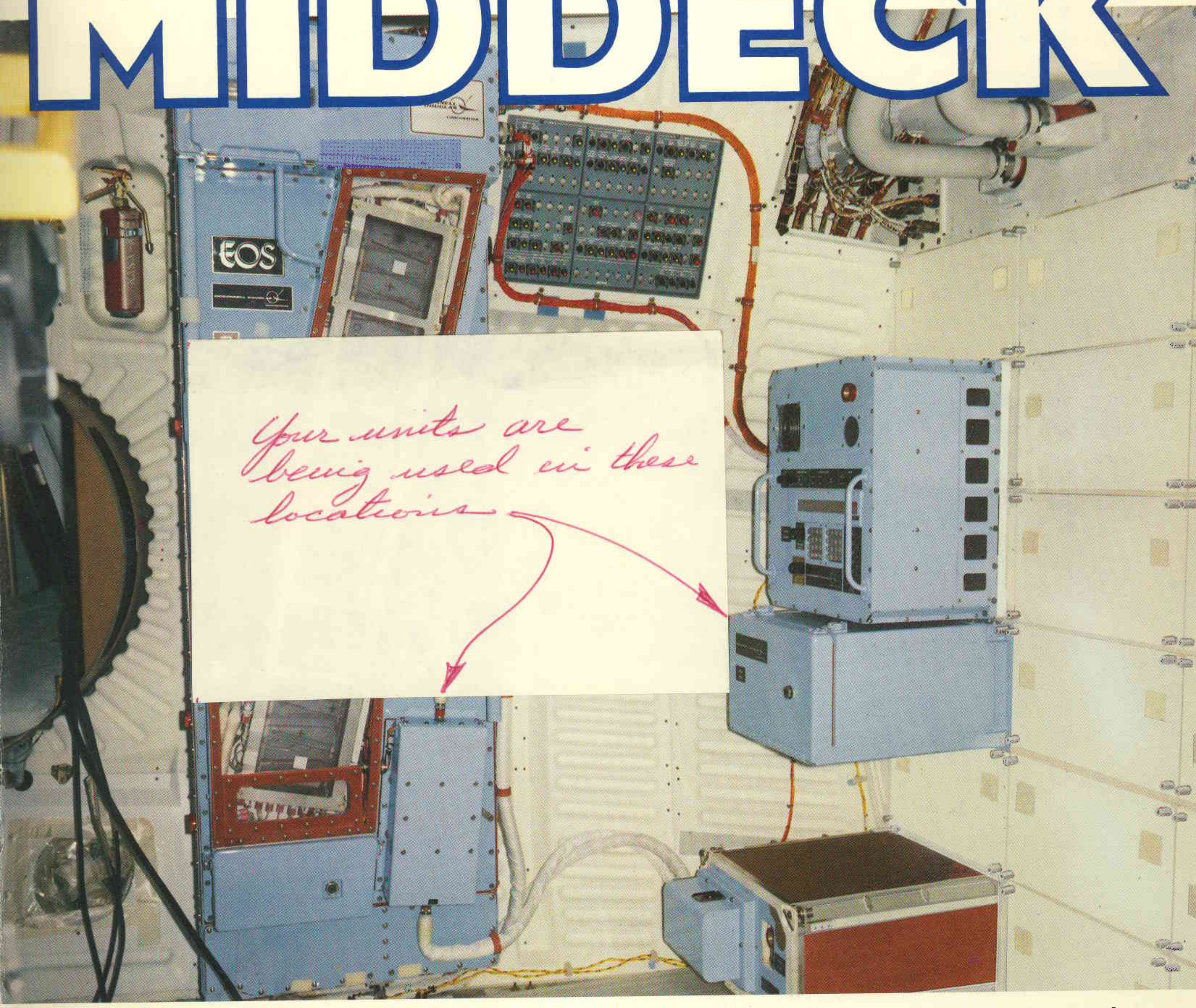
The goals of the second EOS flight, in April of 1983 (STS-6), were to separate even greater quantities of material and to achieve higher levels of purity. If a higher voltage could be applied across the chamber, the materials would separate more quickly and by greater distances. But a higher voltage would generate more heat, which might bother the astronauts. McDonnell Douglas solved this problem by using water from the Shuttle to cool the EOS equipment, allowing us to more than double the voltage. This solution enabled the middeck unit to separate over 700 times more material and to reach purity levels more than four times higher than have been achieved in the ground unit.

