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TYPE: ACTION DOCUMENT NUMBER: 9124279
ORIGINATOR: 02 STATUS I DIRECTORATE STATUS

FROM: MORSE, Thomas M.

TO: DR. D.A. BROMLEY

OCT 4 1991

DATE OF CORRESPONDENCE: 09/21/91

SUBJECT: RE: AN APPROACH TO THE MOON AND MARS, "IEPC 91-040 TO PLANETS USING NUCLEAR-ELECTRIC THRUST TO L1, THEN CHEMICAL FUEL TO OBTAIN LUNAR FUEL, SHIELDING, SUPPLIES NAD EARTH GRAVITY ASSIST".

DIRECTORATE ASSIGNED: PHYSICAL SCIENCES STAFF ASSIGNED: *Doug Beason*

*(Please hold for his arrival & consideration)
10/6'*

ACTION REQUIRED: AS NECESSARY STAFF ACTION:

SENDER'S DUE DATE: 10/16/91 STAFF DUE DATE: 11/7/91
DATE COMPLETED: DATE COMPLETED/DEPT:

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REMARKS: *Reproduced w/ letter*

OSTP RECEIVED: 10/02/91 DEPT RECEIVED:
FILE: P-PHYSICAL SCIENCES-SPACE



4279

RECEIVED

Dr. Allan Bromley
Science Adviser to the President
C/O White House
Washington, D.C.

RR. 6 Box 1246
Mooreville, NC 28115
Sept. 21, 1991

SEP 22 11:30

SEP 30 11:24

Dear Dr. Bromley:

OFFICE OF THE DIRECTOR

OFFICE OF THE DIRECTOR

I am sending you an approach to the moon and Mars which, if used in SEI, will save an estimated \$200 billion over a chemical approach or a nuclear-thermal approach, during 15 years of the program. The approach is compared with chemical, and nuclear-thermal, in the chart shown on page 5 of the enclosed paper.

I am 80 years old and have been working in this general approach since 1946, with a great deal of effort during the 1960s. Yet I have been unable to gain attention for it, even though it was entered last year in the nationwide SEI study by the Synthesis Group. Recently General Dynamics Space Systems Division gained attention (SPACE NEWS pp. 16, Aug. 26-Sept. 8) for an approach close to it, except that their approach uses the Mars vicinity to mate the nuclear-electric cargo with the chemical spaceship, which came direct from LEO, whereas my approach uses L1 of moon, with lunar derived fuel, shielding, and supplies, together with lunar or Earth gravity assist. The saving in cost, weight, and energy, is tremendous. Some say that lunar fuel and shielding cannot be supplied before the Mars mission, but it should be, even if they have to wait on development of a lunar base. But, conceding that the mission won't wait, I must point out that nuclear-electric OTVs can ferry cargo from LEO to L1 cheaper and quicker than they can to Mars, and the time delay in communication for telerobotic control is much shorter. Then, when lunar supplies became available on the moon, the approach will already be in place and working. Lunar fuel will make the aerobraking technology needless, and travel time can be further shortened, under what I show in the chart, since low-gravity fuel can be used to accelerate to high velocity, and then for braking, for Mars entry.

General Dynamics had a man present when I gave a paper at the AIAA conference in Orlando in July 1990. I talked with him and could see that he was interested in the approach. While I disagree with using Mars instead of the moon, at least the publicity helps by getting the general approach considered.

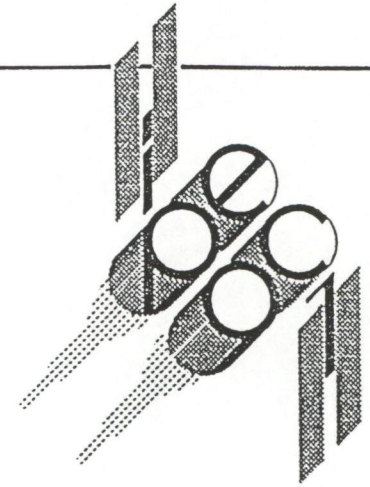
Respectfully yours,

Thomas M. Morse

Thomas M. Morse, Consultant

P.S. Manned travel time to Mars can be shortened under that shown in the chart, certainly to less than allowed for nuclear-thermal, since low-gravity fuel can be used to accelerate to high velocity, and then to brake for Mars entry.

AIAA



IEPC 91-040

**To Planets Using Nuclear-Electric
Thrust to L1, Then Chemical Fuel
to Obtain Lunar Fuel, Shielding,
Supplies, and Earth Gravity Assist**

T. Morse

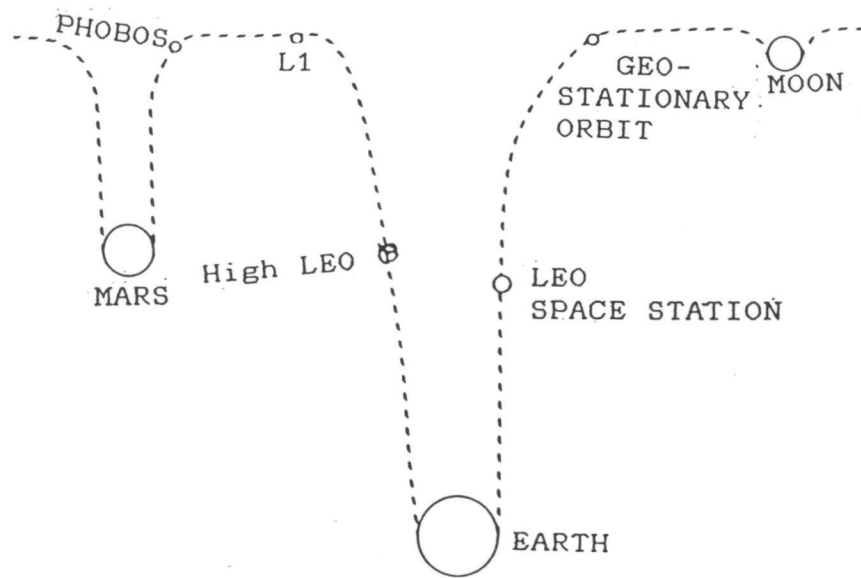
Consultant

Mooreville, N. C., USA

**AIDAA/AIAA/DGLR/JSASS 22nd International
Electric Propulsion Conference**

October 14-17, 1991 / Viareggio, Italy

GRAVITY WELLS



Gravity wells of Earth, Mars, and Moon are shown. Note that high LEO, where Mars lander is to be parked, has gravity equal to Mars. Orbital momentum offsets gravity, but much energy is required to change orbital course to near vertical. The electric thruster uses a spiral trajectory beyond LEO, in going to L1, thus requiring much less thrust for lift.

The Sun's gravity reaches to all the planets, but, at Earth's distance from the Sun, the Sun's gravity has slightly less pull on Earth than the moon has.

Once in "free" space, far from planets and moons, we can travel millions of kilometers on small amounts of energy-fuel. That's the significance of the plateau at top of the wells. The N-E-C thrust and low weight to LEO, L1, and in the plateau, is most conserving of energy, environment, and money. Scientists and engineers should give N-E-C deep thought.

COMPARISON: SALIENT FEATURES of CHEMICAL, NUCLEAR-ELECTRIC-CHEMICAL, and NUCLEAR-THERMAL PROPULSION MISSIONS to MARS

	<u>CHEMICAL</u>	<u>NUCLEAR-ELECTRIC-CHEMICAL</u>	<u>NUCLEAR-THERMAL</u>
Specific impulse:	475 s.	5,000-9,000 s.	925 s.
Thrust:	150 m.t.	80 Newtons	250 m.t.
Thrust/weight:	Very good	Very poor	Good
Initial mass to LEO:	1250 m.t.	360 m.t.	750 m.t.
Initial trips LEO:	5	4 (incl. lander)	3 m.t.
Later trips to LEO:	4	1	2
Roundtrip time:*	460 days	360 days**	320 days
Lift vehicle req.:#	250 m.t.	90 m.t.	250 m.t.

*Not counting days on Mars.

**Includes only manned part of trip, L1 Delta-V advantage, and Earth gravity assist.

#For reference, lunar Saturn Apollo had 140 metric tons.

DEFINITIONS and DESCRIPTIONS

- Specific impulse: Engine thrust in pounds, divided by propellant flow rate in pounds per second.
- Thrust/weight: Ratio of engine thrust to engine weight.
- m.t. Metric tons.
- Newtons: One Newton equals 0.2248 pound of thrust.
- Delta-V Velocity change required to change orbits and course, to achieve destination. Is expressed in km/second.

