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<u>מיקום בארכיון</u>
ארגז: 25
תיק: 3
תת תיק: --

Title: Mars sculpture
Photographs, booklets, books, sketches, map, texts

<u>Location in Archive</u>
Box: 25
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Sub folder: --

PARTICIPANT

EZRA ORION
ISRAEL

ISRAEL '94 · INTERNATIONAL ASTRONAUTICAL CONGRESS

45th INTERNATIONAL ASTRONAUTICAL CONGRESS
JERUSALEM, ISRAEL, OCTOBER 9 - 14, 1994

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עזרא אוריון: אקט פיסולי על מאדים 1982-1983

EZRA ORION: SCULPTURAL ACT ON MARS

Ezra Orion's idea for the sculptural act to be performed on Mars with the aid of a spacecraft sampling arm actually began to take shape over twenty years ago. In the 1960's, his art crystallized around a number of major concepts: a) The creation of sculpture on a gigantic scale which acts on the viewer much like architecture; b) The view of sculpture as a structural complex imbued with an expressive and spiritual force; c) The importance of the vertical projections in sculpture, embodying "a sense of revolt against submissiveness, helplessness and resignation", and expressing, moreover, a desire to become one with the universe, with the cosmic existence that extends beyond man's minuscule existence on earth. This last point is reminiscent on the one hand of what is termed by various experts of the psyche "an oceanic experience" (the assimilation of self in a greater consciousness) and on the other hand of a kind of cosmic atheism — —

In the 1960's and 1970's, Orion's preoccupation with these concepts gave rise to his interest in gothic church architecture and in the creation of cathedral-like structures, and subsequently to the idea of the sculpture-field in the Negev (exhibited at the Israel Museum in 1974). The sculpture-field was designed as a set of expressive sculptural spaces which became an integral part of the desert landscape.

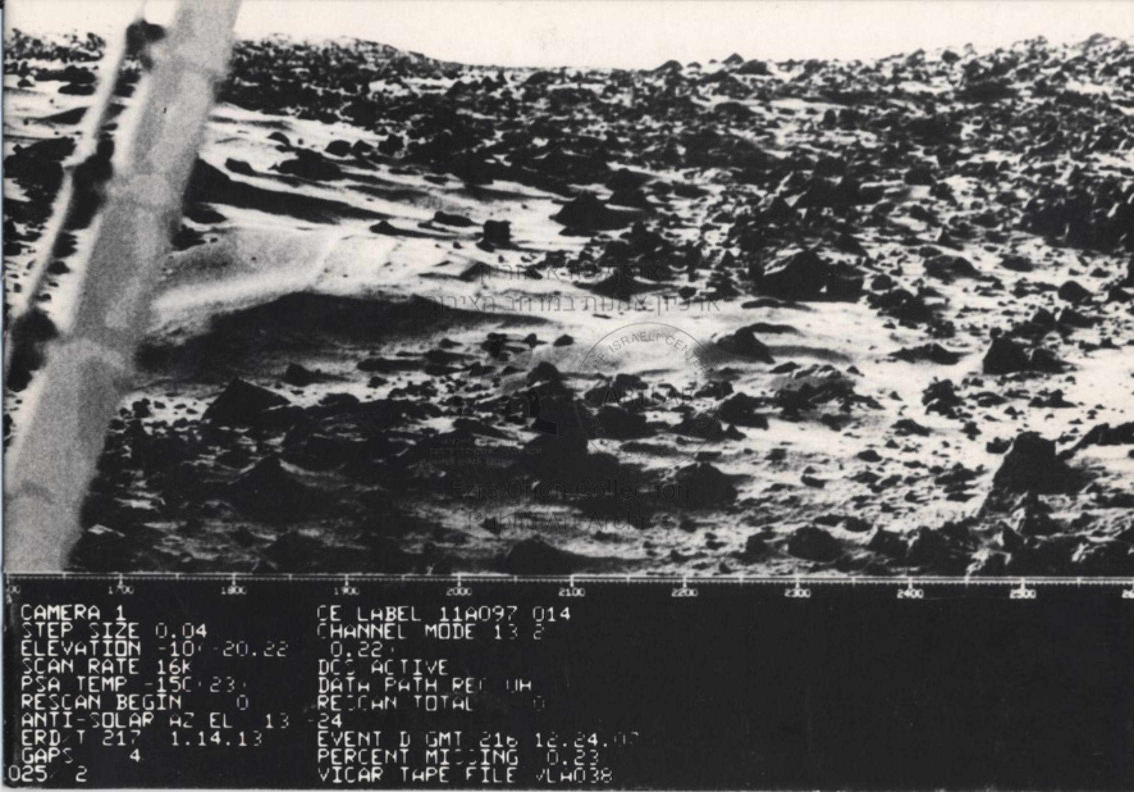
The morphology of Har Hanegev increased Orion's awareness of the expressiveness of tectonic processes and the importance of the pristine nature of the desert. It was at this time that the idea which has provided the underpinnings of most of his recent work took shape, i.e., the view of the changes in the crust of the earth, created by folding and faulting, as sculpture. By taking these conceptual elements to their extreme, magnifying them and sublimating them, the physical object was subsumed into the large and absolute sculpture, — the crust of the earth and its relationship to other tectonic or formative processes in the universe. Thus, in the 1980's, he began to create works such as "Towards the Rift" at Tel Hai, and sculptural works in the Negev and the canadian Rockies. these are linear "laconic" structures made of local stone, which draw the eye of the viewer to the edges of cliffs or mountain tops and which serve as "cognitive runways". They are no longer objects in a given environment, but "launching sites of the mind" to high ridges which, in turn, launch consciousness to astronomical distances.