During the third middeck flight in June of 1983 (STS-7), we separated dyed latex beads for NASA to investigate fluid dynamics in the zero-gravity environment of space. We also separated cell culture media to provide a data base for semiautomated continuous production in June of 1984.

The flight of STS-8 in August 1983 marked our first attempt to separate live pancreatic, kidney, and pituitary cells in space. Extraordinary handling criteria had to be established because of the cells' extreme sensitivity to adverse conditions. From the pancreatic cells, we separated beta cells that produce insulin. This could lead to new treatments -- and possibly a cure -- for diabetes. Fractions from the kidney cells produced large amounts of various hormones needed for treating disorders such as blood clots. And from the pituitary cells, we isolated cells that produce substantial amounts of growth hormone.

EOS

MIDDECK



Your units are being used in these locations

The two remaining middeck flights of the EOS unit are scheduled for June and October of 1984. A McDonnell Douglas engineer, Charles Walker, will ride aboard the first (and possibly the second) of these flights to ensure the unit meets its objective of 80-100 hours of continuous separation. When the Space Shuttle Discovery is launched, Walker will make history as America's first industry representative to fly in space.

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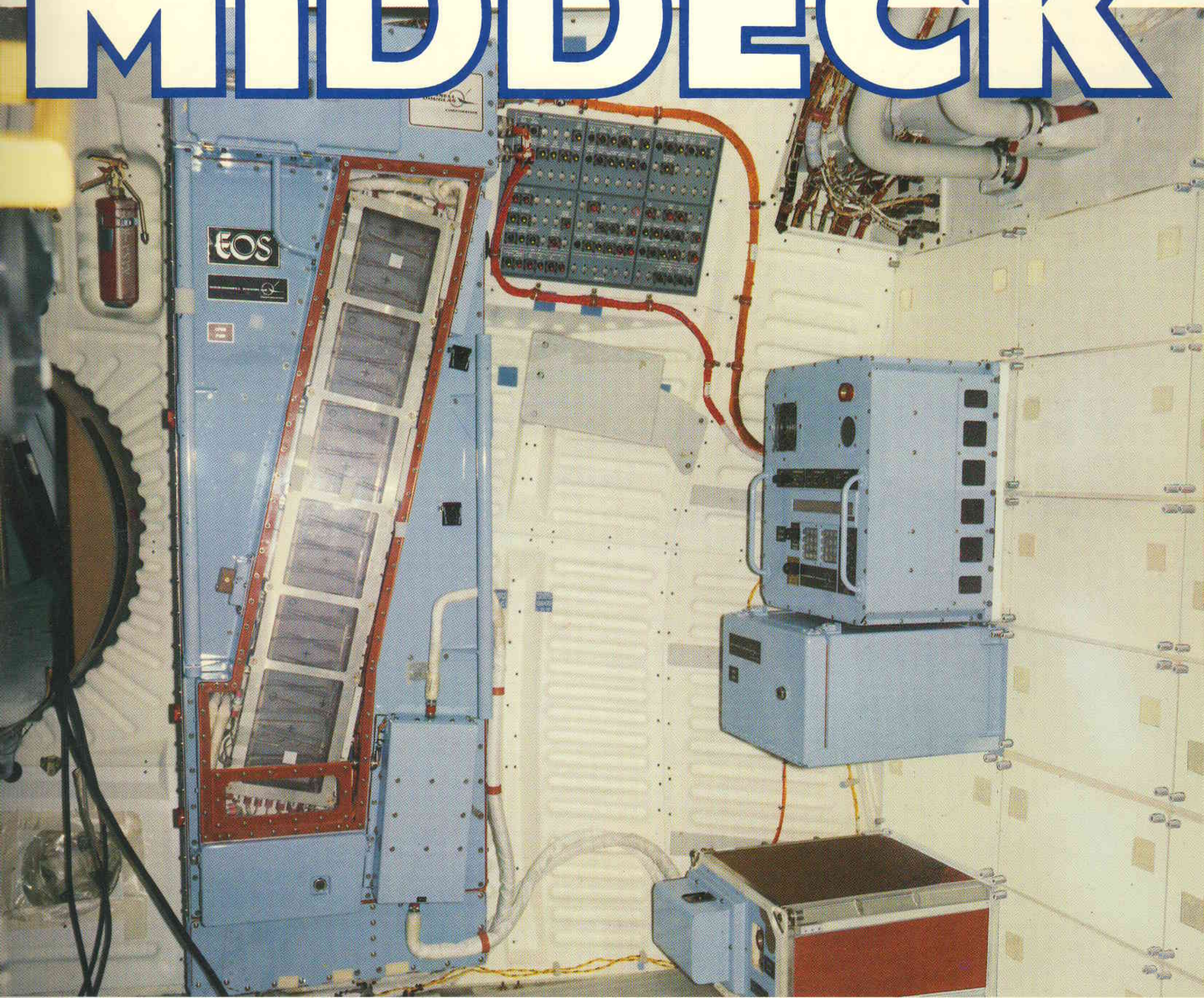
MIDDECK