The high specific impulse advantage of electric is largely offset by the low thrust and poor thrust/weight ratio. The first three comparisons are unimportant, because the nuclear-electric portion of the mission is unmanned, so we do not care how long it takes. The important items to note are:

- (1) the initial mass to LEO required.
- (2) number of initial and subsequent trips to LEO required.
- (3) the lift vehicle requirement.
- (4) the roundtrip time requirement.

The resultant of the four items above is that nuclear-electric-chemical propulsion has a tremendous advantage over nuclear-thermal in cost and weight, which builds up rapidly over a number of missions. There is almost no disadvantage in roundtrip time. The roundtrip time can be further reduced, depending upon how much low-gravity fuel from the moon is used for accelerating and braking in "free" space.

If fuel wasn't available on the moon, the orbital transfer vehicle (OTV) can still haul fuel to L1 much cheaper than the other methods. Then there is the probability that a method of beaming power to the spaceship, by laser, will be developed.

TO PLANETS USING NUCLEAR-ELECTRIC THRUST TO L1, THEN CHEMICAL TO
OBTAIN LUNAR FUEL, SHIELDING, SUPPLIES, AND EARTH GRAVITY ASSIST

Thomas M. Morse*

Consultant

Mooresville, N.C. 28115, USA

ABSTRACT

Method uses unshielded nuclear-electric thrust for the OTV to ferry an un manned spaceship from LEO to L1. Spaceship has 3 chemical engines, but empty fuel tanks. Takes 3-5 months to reach L1 via spiral trajectory of Earth. Lunar tankers await in L1 with shielding, fuel, etc. MC robotically removes OTV from spaceship and parks it in L1. Mars lander and crew is launched to LEO and proceeds under own chemical power to L1. Lander docks with spaceship. Crew boards. Spaceship has solar panel to power robotic arcjets and solar-electric station-keeper thrusters. Tanker is brought alongside and fuel is pumped to fill tanks of both ships. Shielding is placed around outside a small compartment for crew refuge from solar flares. Landers 3 engines have enough thrust to escape Mars; spaceship has half as much thrust, but enough fuel to run for days, and more stored in Mars orbit. Engines not used during free-fall except to stay on a course that will clear Earth by 250-400km. Lander's thrust is used sparingly to: (1) aid gravity assist to collision course with Mars, (2) ensure Earth escape, and (3) braking. Spaceship's thrust is used for a long period leaving Earth. Aerobraking in Mars landing is not so important with plenty of low-gravity fuel. Return to L1 takes 5 months. Spaceship parks in L1 until next trip. Crew returns to LEO in lander. Total manned round-trip travel time is one year, which compares favorably with nuclear-thermal planned for SEI. Cost is far less. Only crew and fuel is launched to LEO on later trips, at still less cost; nuclear-reactor is kept away from Earth. OTVs haul tankers to Mars, and beam power to bases from geostationary orbit.

NOMENCLATURE AND DESCRIPTIONS

OTV	Orbital Transfer Vehicle.
LEO	Low Earth Orbit.
MC	Mission Control for telerobotics.
ERV	Earth Return Vehicle.
Spec. Impulse	Engine thrust in pounds, divided by propellant flow rate in pounds/sec.
Thrust/weight	The ratio of engine thrust to engine weight.
Delta-V	Velocity change required to change orbits and course, to achieve destination. Is expressed in km/s.
m.t.	Metric tons.
N	Newton. Equals 0.2248 pound thrust.

INTRODUCTION

A lunar base should be well developed before we attempt a Mars mission. To go to Mars prematurely will delay development of both moon and Mars. Developing lunar bases will benefit Earth more, especially the environment. Thirty years from now, methods of beaming solar-nuclear power to Earth are likely, and in fifty years, obtaining clean nuclear fusion from lunar helium-3 is likely. Lunar observatories will enable astronomers to explain the universe. Spaceships will be built on the moon.

We must avoid space projects that accomplish little, yet cost-delay the main goals, which are: (1) Solve most environmental problems of Earth. (2) Develop lunar bases. (3) Build variety of lunar

astronomy sites. (4) Develop Mars bases. (5) Learn more about the planets and their moons.

Why via moon instead of direct to Mars? A mission using solely chemical fuel, direct or indirect, is impractical because of large weight and cost. Safe robotic nuclear-electric thrust, activated in LEO, will enable economical means of hauling unmanned spaceships and heavy mining-manufacturing equipment to the moon, and to haul tankers of reserve fuel and power supplies to Mars orbit. Chemical fuels and other supplies, manufactured on the moon from lunar sources, will enable fast manned missions to Mars from LEO, via the moon or L1, in about the same elapsed time, and at far less cost, than would nuclear-thermal thrust direct from LEO. Direct missions from Earth to Mars, using nuclear-thermal thrust, will probably never occur, for economic and perceived environmental reasons, if the primary architecture laid out in America's "SPACE EXPLORATION INITIATIVE" (SEI) is followed. ((Note: Trips to Mars using nuclear-thermal thrust in a manner economically and environmentally acceptable, is discussed near end of this paper.))

A space station in LEO isn't immediately required for this nuclear-electric-chemical mission to Mars, where manned part of the mission does not take long, artificial gravity is provided by simple centrifuge, and radiation shielding is obtained from the moon. The need for these will be well understood by then as a result of tests made earlier in an orbiter, and on the moon, to prove concepts and equipment.

A finally, President Bush has directed NASA, in cooperation with other nations, to go via the moon.

A NEW METHOD OF PROPULSION FOR THE NEAR FUTURE

Direct missions to the planets, even stars, using nuclear fusion particle (proton) thrust may be possible, but is many generations in the future.

Probably, in the not too distant future, a new propulsion method will be developed. Nuclear, solar energy will be beamed by laser or maser from space, moon, or Earth, to the spaceship and converted to electric thrust. It would not be too different from using nuclear or solar with electric thrusters, in the method discussed herein. Using laser beamed power would be much superior because the manned spaceship would not have to carry the mass of the nuclear reactor and required shielding. A spaceship could go direct to any planet. High velocities could be attained, since the thrust, while low, would be present almost continuously. The thrust could also be used for braking, changing course, and for the return trip. To those readers taught that all light diminishes in strength with the square of the distance from the source, that does not apply to coherent laser or maser beams. In space, coherent light remains in the same narrow beam forever without losing strength, or, until it strikes an object such as the solar panel of a spaceship. The solar panel, as now made, is only about 30% efficient, but if used with receptor fields resonant to the wavelength of the coherent light, it can be about 80% efficient. For this mission, however, it is assumed that this type of thrust is not yet developed.

REASONS FOR HASTE IN ESTABLISHING LUNAR BASES

There are good reasons for haste in establishing lunar bases. By hindsight, it should have been our first priority after the lunar missions. Instead, we were sidetracked by too many unrelated programs, and by exotic visions of missions direct to Mars.

*Member Planet. Soc., Space Study Inst., Nat'l Space Soc.; Plan. Engr. AT&T Tech. (Retired). Member AIAA.

ally neutralized. As soon as they have docked, the astronauts notify MC, then climb aboard spaceship. They check out the battery, which is kept charged by the solar panels. The crew will later add additional solar panels as soon as they are received from the moon. The astronauts notify MC that they are taking over manual control of the spaceship. The crew then checks that they have control of the arcjets, and the two low power solar-electric thrusters, which enable them to maneuver the ship without the main chemical thrust engines. They then operate each of the three chemical thrust engines, separately, at low power for short period. When they have fully checked out the spaceship, the astronauts notify MC of that fact, and then notify the lunar base that they are ready to take-on cargo.

BRINGING UP SUPPLIES FROM THE MOON

A lunar supply tanker is already waiting in L1, filled with fuel and other supplies from the moon. One could expect that there will be LOX and LH2 in the tanker ready to be pumped over to tanks of the spaceship and Mars lander. In a short while the tanker is brought alongside, and pumping begins. There may also be strap-on tanks, designed to fit the curvature of the spaceship and lander, in places where there is nothing else to interfere. It is also likely that there will be water, and, perhaps, food. Solar panels will have been made on the moon to fit the needs of the spaceship and lander.

A small compartment will be inside the spaceship, just large enough to hold the entire crew, and a few supplies, during solar flares. Shielding for this compartment will be strapped on to the outside of the ship. This shielding may simply consist of plain lunar regolith, or, it may be made of special metal, mined, separated, and formed to fit on the moon.