The climax of this process was the work created by him in the Himalays, "Towards Annapurna I" (the documentation of the project was shown at the Israel Museum in 1982). Orion regards the tectonic forces which lifted and are still lifting the Himalayas; which created the Syrian-African Rift; and which are also connected to galactic events, as tectonic sculpture. With this concept the cycle which included the Israeli works and which related to total planatery processes, was complete.

The evolution from here to the Mars project was consistent — — the awareness of macro-sculpture bridges astronomical ranges... The laconic act on Mars, the sculptural touch of a distant planet, is dictated by the same need to direct the mind towards the existence of an immense system, towards infinity.

Astronomical sculpture (like his ideas on microscpic sculpture) is not performed in the accepted context of environmental sculpture, that of a confrontation between nature and culture. It is an existential act, another stage in the chance of joining the infinite within the framework of finite human existence.

Yigal Zalmona, Jerusalem, June 1983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JET PROPULSION LABORATORY *California Institute of Technology • 4800 Oak Grove Drive, Pasadena, California 91109*

August 2, 1982

Dear Mr. Orion:

This letter is to confirm the result of the stimulating conversation we had today concerning the possibility of creating simple sculptures or art forms on other planets by means of automated spacecraft. In the last twenty years U.S. and Soviet spacecraft have landed on and manipulated to some degree the surfaces of three extraterrestrial objects -- Venus, the Moon and Mars. It now lies easily within our technical capability to mount surface exploration missions with the ability to lift, move and drill surface materials on other planets for scientific as well as aesthetic reasons. We appreciate your interest and that of other artists in the possibilities that our space explorations open up for the expansion of human activity and culture. I hope that we will be able to mount such exciting missions in the near future and that we may look forward to true "space sculpture" as a part of this activity.

מכון לנוכחות ציבורית
INSTITUTE FOR PUBLIC PRESENCE

Sincerely,

Torrence V. Johnson
Senior Research Scientist

Telephone (213) 354-4321 *Twx 910-588-3269* *Twx [illegible]*

"ויקינג 1" שוגר מכף קנברל לעבר מאדים ב־20 לאוגוסט 1975 ו"ויקינג 2" שוגר אליו ב־2 לספטמבר. השיוט לעבר מאדים נמשך קרוב לשנה. רכב הנחיתה 1 נחת על פניו ב־20 ליולי 1976 וזה של "ויקינג 2" נחת ב־3 לספטמבר.

הפעלת זרוע הדגימות של רכב חלל על מאדים ניתנת ע"י שימוש ברשת האנטנות הגלובאלית של "נאסא". את האקט הפיסולי יש לתרגם ל־200 פקודות רדיו משודרות למחשב החללית. פקודות רדיו חוצות ב־30 דקות את כ־300 מיליון הק"מ עד אל אותו כוכב ואותו זמן דרוש למשוב מצולם כדי להגיע חזרה אל אולם הבקרה.

זהו פיסול טלסקופי; או אסטרונומי — —

"Viking I" spacecraft was launched from Cape Canaveral on 20 August 1975 to Mars, and Viking II was launched on 2 September. The cruising to Mars took nearly a year. viking Landor I landed on 10 july 1976 and Viking Landor II landed on 3 September. Activating a Lander sampling arm requires the use of NASA's deep space facility global network. The sculptural act should be translated to 200 radio commands that will be broadcast to the Lander's computer. Radio orders cruise about 30 minutes to Mars and it takes the same time for the camera-monitored feedback to travel back to NASA headquarters.

This is telescopic sculpture, or astronomic one — —

August 24th, 1982

Mr. Bruce Murray
Director
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91109
U. S. A.

Dear Mr. Murray,

This letter is a second step after the preliminary talks I had with Mr. Frank Bristow, Professor T. Johnson, and Professor B. Hager on August 2nd at your laboratory.

I understand that the next mission to Mars may be ten (10) years ahead but there is also the possibility of reactivating the Viking lander arm of 1976. I would, therefore, like to suggest that either by this Viking reactivated arm or by means of an arm of any future spacecraft, a sculptural-laconic-act of lifting a stone from the Martian surface and placing it on top of another stone , through a radio-beamed order from earth.

I would appreciate your consideration and comments on the subject and will be happy to cooperate with any efforts on the side which could, if possible, be made by your laboratory towards the execution of this idea some time in the Eighties.