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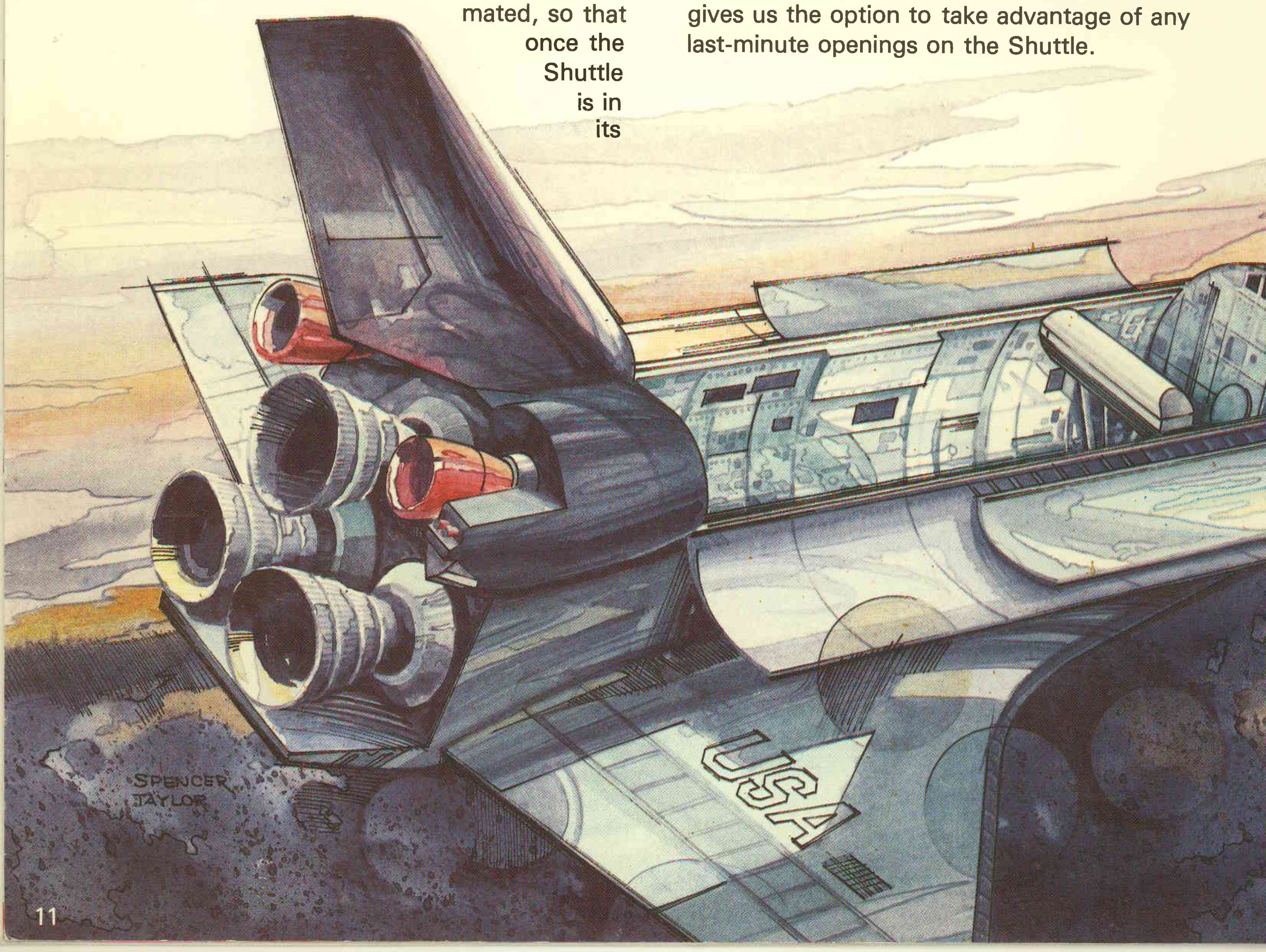
Producing in the PAY