Someday, almost everything required for a space mission, even spaceships, will be built on the moon.

LEAVING MOON FOR EARTH GRAVITY ASSIST ON WAY TO MARS

Figure 1 shows three possibilities for leaving moon enroute to Mars, as follows:

First Method: Spaceship leaves lunar orbit direct.

Second Method: Spaceship leaves L1 for lunar gravity assist on way to Mars.

Third Method: Spaceship leaves L1 for Earth gravity assist on way to Mars.

At first glance, the first method, leaving lunar orbit direct, may look best. However, from an orbit around the moon, a large course change is required of a now relatively massive spaceship to intercept Mars. This would require more fuel and nullify gain.

The second method has quite a bit of merit. By making a relatively slow passage in front of the moon from L1 (arrows Fig. 1), without using much fuel, the moon's gravity has a long time to change the course substantially. The spaceship can pass close to front of moon also, since the moon has no atmosphere. Depending on where the moon is in its orbit, it might be the best method. Using lunar gravity assist was treated in a previous paper.

Third method gains a gravity assist from Earth. Leaving the parking location at L1, the astronauts first use the combination of arcjets and the spaceship's low power chemical engines, to start out on the course that takes them behind Earth, as shown in dashed lines (Fig. 1), until Earth's gravity begins to take over, and the spaceship, with lander, starts free-falling on a course that will take them behind Earth. Thereafter, as they accelerate toward Earth, spaceship's engines are used sparingly, in conjunction with arcjets, to correct course as necessary, so that spaceship passes Earth by the calculated miss distance, somewhere between 250-400 km., to ensure they will experience no drag due to atmosphere. MC is in communication, and monitoring their course during the whole maneuver. The more powerful

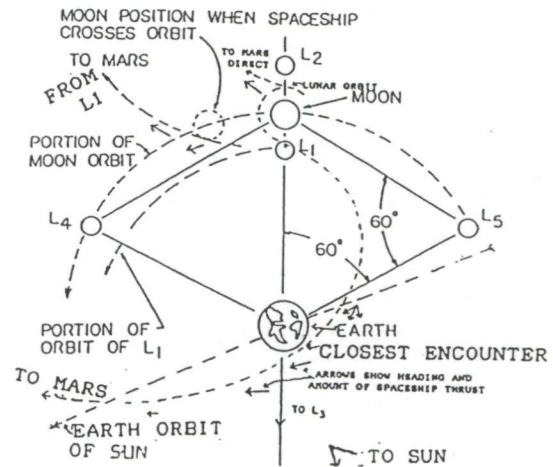


Figure 1: Shows locations of the five libration points, L1-L5, of the Earth-moon system. Three pathways to Mars from moon are shown. One path leaves a lunar orbit direct for Mars. Another path leaves L1, going in front of moon, for lunar gravity assist. A third goes behind Earth for gravity assist.

engines of the Mars lander will be used only momentarily, if needed, during the latter part of the fall to ensure proper miss distance. After the near miss of Earth, at almost escape velocity, both the lander's, and spaceship's engines are used as long as necessary (arrows Fig. 1) to ensure that the spaceship will end up on a collision course with Mars, and that escape velocity is reached. After that, the lander's engines will be shut down. After the close encounter, the spaceship passes by Earth in less than an hour. The spaceship's engines will continue to accelerate the ship for a period, the length of which will depend upon many options, such as: (1) how much fuel was brought from the moon, (2) whether it is planned to use the engines for braking after the coast period, and (3) whether a prepared tanker was sent ahead to Mars orbit.

The Mars lander's engines have twice as much thrust as the spaceship's engines, because the lander needs to lift off from Mars, and also must leave high LEO for L-1. Studies have shown that, in general, the less power engines have, the more conserving of fuel they are, so it is wise to use low power engines that will run for days, where it is feasible. Since there is no friction in space, acceleration continues as long as the engines are operated. Acceleration to a higher velocity than needed, shortens the mission, which is very desirable, but it requires braking after the coast period by the spaceship's engines, which may be undesirable. The spaceship would have to be rotated 180°, by the arcjets, to use the engines for braking. Such braking assumes a plentiful supply of low-gravity fuel.

ARRIVAL AND LANDING ON MARS

When the astronauts arrive vicinity of Mars, they will either go to one of its moons, or, more likely, to the prepared tanker, to refuel. Then they will go to a low Mars orbit for reconnaissance. The crew has a good idea of the best landing sites from previous recon and robotic landings. A crew of four will board the lander, and it will be readied for entry and landing. By then it will be known which types of aerobraking to use, if any. Aerobraking to conserve fuel will not be so important by then, since they will have plenty of low-gravity fuel.

perceived nuclear threat to Earth by a large percent of people. There is possible danger of damage from secondary radiation in the Van Allen belt.

But that is not all. The nuclear-electric OTV is an excellent source of base power. Hopefully, it can be used to beam power to the moon from L1, and to Mars from geosynchronous orbit. It can be landed, with aid of rockets, if necessary, for direct power use. The nuclear-thermal engine, on the other hand, cannot be readily used for base power. Without the nuclear-electric OTV, billions of dollars will have to be spent for power sources for Mars and moon.

One criticism expected of the foregoing comparison is that the huge cost of developing the moon, over a period decades, is not figured into the cost of the nuclear-electric-chemical architecture. The answer is that the moon will stand alone in its development. The moon will be developed, in any case, for what it has to offer Earth. To not use its many features would be unwise. If nuclear-electric-chemical development helps the moon, that is fine. One could just as logically cite the huge cost of the nuclear-thermal Rover (NERVA) engine development since the late 1950's, which, if finally adopted, will continue until the nuclear-thermal engine has been proven, or disproven, in space.

The nuclear-thermal engine does not promise an increase in power, with development, without a corresponding increase in mass. The nuclear-electric thrusters, on the other hand, have been proven many times in space, and the future promises more powerful thrusters without much increase in mass. It will be aided by developments in related MagnetoPlasma-Dynamic (MPD), and also related microwave plasma, thrusters. Development of the related laser beamed power thruster would greatly reduce mass.

COMPARISON OF SALIENT FEATURES OF CHEM., N-E, AND N-T PROPULSION TO MARS

	<u>CHEMICAL</u>	<u>NUCLEAR-ELECTRIC (Chem)</u>	<u>NUCLEAR-THERMAL</u>
Spec. Impulse:*	475sec	5,000-9,000sec	924sec
Thrust:	150 m.t.	80-N	250 m.t.
Thrust/weight:	Very good	Very poor	Good
Init. Mass LEO:	1250 m.t.	270 m.t.	750 m.t.
Init. Trips LEO:	5	3 (incl Mars l.)	3
Later Trips LEO:	4	1	2
Round Trip Time**	460 days	360 days***	320 days
Lift Veh. Req. #	250 m.t.	90 m.t.	250 m.t.

*Refer to INSTRUCTIONS on first page.

**Not counting days spent on Mars.

***Includes only manned part of trip. Also, L1 Delta-V, and Earth gravity assist.

#For reference, lunar Apollo had 140 m.t.

In the above table, it is evident that we are dealing with two vastly different types of nuclear thrust. From some figures, nuclear-thermal looks best, but careful analysis shows strongly that nuclear-electric-chemical is far less costly, and requires only 40 more days roundtrip time for the manned Mars mission.

PROPOSED MISSION TO MARS SCENARIO FOR NUCLEAR-THERMAL ROCKET THAT ENABLES A MUCH REDUCED COST AND AVOIDS THE PERCEIVED THREAT TO EARTH

The idea is to go to Mars via L1 (or the moon) in basically the same manner described for the nuclear-electric-chemical spaceship, except the OTV, and, perhaps, the Mars lander, would not be used. The nuclear-thermal rocket would only carry enough propellant to take the rocket from LEO to L1 (or to the moon), where it is parked while propellant, fuel, solar flare shielding, solar panels, etc., are taken on board for the mission. An alternative would be to land the rocketship on the moon to load supplies on board, rather than rendezvous in L1. With this alternative, the design would include landing legs,

and the ship would also be able to land on Mars. The Mars lander would be unnecessary. Instead, an ERV would be left parked on the moon, or at L1, during the trip to Mars. This would have the added advantage of not requiring the spaceship to be left in Mars orbit during long stays, with its occupants subjected to space radiation. On the return from Mars, the nuclear-thermal rocketship would be parked on the moon (or at L1) until the next mission and the crew would return to LEO in the ERV. On subsequent trips, the crew would be taken from Earth to LEO by shuttle, and thence by ERV to the moon or L1.