Hoping to receive your reply at your earliest opportunity, I am

Yours sincerely,

Ezra Orion
Sculptor
Midrashat Sde-Boker

EO:mro
encl. (2)
cc: Prof. T. Johnson, Frank Bristow
Prof. B. Hager
Dr. CArl Sagen, Prof. Robert Hobbs
David Furchgott
Dr. Roger Malina

מ־1980 אני מפתח מתוך הפיסול המדברי את תפיסת הפיסול הטקטוני. העבודות המבטאות תהליך זה הן ״שדה צין״ ליד שדה בוקר, ״הר ארדון״ על מצוק מכתש רמון, ״מול הר עריף־א־נקה״ בצפון סיני, ״מול השבר״ ליד תל־חי, ״מול האנאפורנה״ בהימליה ו״מול הר רובסון״ ברוקיס הקנדיים.

אלו הן נוכחויות לקוניות, בנויות באבן מקומית, המתייחסות אל התנשאויות טקטוניות של קרום האדמה; אלה נתפסות כאתרי שיגור של ההכרה אל הטווחים האסטרונומיים.

החלת תפיסה זו אל מעבר לכוכב ארץ היא השלב הנוכחי של תהליך זה. בקיץ 82 יצרתי קשר עם ״המעבדות להנעה סילונית״ בפסדינה, ארה״ב, ונפגשתי שם עם מספר מדענים. בשיחות אלו העלה הרעיון לבצע אקט פיסולי על פני מאדים.

בחדשים שלאחר מכן אני מנסה לקדם פרוייקט זה בעזרת הפסל האמריני ג׳ו דיויס מ־ M.I.T.

Since 1980 I have been developing the concept of "Tectonic sculpture" from my earlier "desert sculpture".

The works that express this process are "Sde-zin" near Sde-Boker, "Har Ardon" on the cliff of the Ramon crater, "Towards Mount Arif-e-Naka" in northern Sinai, "Towards the Rift" near Tel-Hai, "Towards Mount Robson" in the Canadian Rockies, and "Towards Annapurna" in the Himalayas.

These are laconic presences, built from local stone, related to tectonic uplifts of the earth's crust; they are apprehended as launching the mind to astronomical distances.

The extension of this concept beyond Earth is the present stage of this process. In the summer of 1982 I contacted the "Jet Propulsion Laboratories" in Pasadena, U.S.A., and there met a number of scientists. It was during these talks, that the idea of a sculptural act on Mars was proposed.

In the last few months I have been trying to go ahead with the project with the help of the American sculptor Joe Davis of M.I.T.

אפשר לתפוס פיסול כעיצוב מסות ע״י כוחות בחלל אינסופי — —
הטקטוניקה של הפלטות היא פיסול המעצב את הקרום הסלעי של כוכב הלכת הזה, של מאדים וסביר שגם של מדבריות דואים יקומים מכאן — — תהליכי בליית פני קרומים סלעיים, מקומטים, שבורים, הם פיסול אירוזיבי — — עיצוב מרחבי דיונות ע״י רוחות הוא נדידת עמי קווארץ אינסופיים; על פני מרחבי הקוטב הצפוני של מאדים נע ים דיונות אבק־בזלת; זהו פיסול איאולי — — מדבריות סלע דואים מורעשים ללא הרף במטחי מטאוריטים, מעוצבים עיצוב סקילה, מכתשי; זהו פיסול מטאוריטי — —

פיסול אנושי, מיקרוסקופי, מודע, מצטרף לתהליכי עיצוב אלה בעשרות אלפי השנים האחרונות; משגר מסָרים ראדיאליים אל סביבתו האנושית, החולפת, המרתקת, בת עשיריות השנייה — ההומו־סאפיינס תופס את כיוון רגליו היחפות, כיוון מטה, כביוון הליאות, אפיסת הכוחות, כיוון האבק שממנו בא ואליו ישוב, הכניעה, האֶנטרופיה — ואת זקיפותו כוֶקטור מתקומם, אנטי־גרביטאי, אנטי־אנטרופי, כדחף רוחני להמראה אנכית — —

באחת מזרועותיה של הגאלאכסיה הזאת, כמאה מליארד שמשות, אנחנו דואים, מקיפים את צירה אחת ל־250 מליון שנה, כך שעברנו ״כאן״ לאחרונה בעידן פֶּרם; ולפני כן בעידן קמבריום — טלסקופים מזהים סביבנו מיליארדי גאלאכסיות וערפיליות גאז זוהר; הרחוקות שבהן מתרחקות לכל עבר במהירויוֹת של עד מחצית מהירות האור וקטור מיקרוסקופי, נידח, מצטרף להרף לכוחות האנטי־כבידה הגאלאכתיים — —

שני תחומים ממתינים עדיין לפיסול כאדמות בתולה: החלל האסטרונומי והחלל המולקולארי. בטווחי ״מערכת השמש״ ניתן כיום במיכשור מופעל ע״י פקודות רדיו מכדור הארץ, לבצע אקטים פיסוליים, לקוניים, על פני מדבריות הירח, נוגה, מאדים וצדק; כאשר החומרים לאקטים מרוחקים אלה יכולים להיות אבנים, חצץ או אבק.
ניתן כיום לגדל במעבדות גבישים; כאשר תמיסות מינראלים שונים יגובשו ויתרמו צורות ייחודיות לקומפוזיציות של פיסול מיקרוסקופי או אדריכלות מיקרוסקופית — —