In July of 1985, McDonnell Douglas plans to fly an EOS production unit in the payload bay of the Space Shuttle. This 5,000-pound unit will be 3.5 feet wide and 14 feet long and have 24 times the separation capacity of the present middeck unit. The unit will also be fully automated, so that once the Shuttle is in its five- to seven-day orbit, an astronaut will simply turn it on and the samples will be continuously processed during the flight.

Another advantage of this unit is that it can fit just about anywhere in the payload bay. This provides flexibility in scheduling flights and gives us the option to take advantage of any last-minute openings on the Shuttle.



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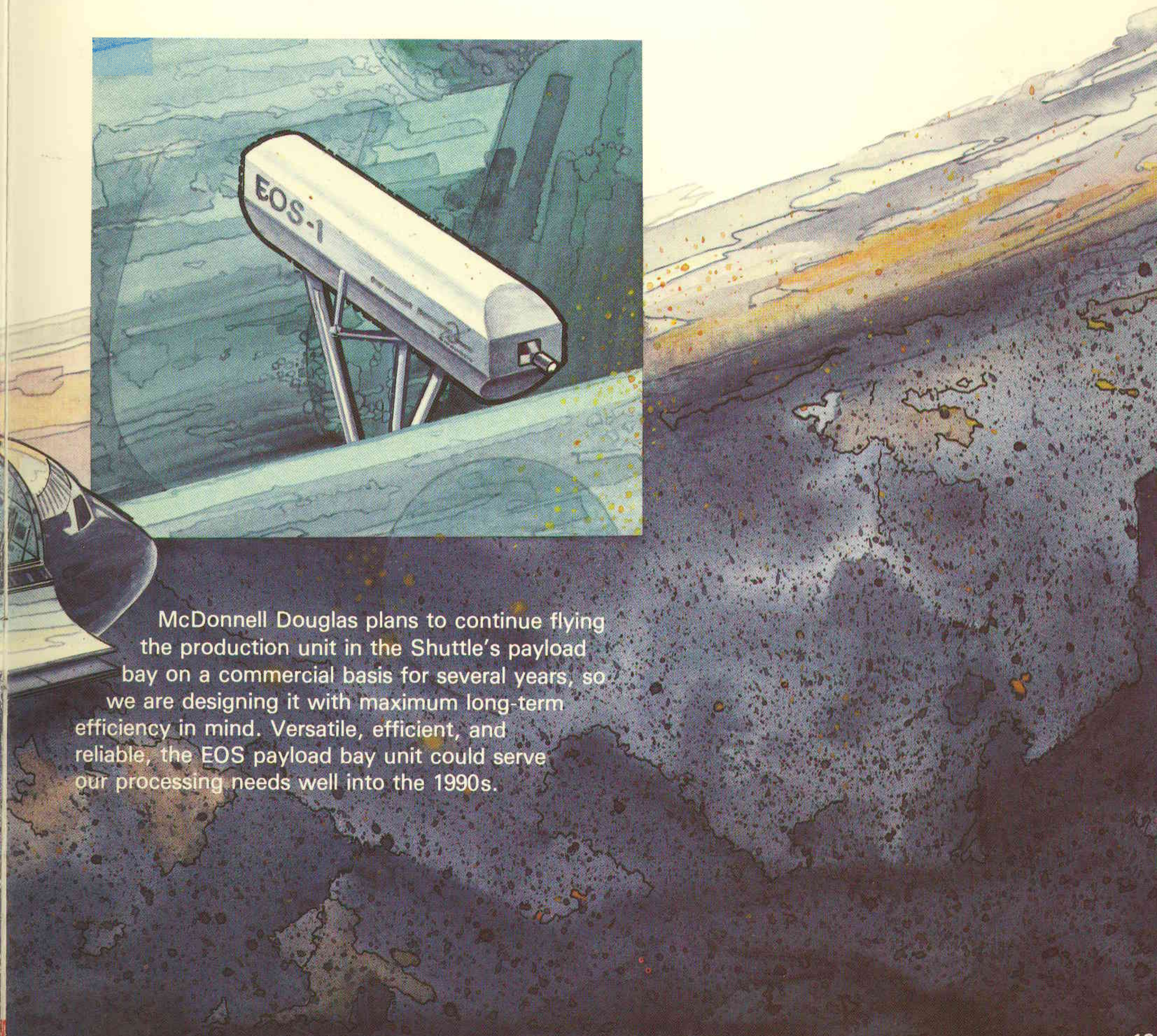
LOAD BAY



McDonnell Douglas plans to continue flying the production unit in the Shuttle's payload bay on a commercial basis for several years, so we are designing it with maximum long-term efficiency in mind. Versatile, efficient, and reliable, the EOS payload bay unit could serve our processing needs well into the 1990s.