The important advantages of this scenario are:
 (1) the nuclear-thermal reactor is not left for long intervals in LEO to frighten some people on Earth;
 (2) lunar material is used whenever possible; and
 (3) there is no need to take a Mars lander to Mars.

It is assumed that a single gaseous element will be available on the moon to serve as propellant for the nuclear-thermal engine. We know that oxygen is available in large amounts, but oxygen reacts or burns readily with most elements under conditions of high pressure-temperature. It may not be compatible with the walls of the compression chamber. Hydrogen is present on the lunar surface in small quantities that may be sufficient. Helium is not plentiful. An element, or combination of elements, may be found that inhibits oxygen from reacting readily.

It is doubtful whether the nuclear-thermal engine can compete with nuclear-electric-chemical, and its various related developments. Both architectures need further study and development before anyone can be sure. The wrong choice may bankrupt America, or, regrettably, end our space program.

A CENTRIFUGE FOR ARTIFICIAL GRAVITY ON MARS MISSION

The Soviet experience, as well as our own, is that artificial gravity equipment is necessary on trips of long duration. A simple centrifuge, which can hold three astronauts, should suffice. It will occupy little space in the cabin, and can provide from 0-1g. It is believed that 0.6g will be found adequate, if used by each astronaut for at least eight hours daily. Each astronaut will be compartmented separately, but can communicate. Some scientists say that a small centrifuge can't be used because coriolis effect, chiefly on the brain and inner ears, would cause dizziness. Based upon my own experiences, there will be no dizziness, or other ill effects, because the inner ears and both halves of the brain, will be kept close to the same distance from the axis of rotation, and because he/she will not see any surroundings that are not moving with the astronaut. To his/her mind, they will not be moving. Artificial gravity will be applied while astronaut is sleeping, reading, hearing music, etc.

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EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

November 7, 1991

Dear Mr. Morse:

Thank you for your recent letter and accompanying article which you sent to Dr. Bromley. We appreciate your concern for the Space Exploration Initiative. Best wishes in your future endeavors.

Sincerely,

A handwritten signature in black ink, appearing to read "J. Douglas Beason". The signature is fluid and cursive, with a large initial "J" and "B".

J. Douglas Beason
Policy Analyst

Mr. Thomas M. Morse
RR. 6, Box 246
 Mooresville, NC 28115

TYPE: Information

DOCUMENT NUMBER: 9129346

ORIGINATOR: 03

STATUS

DIRECTORATE STATUS C

FROM: VP Quayle

TO: Richard Truly

DATE OF
CORRESPONDENCE: 03/19/91

SUBJECT: Expressing the Administration's commitment to Space
Station Freedom.

DIRECTORATE
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STAFF
ASSIGNED:

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OSTP DUE DATE:
DATE COMPLETED:

STAFF DUE DATE
DATE COMPLETED/DEPT:

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REMARKS:

OSTP RECEIVED:
FILE: PS-SPC-SPACE STATION

DEPT RECEIVED:

CENTRAL FILES:



346

THE VICE PRESIDENT
WASHINGTON

March 19, 1991

Admiral Richard Truly
Administrator
NASA Headquarters
400 Independence Avenue, N.W.
Washington, D.C. 20546

Dear Dick:

As you know, the President has made space exploration a high priority. He has done so because of his conviction that opening up the frontiers of space is not only in America's interest, it is America's destiny.

The President has provided the necessary leadership by setting a long term goal for space exploration and aggressively pursuing a reform agenda for our space program.

This Administration has made a strong commitment of resources to the future, by requesting over a 40% increase in spending for our civil space program. The Congress has supported much of our request for an increased investment in space, but more support is needed. One of the central items, the future of which is yet to be resolved, is Space Station Freedom.

NASA has recently forwarded a new concept design for the Space Station to the National Space Council for approval. This new design reflects a focusing of the Space Station program that recognizes certain fiscal and physical realities. The restructuring of the program would reduce the total cost of the station by about 15%, decrease its reliance on shuttle flights by over 20%, and address other logistical problems, including the amount of time required for extra-vehicular activity. Implementing these changes will increase greatly the nation's confidence in the feasibility of this program.

Recently, some in the scientific community have argued that the purely scientific returns on this investment are not sufficient to warrant the necessary commitment of resources to achieve them. This argument is not entirely appropriate. The Space Station unquestionably can make a valuable research contribution -- a contribution that becomes more cost-effective in the latter stages of the Station's development. But more fundamentally, the ability of the Space Station to provide America with a unique research facility for microgravity and life sciences research is but one reason for building a space station.

The most compelling reason for building a space station is that it is a necessary step to further American leadership in exploring space. It is clear that the future of America's space program is inextricably linked to the building of the Space Station.

It is vital, therefore, that the Space Station be considered an essential part of the larger Mission From Planet Earth. That Mission includes the development of new infrastructures and the pursuit of new initiatives aimed at gaining scientific knowledge and establishing a permanent presence in space. This is the next vital step in the historic space mission America began over thirty years ago.

The Space Station is an integral part of a balanced plan of future exploration, future acquisition of scientific knowledge, and future space leadership. The successful pursuit of such leadership will require not only the Space Station, but also the development of a new launch system and research on the architectures and technologies which constitute the Space Exploration Initiative.

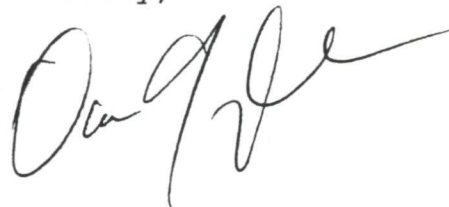
The Space Station will therefore, be more than a science facility and microgravity lab, more than a training facility, and more than a life science laboratory. The ultimate mission of the Space Station will exceed the sum of these uses. The ultimate mission is necessary to the reaffirmation of the leadership in space of the United States of America, the world's only superpower.

The importance of the Space Station, thus, is not the size of its span nor the power of its circuits; it is the size of the dream and the depth of the commitment it represents.

President Bush and I are prepared to make the commitment to build a permanently manned space station in this decade. We are convinced of its merit. We are committed to the balanced plan for space exploration to which the newly configured space station contributes.

Therefore, I am authorizing you to forward NASA's new concept design for Space Station Freedom to the Congress. We need to ensure that, as we proceed through this and future budget cycles, the balance of our Mission From Planet Earth be preserved. We will "go-as-we-pay," but we must go -- and we will proceed along a balanced front aimed ultimately at the exploration of space and the quest for new horizons.

Sincerely,



"CORRESPONDENCE TRACKING"

TYPE: INFORMATION

DOCUMENT NUMBER: 9120814

FROM: TRULY, Richard H.: NASA

TO: DR. BROMLEY

DATE OF
CORRESPONDENCE: 03/15/91

SUBJECT: AN INITIAL RESPONSE TO THE NATIONAL RESEARCH
COUNCIL'S PAPER ON LIFE SCIENCES AND MATERIALS
SCIENCE CAPABILITIES ABOARD THE REDESIGNED SPACE
STATION.

ASSIGNED TO:

ACTION REQUIRED:

SENDER'S DUE DATE:

OSTP DUE DATE:

DATE COMPLETED:

COPIES TO: D. Allan Bromley
Dr. Wong
Life Sciences

WHITE HOUSE TRACKING #:

CONTACT PERSON:

REMARKS:

DATE RECEIVED: 03/20/91

FILE: SPACE



National Aeronautics and
Space Administration

Washington, D.C.
20546

Office of the Administrator

9120914

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91 MAR 20 1991
March 15 9:36

OFFICE OF THE
DIRECTOR

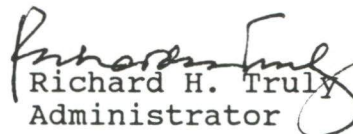
The Honorable D. Allan Bromley
Assistant to the President
for Science and Technology and
Director, Office of Science and
Technology Policy
Executive Office of the President
Washington, DC 20506

Dear Dr. *Allan* Bromley:

As I promised on the telephone this morning, we developed the enclosed material as an initial response to the National Research Council's paper on life sciences and materials science capabilities aboard the redesigned Space Station.

Our aim was to satisfy congressional budget restraints, honor international commitments and maintain the long-term capability to meet user requirements. We believe the Station redesign does this.