בשני המרחבים הבלתי־נראים האלה נוכל לחוות את הפיסול בהתמרה של קְני מידה, טווחים ואותות רדיו למסרים חזותיים. החוויות תהיינה של חימדדיות מרוחקת, אשר מבעדה תתחוורנה הכרות קיומנו מול האינסופי — —

Sculpture can be conceived as the shaping of masses by forces in infinite space— —
Plate tectonics is sculpture which shapes the rocky crust of this planet, of Mars and probably of distant deserts, light years away — — Erosional processes which shape the surfaces of the folded, faulted crusts are erosional sculpture — — the shaping of dune planes by winds is the shifting of infinite quartz nations; a dune ocean of basaltic dust stretches upon the north polar planes of Mars; this is aeolic sculpture — — Rocky deserts are constantly bombarded by salvos of space rocks. this cratering is meteoritic sculpture — —
Human sculpture, conscious, microscopic, has joined these shaping processes in the last ten thousand years, transmitting radial messages to its human, temporal, split-second environment.
Homo sapiens grasps the direction of his bare feet, downwards, as the direction of weariness, exhaustion, of the dust from which he comes and to which he is doomed to return of surrender, of entropy — — and that of his verticality as a vector of resistance, spiritual, anti-gravitational, anti-entropical, a drive for vertical take-off — —
We glide in one arm of this galaxy, a hundred billion suns, revolving round the galactic axis once in 250 million years. We last "passed by here" in the Permian age and the time before that in the Cambrian age— —
Telescopes identify around us billions of galaxies and hazy clouds of luminous gas; the most distant are receding in all directions at half the speed of light — — a remote human microscopic vector joins the anti-gravitational galactic forces for a single instance— —
Two virgin spheres are still waiting for sculpture: astronomical space and molecular space. In the "solar system" range, it is possible today to activate radio-controlled devices to perform sculptural, laconic acts on the desert surfaces of the Moon, Mars, Venus and Jupiter. The materials for these remote acts could be stones, gravel or dust — —
It is possible Today to grow crystals in laboratories, where different mineral solutions will contribute a variety of shapes to micro-sculptural or micro-architectural compositions — —
We can experience sculpture in these two invisible realms through the transformation of ranges, scales and radio signals into visible messages. the experience will be one of remote, creative self-scaling. One which will be an experience of our existence in the face of the infinite — —


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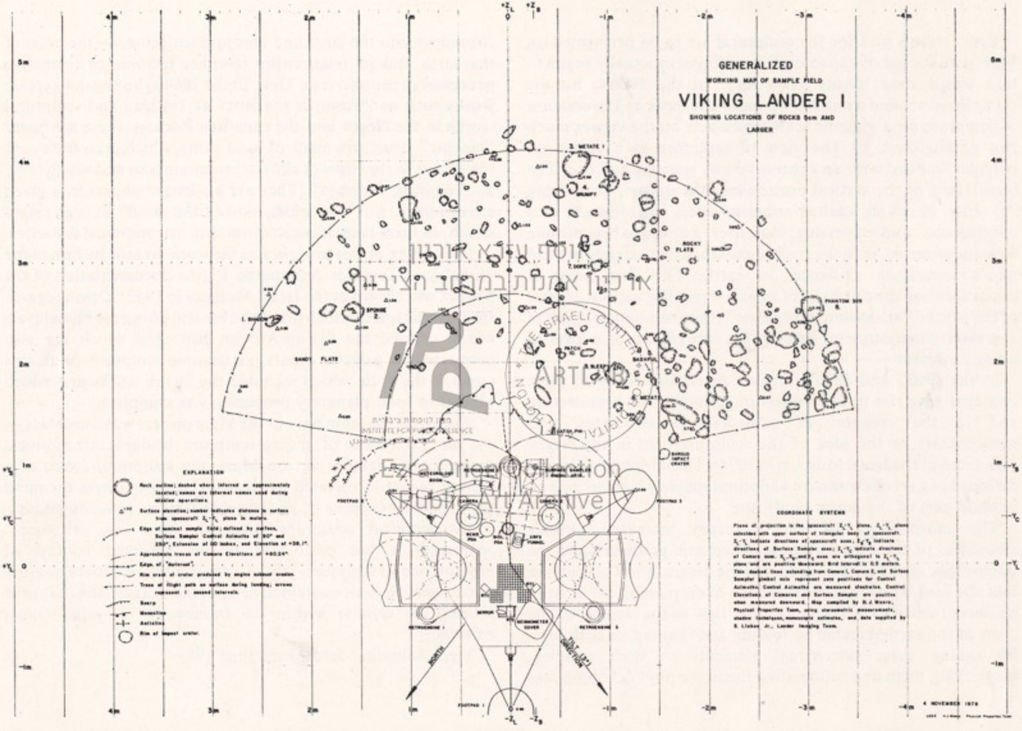
רעיון האקט הפיסולי שמתכנן עזרא אוריון לבצע על פני מאדים בעזרת זרוע הדגימות של רכב חלל החל למעשה את התפתחותו לפני יותר מעשרים שנה. בשנות השישים החלה תפיסתו האמנותית להתגבש סביב כמה עקרונות יסוד: א. יצירת פיסול בקנה מידה גדול במיוחד שפעולתו על הצופה היא מסוג ההשפעה העוטפת והמכוונת שיש לארכיטקטורה על האדם. ב. ראיית הפיסול כיצירת מכלול מבני בעל אופי הבעתי אשר מעורר חוויה רוחנית. ג. חשיבות הפריצות האנכיות בפיסול שגלומה בהן "תחושת ההתקוממות נגד הכניעה, חוסר האונים וההשלמה", ויותר מזאת: שאיפה להצטרפות אל האין־סוף, אל ממדי הוויה שמעבר לזו הגמדית של אבק האדם המתקיים על פני כוכב ארץ. בנקודה אחרונה זו יש משום ביטוי, מחד גיסא, לחוויה שמומחי הנפש כינו "חוויה אוקיאנית" (האיבוד של העצמי בממד שמעבר לו) ומאידך גיסא, סוג של "אתאיזם קוסמי" — —