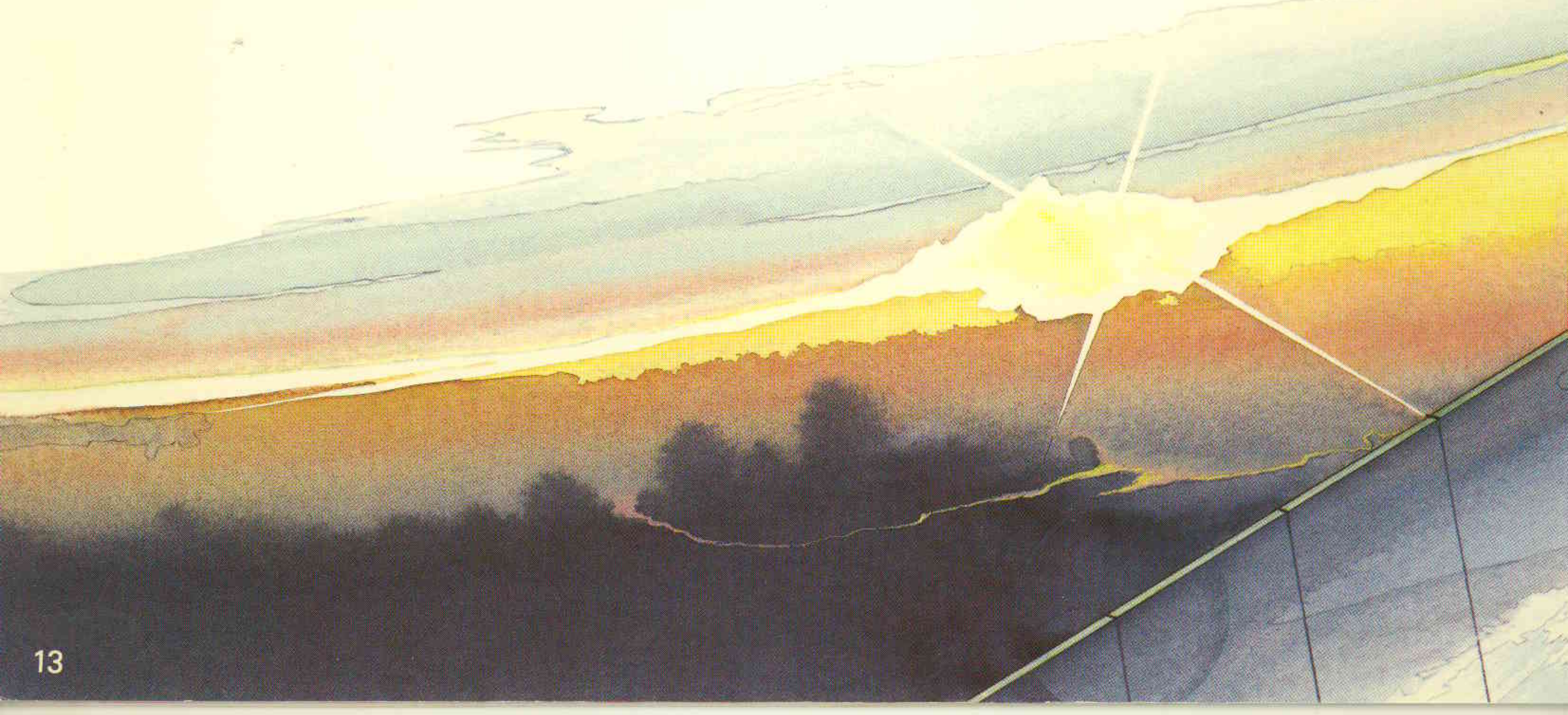
Producing in a SPACE

A space factory would be a large manned or unmanned satellite designed for permanent orbit around the Earth. Such a factory could support one or two EOS production units, weighing up to 10,000 pounds. Both a manned and unmanned space factory would be visited by Shuttle crews about four times a year to collect the separated products and deliver raw materials.

Each type of factory has its own merits. An unmanned factory would be quicker and less expensive to build. A manned factory would allow the crew to monitor and repair production equipment while conducting research and development projects.

Whether manned or unmanned, the space factory concept has three major advantages over payload bay operations. Production would be greatly increased because the equipment would operate all year round. Cost effectiveness would be enormously improved, not only because production runs would be more efficient, but also because the most expensive step -- launching the craft -- need occur only once. Finally, compared to our payload bay unit, which depends on the Shuttle to operate, the space factory concept has almost unlimited growth potential. As more separation capacity is needed, additional factories can be launched into orbit.

We are currently discussing the design and production of actual space factories with a variety of organizations interested in business ventures in space. We hope to begin operating EOS units in a space factory by the early 1990s.