Sincerely,


Richard H. Truly
Administrator

Enclosure

NASA COMMENTS ON THE SPACE STUDIES BOARD REPORT

The basic premise of the Space Station Freedom restructuring was that the Congressionally mandated constraints on budget runout and the International Agreements with Europe, Japan, and Canada, would not be violated.

Having done that, the basic design, timing of Permanent Manned Capability, and priorities for science, applied research, and technology utilization of the Station were effectively determined.

The Space Studies Board concerns would require that NASA violate one or both of the basic premises in order to effect the changes implied by their recommendations. NASA does not unilaterally possess the authority, nor does it believe it is appropriate, to take such action.

NASA believes that the restructured Space Station, during its evolution, will meet the requirements of the principal scientific research for which it is intended, and that it will provide for world-class research in microgravity and life science.

The Space Studies Board listed a number of specific criticisms of the restructured Space Station. In most cases these criticisms are an inaccurate reflection of the Station's current or planned capabilities. The attached comments address specific points made by the Boards' subcommittee reports.

SPACE BIOLOGY AND MEDICINE RESEARCH REQUIREMENTS

The Committee on Space Biology and Medicine and the Space Studies Board conclude that Space Station Freedom, in its present redesigned form, will be inadequate to meet the requirements for space biology and medicine research described above because of the following:

1. *The plan to share limited power among multiple users in all laboratory modules suggests that there will be insufficient power to conduct the volume of long-term biological experiments required to support a human space exploration initiative.*
 - An analysis of the life sciences power requirements indicates that the life sciences share of the OSSA projected 65% allocation allows the full utilization of the proposed life sciences experiment hardware during all phases of operation.
 - At PMC and beyond, power equates to more than the power provided to three simultaneous dedicated Spacelab module missions, such as SLS-1.

2. *Plans for the size and location of a centrifuge and of animal-holding facilities are insufficiently defined for proper evaluation. As emphasized in the Boards 1987 strategy report, an adequate centrifuge is essential to provide a 1-g control for 0-g experiments and also to explore the adequacy of artificial gravity for long-duration spaceflight.*
 - The Space Station Freedom Program Requirement Definition (PRD) document has accepted a baseline requirement for a 2.5 meter centrifuge and the associated animal holding facilities on the Station. Options for specific location and accommodations are still being evaluated.
 - The Japanese module has both the proper plumbing and space for a 1.8 meter centrifuge.

3. *The proposed crew size is insufficient to conduct the requisite experiments in a reasonable time period.*

- The reduction to an initial crew size of four from the eight previously baselined will necessarily extend the time required to develop appropriate statistics on areas related to long-term exposure to the space environment.
- The inherent capability to restore crew size to eight after PMC has been retained in the restructured Space Station and its implementation is paced only by budget availability.

4. *The absence of a dedicated life sciences laboratory will prohibit some experiments and will severely restrict most others, prolonging the acquisition of data required to answer fundamental questions related to the feasibility of long-duration human space exploration.*

- We are unaware of any validated science rationale which can only be met by a dedicated laboratory for life sciences.
- We are aware of proximity requirements for selected life sciences suites of instruments and those requirements are being met.

MICROGRAVITY RESEARCH REQUIREMENTS

The redesigned Space Station Freedom would be inadequate to meet the requirements of microgravity science and applications because it lacks the following:

1. *A low, quiescent acceleration environment unhampered by crew activities, docking maneuvers, and other system activities necessary to sustain a permanently occupied presence.*
 - The National Academy of Sciences Report of the Committee on a Commercially Developed Space Facility, 1989, found ". . . that over 85 per cent of the proposed [*microgravity sciences*] experiments could be accommodated in a 16-day mission, and that a 28-day mission would accommodate virtually all of the remainder. Experiments or processes needing on-orbit duration greater than presently available include such things as biotechnology research with living cells and crystal growth."
 - During the Man Tended phase of Space Station utilization, periods of up to 45 days will be available and provide a quiescent microgravity acceleration environment unhampered by crew activities and docking maneuvers.
 - Post-PMC, the baselined Station specification for the restructured Station will provide a microgravity environment for periods of up to 30 days free of significant disturbances .
 - The Space Station program has baselined a U.S. Laboratory Acceleration Mapping System which allows for monitoring and will facilitate control of the acceleration environment. Additionally, the Station has committed to implementing a vibro-acoustic control plan.

2. *A crew that would spend sufficient time working with the experiment equipment.*

- During Man Tended phase utilization flights a dedicated payload crew of up to four will be available to operate with experiments.
- Inherent capability to restore crew size to eight after PMC has been retained in the restructured Space Station and its implementation is paced only by budget availability.
- However, even beyond PMC when a crew of eight could be available, dedicated experiment crew time will still be one of Space Station's most precious resources.

3. *Sufficient power, data-handling capabilities, and research volume.*

- An analysis of the microgravity sciences power requirements indicates that the microgravity sciences share of the projected OSSA 65% allocation allows the full utilization of the proposed microgravity sciences experiment hardware.
- As a minimum, the data handling and down link capabilities of the restructured station equals or exceeds the current Spacelab capability.
- The inherent capability to restore a 300 mbps data handling system after PMC has been retained in the restructured Space Station, is still a high priority, and its implementation is paced only by budget availability.
- However, on-orbit data storage and processing for user payloads remain unresolved issues which are subjects of continuing study.
- The inherent capability to restore the Station to the full volume of user laboratory racks previously baselined has been retained in the restructured Space Station in the form U.S. Laboratory B (which offers 12 additional U.S. user payload racks) and its implementation is paced only by budget availability.

4. *The flexibility to upgrade systems; this deficiency is especially disconcerting in the area of computers, in which obsolescence is extremely rapid.*

- Current station design has incorporated state of the art data standards (e.g., Fiber Distributed Data Interface - FDDI). This basic fiber optic system is capable of handling higher data rates with future upgrades in terminating hardware, data handling and computational systems.
- Modularity of experiment and infrastructure systems will be applied to both payload and station design/utilization.

Other Issues

"During the crew-tended phase, NASA plans to fly Spacelab experiment hardware on the Space Station Freedom because other, newer hardware will not be available. Most of this Spacelab hardware will require manual intervention and therefore will be operable only when people are present."

- During the initial man tended phase of Space Station (1997 - 98), NASA plans to fly hardware developed for Spacelab to support peer-reviewed science investigations that continue into this timeframe. The transition to station is evolutionary, as is the science performed in space. Accommodating this class of hardware on the restructured Station during the initial utilization period precludes discontinuities in the science program were NASA to stand down to retool for the new spacecraft.

"Unfortunately, the crew-tended phase is a time when significant acceleration disturbances will exist due to concurrent hardware integration and assembly and construction activities. Therefore, the man-tended phase will not be suitable for many microgravity experiments."

- The concept of utilization flights during the assembly sequence of Space Station was to ensure that the science, applied research, and technology activities during the man tended phase were distinct and isolated from the construction and verification activities. This promotes efficiencies in utilization during the assembly period, while providing continued research in space as we transition from Spacelab to Space Station.

"CORRESPONDENCE TRACKING"

TYPE: INFORMATION

DOCUMENT NUMBER: 9120761

FROM: PRESS, Frank: NATIONAL RESEARCH COUNCIL

TO: DR. BROMLEY

- DATE OF
CORRESPONDENCE: 03/14/91

SUBJECT: A POSITION PAPER PREPARED BY THE NRC'S SPACE STUDIES
BOARD ON THE RECENT REDESIGN OF SPACE STATION
FREEDOM.

ASSIGNED TO:

ACTION REQUIRED:

SENDER'S DUE DATE: OSTP DUE DATE:

DATE COMPLETED: 4/2/91

COPIES TO: D. Allan Bromley
Karl Erb
Dr. Phillips

WHITE HOUSE TRACKING #: CONTACT PERSON:

REMARKS:

File *Space Station*

DATE RECEIVED: 03/15/91

FILE: SPACE

NATIONAL RESEARCH COUNCIL

2101 CONSTITUTION AVENUE WASHINGTON, D. C. 20418

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01 MAR 15 10:08

March 14, 1991

OFFICE OF THE
DIRECTOR

OFFICE OF THE CHAIRMAN

Dr. D. Allan Bromley
Assistant to the President
for Science and Technology
Old Executive Office Building
17th Street & Pennsylvania Avenue NW
Washington DC 20506

Dear Allan:

I am forwarding a position paper prepared by the National Research Council's Space Studies Board on the recent redesign of Space Station Freedom—specifically, the suitability of that redesign for space research. The Board evaluated the results of this redesign effort, as presented by NASA space station officials, in the context of published Board research recommendations. The evaluation was conducted by the Board and its discipline committees in microgravity research and space biology and medicine. The enclosed cover letter addressed to Admiral Truly provides a brief history of the evolution of the statement.