בשנות השישים והשבעים הביא אותו העניין בעקרונות אלה לעיסוק באדריכלות כנסייתית גוטית וליצירת מבנים דמויי קתידרלות ולרעיון שדה הפסלים בנגב (הוצג במוזיאון ישראל, ירושלים בשנת 1974). שדה הפסלים הוא מערכת חללים מעוצבים כצורות פיסוליות הבעתיות אשר הופכות לחלק אינטגרלי של הנוף המדברי. המציאות המורפולוגית של הר הנגב הגבירה את מודעותו של אוריון לכוחם ההבעתי של התהליכים הטקטוניים ולחשיבותה של הרגשת הבראשית שב"מצב של מדבר". אז החל להתגבש הרעיון המרכזי המכוון את יצירתו בשנים האחרונות והוא: ראיית השינויים במִבנה קרום כדור הארץ אשר נגרמים על־ידי קימוט ושבירה — כפיסול. נתונים רעיוניים אלה הובאו עד לקיצוניות, התעצמו ועברו תהליכי סובלימציה עד שהשאות את האובייקט האמנותי הפיזי במיעוטו, והפכו אותו למחולל של התיחסות אל קרום כדור הארץ והתייחסותו אל תהליכים טקטוניים או עיצוביים אחרים ביקום. כך החל ליצור בשנות השמונים עבודות כ"מול השבר" בתל־חי ועבודות פיסול בנגב ובהרי הרוקי בקנדה. כל אלה הם מבנים "לקוניים" עשויים מאבנים מקומיות, בדרך כלל "קוי אבן", המושכים את עין הצופה לשפות מצוקים או פסגות הרים ומשמשים כ"מסלולי המראה הכרתיים". לא עוד אובייקטים בסביבה נתונה, אלא "משגרים הכרתיים" אל רכסים המהווים בתורם משגרי ההכרה אל הטווחים האסטרונומיים. שיאו של תהליך זה היתה העבודה שיצר אוריון בהימאליה מול רכס האנאפורנה (תעוד הפרוייקט הוצג גם הוא במוזיאון ישראל בשנת 1982). התייחסותו של אוריון היתה אל הארועים הטקטוניים שהרימו (ומרימים) את ההימאלאיה בעבר ובהווה הגיאולוגי שגרמו להיבקעות השבר הסורי־אפריקני והקשורים גם לאירועים גאלאקטיים — כאל פיסול טקטוני. בעבודה זו נסגר מעגל.

מכאן לעבודה במאדים, הדרך עקבית... תודעת המַקרו־פיסול סוגרת את הטווחים האסטרונומיים... האקט הלקוני במאדים, הנגיעה הפיסולית בכוכב רחוק, מונעת על ידי אותו הצורך בטיווח ההכרה אל קיומה של מערכת גדולה, אל האין־סוף — —

הפיסול האסטרונומי (כמו הרעיונות שלו הקשורים לפיסול מיקרוסקופי) אינו נעשה בקונטקסט המקובל בעבודות אמנות סביבתיות, זה של העימות בין טבע לתרבות. זהו אַקט קיומי, שלב נוסף בסיכויי ההצטרפות לאין־סופי במגבלות של הקיום האנושי.

יגאל צלמונה, ירושלים, יוני 83


GENERALIZED
WORKING MAP OF SAMPLE FIELD
VIKING LANDER I
SHOWING LOCATIONS OF ROCKS 5cm AND LARGER
EXPLANATION
COORDINATE SYSTEMS
SANDY FLAT
ROCKY FLAT
PHANTOM BOX
FOOTPAD 1
FOOTPAD 2
FOOTPAD 3
NORTH
4 NOVEMBER 1976

Photographs: Courtesy J.P.L.

Enlargment of photographs: Avraham Hai
Printed By Sabinsky.

Beyond Sculpture in the Solar System - an Intergalactic Sculpture

....