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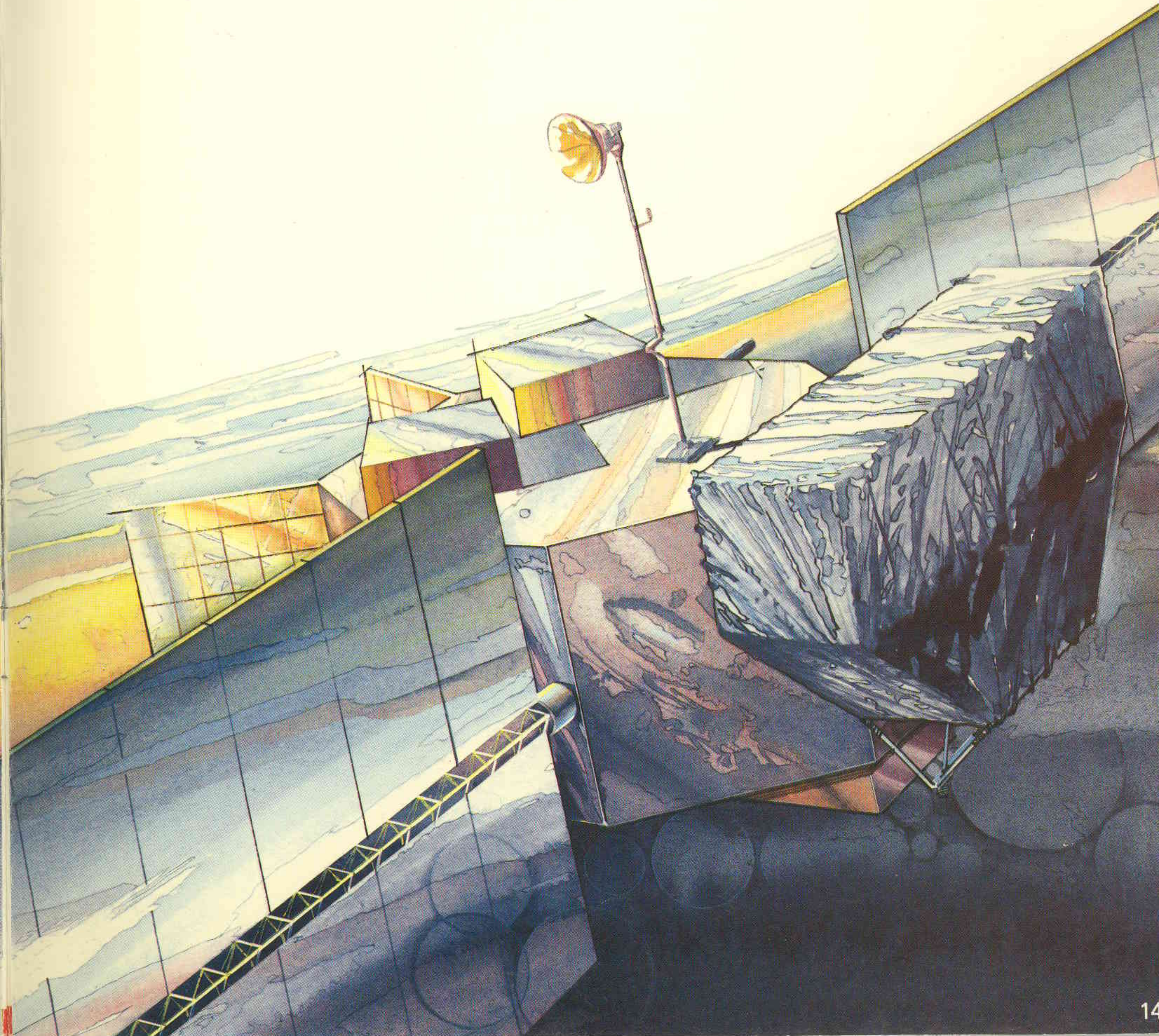
FACTORY



The Flight Log

STS—4
JUNE 1982

STS—6
APRIL 1983

STS—7
JUNE 1983

STS—8
AUGUST 1983

41-D
JUNE 1984

EOS

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY - ST. LOUIS DIVISION

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MCDONNELL DOUGLAS CORPORATION

INFORMAL MEMO

DATE 6 May, 85

TO Andy Brecklin

Enclosed is the brochure for the McDonnel Douglas EOS Program.

Your TEU's are being used on the middeck systems - see pages 9+10.

They have given us trouble free service through six launches since 1982.

Your interest and past service are appreciated.

SIGNED Al Rose

AVOID VERBAL ORDERS

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