We look forward to the opportunity to discuss this report with members of the OSTP, OMB, and Space Council staffs tomorrow morning.

Yours sincerely,



Frank Press
Chairman

Enclosures

SPACE STUDIES BOARD POSITION

ON

PROPOSED REDESIGN OF SPACE STATION FREEDOM

SUMMARY

The United States has contemplated for many years the construction of a space station that would further a variety of national goals, one of which is space science and applications. The recent report of the presidentially appointed Advisory Committee on the Future of the U.S. Space Program, chaired by Norman Augustine, recommended that the development of a U.S. space station with research facilities must give top priority to life sciences research, with microgravity research assuming a significant but secondary role.¹ The Board notes that this recommendation is fully consistent with the 1983 Space Studies Board position on the space station, as well as with the 1988 National Academy of Sciences/National Academy of Engineering report to then newly-elected President Bush.^{2,3} *In the judgment of the Board, Space Station Freedom, at the present stage of redesign, does not meet the basic research requirements of the two principal scientific disciplines for which it is intended: (1) life sciences research necessary to support the national objective of long-term human exploration of space, and (2) microgravity research and applications.* This conclusion as to the station's research capabilities is based upon an assessment of its redesign as of March 1991.⁴ Attachments 1 and 2 summarize the research requirements for space biology and medicine and for microgravity research and their relationship to the redesigned space station.

The Space Studies Board's membership is not constituted such that it can provide an engineering judgment on the feasibility of the redesign, and therefore has not done so.

RESEARCH RETURN ON TAXPAYER INVESTMENT

The Space Studies Board considered the quantity and quality of research that might be conducted on the proposed redesigned space station in the context of the level of investment that will be required to bring it to completion. The Board believes that neither the quantity nor the quality of research that can be conducted on the proposed station merits the projected investment. As redesigned, a maximum of \$2.6 billion per year would be expended on the station to achieve an initial crew-tended capability by the mid-1990s, not including associated Space Transportation System and user costs.⁵ Additional funding at a comparable rate of expenditure would be required to achieve a permanently occupied capability late in the decade. In the initial, crew-tended configuration, the redesigned station would be devoted primarily to microgravity research. Life sciences research unique to the space station would not begin until the end of the decade, when the permanently occupied configuration would be established. For comparison, the 1991 NASA budget allocates roughly \$102 million to microgravity research. In other words, during each of the next five years, the amount of funding devoted to space station construction for microgravity research would be approximately 20 times the level of the current research program for this discipline. In addition, the monthly cost of constructing the redesigned station would approach the annual total funding devoted to both NASA's life sciences and microgravity science and applications divisions during the current fiscal year.

SPACE RESEARCH REQUIREMENTS, OPPORTUNITIES, AND ALTERNATIVES

Life Sciences Research

The Augustine Committee recently concluded that the primary objective of a space station should be life sciences research.¹ The Space Studies Board strongly endorses the position that a space-based laboratory is required to study the physiological consequences of long-term space flight.^{7,8} The Board notes that many of the fundamental problems in life sciences research involve a long period of time for their pursuit and solution. In its present form, the redesigned space station does not provide the facilities required for such research. (See Attachment 1.)

Microgravity Research

In the judgment of the Board, the limited microgravity research that could be conducted on the redesigned space station as currently proposed does not merit the investment. If such funds were made available, the research community would likely choose to spend them in a very different way. (See Attachment 2.) The Board believes specifically that more research progress could be achieved in a shorter period of time and at a fraction of the cost through an expanded program of Spacelab missions and of free-flyer experiments.^{6,8,9}

NATIONAL GOALS AND THEIR ACHIEVEMENT

In conclusion, the SSB recognizes that there are national considerations for building a space station other than scientific research. Included among these are the possibilities of enhancing international prestige, stimulating the nation's educational achievement, stimulating the U.S. technology base, and supporting a long-term human space exploration initiative.

In the judgment of the Board, the proposed redesign of Space Station Freedom does not meet the stated national goal of enabling the life sciences research necessary to support extended human space exploration, nor does it meet the stated needs of the microgravity research community—most of whose goals could be achieved in both a more timely and more cost-effective manner by alternative means. Continued development of Space Station Freedom, as currently redesigned, cannot be supported on scientific grounds. If the present station redesign is implemented, this major national investment must be justified on the basis of considerations other than research in these two disciplines.

ATTACHMENT 1

SPACE BIOLOGY AND MEDICINE RESEARCH REQUIREMENTS

Requirements for conducting space biology and medicine research are described in detail in the 1987 report, *A Strategy for Space Biology and Medical Science for the 1980s and 1990s*.⁷ The major goals established in that report for this area of research are:

- a. "To describe and understand human adaptation to the space environment and the readaptation upon return to Earth."
- b. "To use the knowledge so obtained to devise procedures that will improve the health, safety, comfort, and performance of the astronauts. Specifically, we must improve our understanding of the microgravity induced alterations in physiologic and psychological processes as well as effects of radiation before long duration human exploration can be safely and effectively pursued."

Critical Requirements for Conducting Space Biology and Medicine Research

The Board's 1987 report⁷ emphasizes that a space station is **pivotal** to the conduct of life sciences research, and it documents the following as critical requirements for a space station:

1. A dedicated life sciences laboratory with adequate scientific crew to conduct research.
2. A variable speed centrifuge of sufficient radius to accommodate small primates.
3. Sufficient numbers of experimental subjects (humans, plants and animals) to address the stated scientific goals.
4. Sufficient laboratory resources, i.e., power, equipment, space, and atmosphere, to support the above research requirements.

The Space Studies Board's Committee on Space Biology and Medicine, and the Board itself wish to emphatically emphasize that the above requirements are absolutely fundamental to the acquisition of the data necessary to determine the feasibility of long-term human space exploration.

Inadequacy of the Redesigned Space Station Freedom for Space Biology and Medicine Research Requirements

The Committee on Space Biology and Medicine and the Space Studies Board conclude that Space Station Freedom, in its present redesigned form, will be inadequate to meet the requirements for space biology and medicine research described above because of the following:

1. The plan to share limited power among multiple users in all laboratory modules suggests that there will be insufficient power to conduct the volume of long-term biological experiments required to support a human space exploration initiative.
2. Plans for the size and location of a centrifuge and of animal-holding facilities are insufficiently defined for proper evaluation. As emphasized in the Board's 1987 strategy report⁷, an adequate centrifuge is essential to provide a 1-g control for 0-g experiments and also to explore the adequacy of artificial gravity for long-duration spaceflight.
3. The proposed crew size is insufficient to conduct the requisite experiments in a reasonable time period.
4. The absence of a dedicated life sciences laboratory will prohibit some experiments and will severely restrict most others, prolonging the acquisition of data required to answer fundamental questions related to the feasibility of long-duration human space exploration.

ATTACHMENT 2

MICROGRAVITY RESEARCH REQUIREMENTS

The National Research Council, as well as several NASA advisory committees, has published reports over the years that specifically address the minimum research requirements for this field of space research.^{6,8,9}

The Space Studies Board's Committee on Microgravity Research has advised the Board that, unlike research in the field of space biology and medicine, only a limited amount of the desired research in microgravity, at least over the next decade, can best be accomplished with a space station. The use of crew-tended free-flyers, drop towers, extended duration Spacelabs, and so forth, offer adequate, and in fact more viable, opportunities for the research needs in many cases. There are, however, important experiments requiring measurements and human observation and interaction over extended periods of time. The space station is a means to provide this capability. *If plans proceed to conduct microgravity research on the redesigned Space Station Freedom, the Board and its Committee on Microgravity Research recommend that adequate provisions be made for supporting only those microgravity research questions that can best be addressed using a space station.*

The following minimum facility requirements for microgravity research aboard a space station are based on the conclusions and recommendations described in the cited reports and on recent briefings presented to the Committee on Microgravity Research and the Space Studies Board.⁴

Critical Requirements for Conducting Microgravity Research on a Space Station

1. Adequate power, research volume, and support space.
2. Skilled on-board scientific personnel in sufficient numbers to carry out experiments and to diagnose and correct malfunctions.
3. Suitable acceleration environment and adequate monitoring.
4. Affordable de-integration and re-integration of experiments on orbit.
5. Capability to integrate advanced techniques and instrumentation as these become available.
6. Fast turnaround for specimens that must be characterized on Earth.