Ezra Orion

Abstract - Following his article: Sculpture in the Solar System LONARDO Vol. 18, 1985, the author assesses the situation of contemporary sculpture; Reports on a lazer beem launch, a milliard km. long, which he sent verticall to the plane of the Milky Way; Reflects on the substance of this space-time infinity; and propose two more powerfull launches. He terms these acts and concept "An Intergalactic Sculpture.

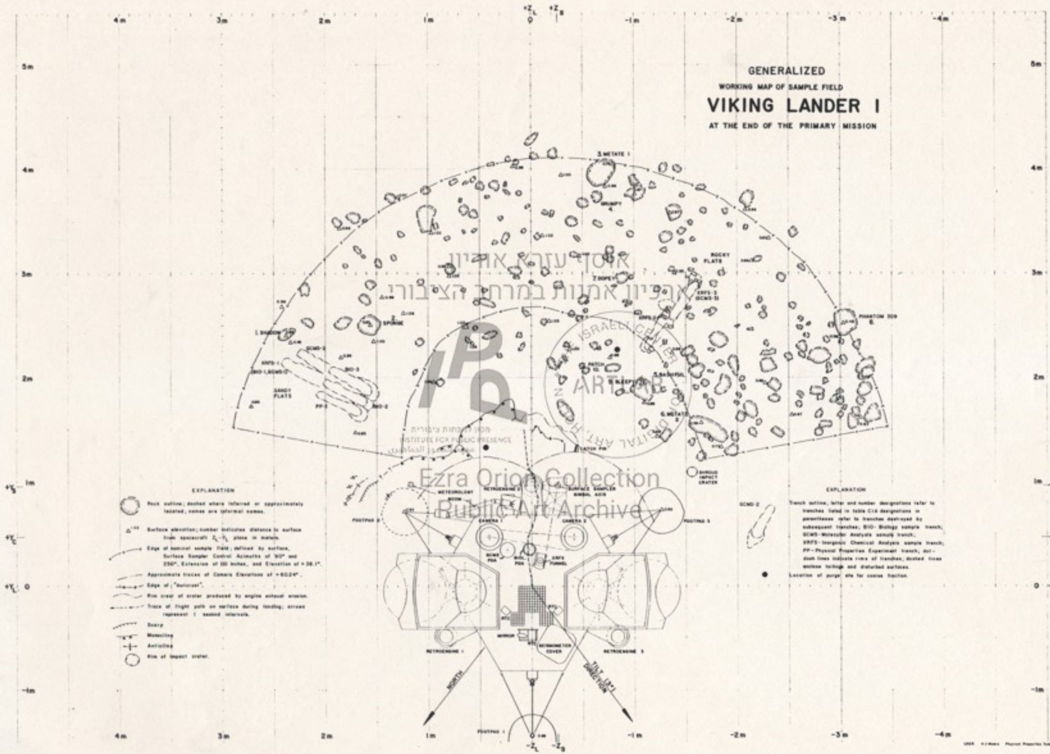
1. Sculpture in the Solar System

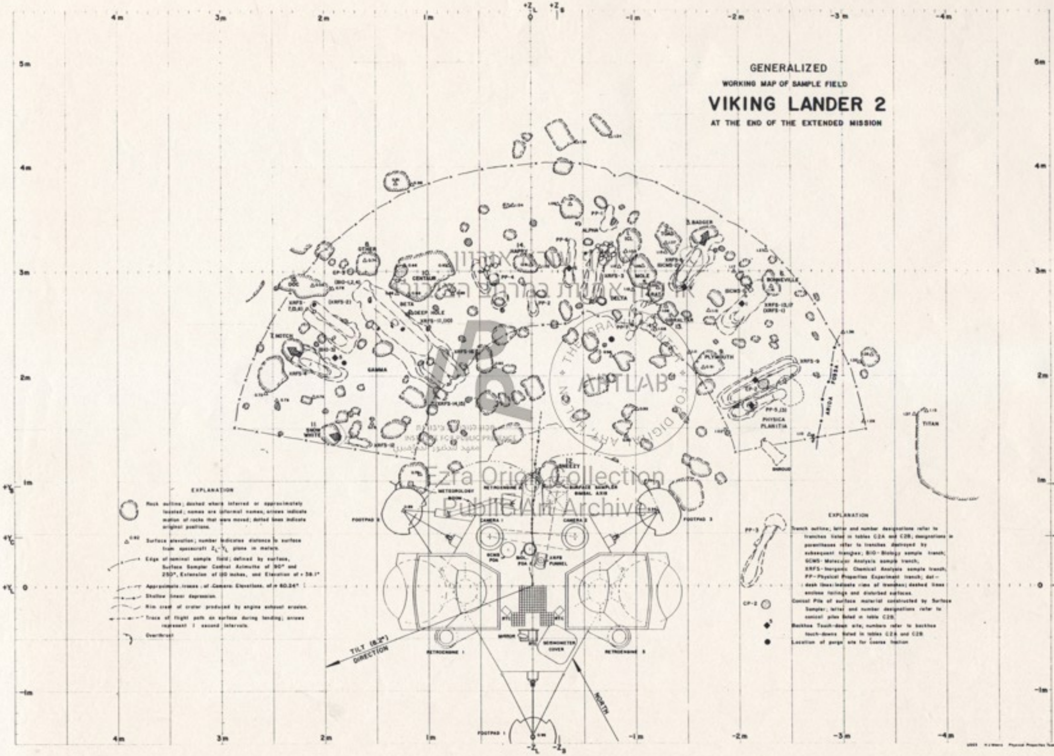
I am an environmental-desert sculptor, living [illegible] since 1967 in a desert campus, in the Negev desert, southern Israel. Most of the works I have done in these years are in this region or in Northern Sinai. In the years 1981, 1983, I went on with two small expeditions to build a local stone sculptural structure, 4000 m. altidude, in the Annapurna basin, Central Himalaya, Nepal. As a theoretical background to these works I developed the concept of [illegible] Erosional-Aeolic-Volcanic-Meteoritic Sculpture.

Accordingly I met [illegible] the Jet Propulsion Laboratories Pasadena, on 2nd August 1982. These were dialogues exploring the fisibility of performing a robotic geometrical sculptural works by the 1976 Viking Landers 1,2.

The last dialogue was held on 19 January 1988, with NASA's Director of Solar System Exploration Program at NASA headquarter, Washington D.C. It was focused on verious aspects of the MarsRover Semple return mission.

The launching is scheduled for 1998. After cruising for 10 months and reaching Mars, the return spacecraft will leave the Orbiter one and land on the surface. The MarsRover will get [illegible] out of it and start one year of scientific sample collecting tour. It was emphasised how [illegible] complicated this tele-mission is. Completing it safely the Rover will unload its harvest of samples into the waiting mother return spacecraft. After its successful takeoff back to Earth, the


GENERALIZED
WORKING MAP OF SAMPLE FIELD
VIKING LANDER I
AT THE END OF THE PRIMARY MISSION
3.METATE 1
ROCKY FLATS
SANDY FLATS
PHANTOM 309
METEOROLOGY BOOM
CAMERA 1
CAMERA 2
FOOTPAD 2
FOOTPAD 3
FOOTPAD 1
RETROENGINE 1
RETROENGINE 3
SURFACE SAMPLER GIMBAL AXIS
SHROUD IMPACT CRATER
SEISMOMETER COVER
MIRROR
NORTH
TILT DIRECTION
EXPLANATION
Rock outline; dashed where inferred or approximately located; names are informal names.
Surface elevation; number indicates distance to surface from spacecraft Z_L-Y_L plane in meters.
Edge of nominal sample field; defined by surface, Surface Sampler Control Azimuths of 90° and 250°, Extension of 00 inches, and Elevation of +38.1°.
Approximate traces of Camera Elevations of +60.24°.
Edge of "duricrust".
Rim crest of crater produced by engine exhaust erosion.
Trace of flight path on surface during landing; arrows represent 1 second intervals.
Scarp
Monocline
Anticline
Rim of impact crater.
EXPLANATION
Trench outline; letter and number designations refer to trenches listed in table C1A designations in parentheses refer to trenches destroyed by subsequent trenches; BIO-Biology sample trench; GCMS-Molecular Analysis sample trench; XRFS-Inorganic Chemical Analysis sample trench; PP-Physical Properties Experiment trench; dot-dash lines indicate rims of trenches; dashed lines enclose tailings and disturbed surfaces.
Location of purge site for coarse fraction.



GENERALIZED
WORKING MAP OF SAMPLE FIELD
VIKING LANDER 2
AT THE END OF THE EXTENDED MISSION
EXPLANATION
Rock outline; dashed where inferred or approximately located; names are informal names; arrows indicate motion of rocks that were moved; dotted lines indicate original positions.
Surface elevation; number indicates distance to surface from spacecraft Z_L-Y_L plane in meters.
Edge of nominal sample field; defined by surface, Surface Sampler Conical Azimuths of 90° and 250°, Extension of 120 inches, and Elevation of +38.1°
Approximate traces of Camera Elevations of +60.24°
Shallow linear depression.
Rim crest of crater produced by engine exhaust erosion.
Trace of flight path on surface during landing; arrows represent 1 second intervals.
Overthrust
EXPLANATION
Trench outline; letter and number designations refer to trenches listed in tables C2A and C2B; designations in parentheses refer to trenches destroyed by subsequent trenches; BIO-Biology sample trench; GCMS-Molecular Analysis sample trench; XRFS-Inorganic Chemical Analysis sample trench; PP-Physical Properties Experiment trench; dot-dash lines indicate rims of trenches; dashed lines enclose tailings and disturbed surfaces.
Conical Pile of surface material constructed by Surface Sampler; letter and number designations refer to conical piles listed in table C2B.
Backhoe Touch-down site; numbers refer to backhoe touch-downs listed in tables C2A and C2B.
Location of purge site for coarse fraction
PP-3
CP-2
FOOTPAD 1
FOOTPAD 2
FOOTPAD 3
CAMERA 1
CAMERA 2
METEOROLOGY BOOM
SURFACE SAMPLER GIMBAL AXIS
RETROENGINE 1
RETROENGINE 3
SEISMOMETER COVER
TILT (8.2°) DIRECTION
NORTH
SHROUD
TITAN
PHYSICA PLANITIA
ARIDA FOSSA
BADGER
BONNEVILLE
PLYMOUTH
MOLE
ALPHA
DELTA
BETA
GAMMA
CENTRUM
DEEP HOLE
NOTCH
SNOW WHITE