Inadequacy of the Redesigned Space Station Freedom for Microgravity Research Needs

The redesigned Space Station Freedom would be inadequate to meet the requirements of microgravity science and applications because it lacks the following:

1. A low, quiescent acceleration environment unhampered by crew activities, docking maneuvers, and other system activities necessary to sustain a permanently occupied presence.

2. A crew that would spend sufficient time working with the experiment equipment (See Attachment 1, item 3.).
3. Sufficient power, data-handling capabilities, and research volume (see Attachment 1, item 1).
4. The flexibility to upgrade systems; this deficiency is especially disconcerting in the area of computers, in which obsolescence is extremely rapid.

Other Issues

During the crew-tended phase, NASA plans to fly Spacelab experiment hardware on the Space Station Freedom because other, newer hardware will not be available. Most of this Spacelab hardware will require manual intervention and therefore will be operable only when people are present. Unfortunately, the crew-tended phase is a time when significant acceleration disturbances will exist due to concurrent hardware integration and assembly and construction activities. Therefore, the man-tended phase will not be suitable for many microgravity experiments. Only a limited number of experiments could be run during the free-flying mode between shuttle visits during the crew-tended phase.

If the bulk of the microgravity research program planned for Freedom were removed, the station would then be devoted almost exclusively to life sciences research. The benefits of this action would be that (a) the g-level on the station would not have to be strongly controlled, thus resulting in significant cost savings, (b) some low-gravity experiments (e.g., fluids handling, fire safety) could still be done on the space station, and (c) the bulk of the microgravity program could be conducted using independent, more cost-effective facilities.

ENDNOTES

1. *Report of the Advisory Committee on the Future of the U.S. Space Program*. Superintendent of Documents (GPO) December, 1990.
2. Space Science Board Assessment of the Scientific Value of a Space Station and letter to NASA Administrator James Beggs, September 9, 1983. See also Space Studies Board, Testimony to U.S. Senate Subcommittee on Science, Technology and Space, May 10, 1990.
3. *Toward a New Era in Space--Realigning Policies to New Realities--Recommendations for President-Elect George Bush*. Committee on Space Policy, NAS/NAE (NAP) 1988.
4. Briefing to Committee on Microgravity Research, William Taylor, Chief Scientist, Space Station Freedom, January 10, 1991. Briefing to Committee on Space Biology and Medicine, William Taylor, Chief Scientist, Space Station Freedom, February 8, 1991. Briefing to Space Studies Board, William Raney, Special Assistant, Space Station Freedom, and John-David Bartoe, Deputy Director, Space Station Freedom Operations and Utilization, February 28, 1991.
5. Conference Report 101-900, HUD and Independent Agencies, FY 1991.
6. *Microgravity Science and Applications--Report on a Workshop*, Panel on Microgravity Science and Applications, Solid State Sciences Committee, Board on Physics and Astronomy (NAP) 1986. *Review of Microgravity Science and Applications Flight Programs*, Committee To Review the Microgravity Science and Applications Flight Program, USRA, January-March, 1987. Space Studies Board Workshop on Microgravity Research, NAS Beckman Center, January 16-17, 1989.
7. *A Strategy for Space Biology and Medical Science for the 1980s and 1990s* (NAP) 1987. *Space Studies Board Assessment: Space Biology and Medicine Research--1990* (in press). Space Studies Board/Committee on Space Biology and Medicine, letter to Andrew Stofan, Associate Administrator, Office of Space Station, NASA Headquarters, July 21, 1987. Space Studies Board/Committee on Space Biology and Medicine, Testimony to the U.S. Senate Subcommittee on HUD Appropriations, May 1, 1987.
8. Space Studies Board letter to Joseph Alexander, Assistant Associate Administrator, Office of Space Science and Applications, NASA Headquarters, December 12, 1990. *Space Station Summer Study Report*, SESAC Task Force on Scientific Uses of a Space Station, NASA, March, 21, 1985. *Space Station Summer Study Report*, SESAC Task Force on Scientific Uses of a Space Station, NASA, March, 1986.
9. *Materials Processing in Space*, Committee on Scientific and Technological Aspects of Materials Processing in Space, Space Applications Board, (NAS) 1978. *Industrial Applications of the Microgravity Environment*, Space Applications Board (NAP) 1988.

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Joyce M. Purcell
Executive Secretary

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The Howard Hughes Medical Institute/Yale University

John R. Carruthers, Manager, Components Research, INTEL

Joyce M. Purcell
Executive Secretary

NATIONAL RESEARCH COUNCIL
COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS, AND APPLICATIONS

2101 Constitution Avenue Washington, D.C. 20418-0001

SPACE STUDIES BOARD

Office Location:
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March 14, 1991

Rear Admiral Richard H. Truly (Ret.)
Administrator
National Aeronautics and Space Administration
Code A
Washington, D.C. 20546

Dear Admiral Truly:

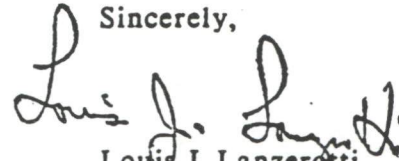
As you know, the research utilization of a manned U.S. space station has been a subject of considerable interest to the Space Studies Board since the inception of the program. In a letter to Mr. Beggs in 1983, the Board expressed reservations about the national requirement for a manned station for supporting space science, other than life science. Since that time, station planning and design have evolved rapidly.

Beginning in late 1990, and particularly after the release of the Augustine Report and its recommendations for development of a U.S. space station, two of the Board's discipline committees have become increasingly concerned about the research capabilities of the station as redesigned under the Congressional mandate. In addition, the Board itself has expressed concern as to whether the redesigned station will adequately support the research required to make important national decisions about long term human spaceflight. The Committee on Microgravity Research and the Committee on Space Biology and Medicine were briefed by space station officials on redesign ground rules and guidelines on January 10 and February 8 of this year, respectively. On February 28, the full Board was briefed on the preliminary results of the redesign study, with the chairmen and several key members of the two committees in attendance. The briefing officials from the space station office were most generous with their time and very frank in their discussions. We thank them for their efforts. Based on this briefing and on known research requirements cited in the attached assessment, the consensus of the Board was that the inadequacy of the redesign in its present state for research was sufficiently grave that a formal Board statement expressing these views to you was in order. Please note that the Board did not formulate and does not express any opinion on the engineering feasibility of the present redesign, nor does the Board address possible reasons other than space research for proceeding with the redesigned station.

Admiral Truly
March 14, 1991
Page 2

Enclosed is the assessment that resulted from the deliberations of the full Board, reflecting the participation of the two discipline committees. I will be happy to discuss with you any questions you might have about the Board's conclusions or the supporting rationale. We all share a common commitment to a vigorous and forward-looking national civil space research program.

Sincerely,



Louis J. Lanzerotti
Chairman

Enclosure

cc: The Vice President J. Danforth Quayle, Chairman, The National Space
Council
M. Albrecht
D.A. Bromley
R. Grady

cc (Enclosure only): Chairs and Ranking Minority Members of Congressional
Authorizing and Appropriations Committees

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DOCUMENT NUMBER: 9129323

ORIGINATOR: 03

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DIRECTORATE STATUS C

FROM: DAB

TO: VP Quayle

DATE OF
CORRESPONDENCE: 03/11/91

SUBJECT: Study statement on the scientific rationale for the
redesigned Space Station Freedom.

DIRECTORATE
ASSIGNED:

STAFF
ASSIGNED:

ACTION
REQUIRED:

STAFF
ACTION:

SENDER'S DUE DATE:

OSTP DUE DATE:
DATE COMPLETED:

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FILE: PS-SPC-SPACE STATION *General*

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323

THE WHITE HOUSE
WASHINGTON

March 11, 1991

Dear Mr. Vice President:

Pursuant to your request we have examined the scientific rationale proposed for the redesigned Space Station Freedom. It is my understanding that OMB and DOD have examined the cost estimates and the technical aspects of the redesign in parallel with our activities.

Our conclusions, based necessarily on a less than complete study of the issues, are given in the enclosed statement. Should you wish expansion of any part of the statement I shall be happy to provide it.

I look forward to discussion of these and related issues in forthcoming Space Council meetings.

Sincerely yours,



D. Allan Bromley
Assistant to the President
for
Science and Technology

The Honorable Dan Quayle
Vice President of the United States
The White House
Washington, D.C. 20500

March 11, 1991

SCIENTIFIC RATIONALE FOR THE RESTRUCTURED SPACE STATION

INTRODUCTION

At the request of the Vice President, the Office of Science and Technology Policy has studied the restructured plan for the Space Station Freedom that was prepared by NASA at the direction of Congress. We have focussed our attention on the broad scientific and technological goals of the restructured program. In particular, we have reviewed the merits of the two scientific thrusts -- microgravity materials science, and life science -- that have been advanced as motivations for the Space Station project, and have attempted to place these in perspective with other goals of the program.

It bears emphasis that our study of this new design and its scientific rationale has been carried out under substantial time pressure and in many cases we have had to rely on previous reports and analyses. To the extent possible, in the time available, we have discussed these questions with a number of experts in the field. We cannot, and do not, however, claim to have conducted an exhaustive study of the questions involved; and we are perhaps more aware than most that the history of discovery in fundamental science is consistently marked by surprises.

In the FY 1991 appropriations process, Congress directed that NASA assign highest priority to the establishment of a fully equipped microgravity laboratory, in its redesign of the space station. This mandate contrasts strikingly with the Augustine

Committee's recommendation that the "Space Station Freedom be revamped to emphasize life sciences and human space operations, and include microgravity as appropriate." In view of these opposed recommendations, a careful evaluation of the motivations for the microgravity laboratory is essential.

MICROGRAVITY SCIENCE

The magnitude of the force due to gravity is a variable, together along with temperature, pressure, electric and magnetic field strength, etc., that can influence the outcome of an experiment in materials science. Any experiment that extends any of these variables into a new range is likely to yield new results. The influence of gravity is studied routinely in terrestrial experiments through the use of centrifuges that increase the force of gravity. The novelty of the space environment is that it permits researchers to study the effects of gravity at decreased levels, for extended periods of time. In the early 1980's, when the space station research program was initially formulated, there was considerable optimism for early commercial benefits. However, commercial interest in microgravity materials science experiments aboard the space station has waned over the years. Our review produced no evidence for a significant commercially-driven motivation for a space station microgravity facility, as well as a number of specific indications of decreasing interest. As a very recent (February 1991) CBO study put it, "the last ten years have confirmed that processing materials in space is an expensive, high-risk activity that is not likely to produce economic returns in the near future ... [and] consequently, the private sector has not invested substantial resources in microgravity activity".

With commercial applications no longer the driving force, interest in space station microgravity experiments has shifted to basic research. Here, the arguments for materials microgravity research aboard the space station are generically identical to those used to justify any other materials science basic research initiative, and thus the microgravity work should be evaluated according to the standard merit criteria. We have not attempted to compare in detail the scientific merits of the space station microgravity experiments with materials science experiments conducted on earth or on rockets, Spacelab, Spacehab or on other space vehicles, but we have found no convincing evidence that the space station experiments are dramatically superior to the other materials science research. (In fact, Nobel laureate and American Physical Society President Nicolaas Bloembergen recently stated, in testimony before the House Committee on Science, Space, and Technology, that "Microgravity, to be blunt, is of microimportance to science...."). It has been argued, however, that the space station will offer superior facilities, at little additional cost, for the research that will be underway aboard the Spacelab system in the mid 1990's. In this view, NASA's transfer of these activities from Spacelab to space station simply takes advantage of a "free ride", constitutes a programmatic decision, and poses no policy issues.

With regard to space station microgravity science, we conclude that (a) its commercial prospects are remote, (b) its value as fundamental science is not qualitatively superior to that of other research, (c) its attractiveness depends on the space station being constructed for other purposes. It is important to note, in addition, that many of the primary microgravity experiments cannot be conducted during periods when astronauts are assembling or inhabiting the station. Thus, materials microgravity

research would only represent a transient use of the space station. Given that microgravity research involves little incremental investment, that its benefits are similar to those offered by other basic research projects of comparable incremental cost, and that it will be a temporary activity aboard the station, this activity **does not provide a significant rationale for the space station.**

Having concluded that microgravity materials research is at most incidental to the space station, we turn now to the only remaining potentially important purely scientific rationale for proceeding with this project.

LIFE SCIENCE

The primary thrust of the life sciences research program for the space station is to support the manned space exploration program. There is widespread agreement that manned exploration of space depends on understanding the health effects of exposure to this environment and on developing the ability to counteract such effects. Issues of critical importance to the health of astronauts include bone and mineral metabolism (including loss of bone calcium resulting in osteoporosis); long terms results of cardiovascular adaptation to action under microgravity conditions; muscular atrophy from changes in exercise patterns; behavioral aberrations resulting from operating in a high-stress situation in a far from ideal working/living environment; and potential carcinogenicity or reproductive toxicity of exposure to radiation.

A number of studies have been conducted to identify the research that is needed to address these issues. Some of this research can be carried out on earth. However,

experience on manned missions to date, including accounts from the Soviet space program on flights of long duration, indicates that extensive manned exploration is not feasible without the support of a comprehensive clinical research program conducted in-flight. Long-term, well controlled trials, will be needed to determine whether serious, potentially irreversible effects on physiology may be avoided or ameliorated by exposure to artificial gravity, or by other means. These trials, as well as essential studies of life support systems, will require a permanently-manned space station. It is essential that data be obtained on a substantial number of human subjects to insure that effects of importance are not masked--or simulated by-- individual peculiarities. Indeed, we find that a **man-tended** station, if that were the ultimate goal, would have little merit.

With the case for the redesigned space station thus resting squarely and solely, in our opinion, on its role, from a scientific point of view, in supporting manned space exploration, two issues require resolution. First, the current plan is ambiguous as to whether microgravity experiments would continue into the permanently-manned phase. We believe that they should not, and that the design should focus strictly on the critical space medicine experiments. In any event, the human habitation of the station is fundamentally incompatible with the requirement that the microgravity experiments be unperturbed, and the latter requirement should not be permitted to compromise the former. Second, it is the judgment of experts in the field that the questions related to supporting human life in space cannot be fully answered without the ability to control exposure to gravity. It may well be that some of the abovementioned effects will show thresholds or nonlinearities and in consequence, if

we are to be able to extrapolate observations made in the space station to longer duration exploration activities it is essential that at least one intermediate gravitational field value--between 0 and 1 g--be studied. Intermediate gravitational fields may, in themselves, be essential for long duration manned spaceflight.

We consider that the planned animal centrifuge is an essential feature of the station; however such studies must be extended to humans and thus it is essential that the design of the station not preclude a human centrifuge. The redesign has no such provision, at present.

INTERNATIONAL CONSIDERATIONS

From the outset of the space station program the U.S. has enjoyed active collaboration with scientists and engineers from Japan, Canada, Europe and Japan. In the most recent rescoping of the station, at Congressional direction, these international collaborators have been involved in detail and we are assured that the new design will satisfy their requirements.

This is an important consideration inasmuch as several of us in OSTP have been told personally--and pointedly--by the most senior representatives from Canada, Europe and Japan, that having renounced major components of their domestic space programs in order to participate in ours, should we fail to follow through on our commitments regarding the station it will be very difficult to arrange further cooperation in other areas of science and technology in the foreseeable future.

CONCLUSION

Given a national commitment to manned space exploration, the space station is needed to find means of maintaining human life during long space flights. This is its only scientific justification, in our view, and all future design efforts should be focused on this one purpose. Neither the commercial processes nor the scientific merit of the microgravity experiments come close to justifying the cost and effort required to build, deploy and operate the station; moreover, provision for neither processes nor experiments should, in any way, compromise the life science goals. The issue of compatibility of microgravity experimentation with human habitation makes it questionable whether microgravity experiments should be done at all in the space station, except during the few years when the station is being assembled, and before it becomes permanently manned. Finally, we recommend that high priority be given to including a human centrifuge in the implementation of the design.

Having considered all the above, we are convinced that the ultimate, compelling argument for the space station configured, as the Augustine Committee has suggested, is that of a first step in the great adventure that will take mankind away from the home planet for extended periods--and the true beginning of manned exploration of the solar system and beyond. Although we focus here on the importance of the life science data to be obtained from a permanently manned station, we should not forget, or minimize, the importance of developing much of the space technology and know-how required, for all subsequent exploration, in the relatively convenient low-earth orbit environment to be occupied by the station.

Without having examined the detailed engineering features of the redesigned station, we conclude that its conceptual design is appropriate to the goal of advancing man's exploration of space.

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