NASA JPL Structure & Configuration Group

01-APR-93 15: 27: 26

Database: MAPC 94 PROJECT
View : TRIMETRIC
Task: Assembly
System: 3-SMALL LANDER

SMALL STATION, MARS 94

Units : SI
Display : No stored Option
Bin: 1-MAIN
Update Level: Medium-Low

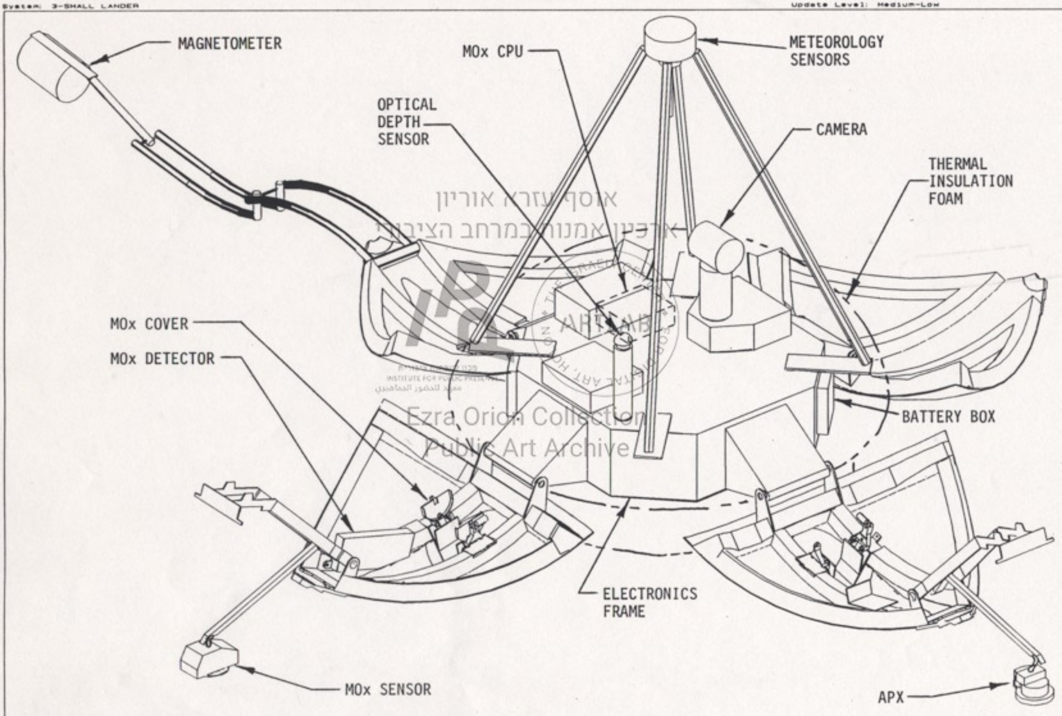


Fig. 718 – This photograph of the great nebula in Andromeda in reality shows us what the nebula looked like 1,500,000 years ago – the time taken for its light to reach us. The observation of distant nebulae carries us far into the past. *(Photo, C. D. Shane, Lick Observatory, 20-inch astrograph; 23 September 1946.)*

NAMED ROCKS

VIKING LANDER 1: CHRYSE PLANITIA

CAMERA 1 CAMERA 2

NASA
National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Viking 2-32
P-19009
June 30, 1977

Photographed during Viking 2's approach, this dramatic color picture of Mars was taken August 5, 1976, from a distance of 419,000 kilometers (260,355 miles). Viking 2 approached Mars more from the dark side than had Viking 1 in mid-June, providing a crescent view of the planet. Contrast and color ratios are enhanced to improve the visibility of subtle surface topography and color variations. Bright plumes of water-ice clouds extend a considerable distance northwestward from the western flank of Ascraeus Mons – the northern-most of the three volcanoes aligned on the Tharsis "bulge." The middle Tharsis volcano, Pavonis Mons, is barely visible within the dawn terminator below and to the west of Ascraeus Mons. The great rift canyon system, named Valles Marineris, extends from the center of the picture at the terminator downward to the east. It stretches nearly 4,800 kilometers (3,000 miles), including the complex at its west end named Noctis Labyrinthus (sometimes called "the Chandelier" because of its branched, inverted-triangle topographic pattern). The bright basin near the bottom is Argyre, one of the largest impact scars on Mars. This ancient crater is near the south pole (which is not visible in this picture), and is brightened by the icy surface frosts and fogs that are characteristic of the near-polar regions when each is experiencing its hemisphere's winter season.

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NASA
National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

	(TOP)	(BOTTOM)
	Viking 2	Viking 1
	P-20475	P-17704
	July 20, 1978	September 8, 1976

SUNRISE, SUNSET – The picture at the top is a Viking 2 Lander picture taken June 14, 1978, at its Utopia Planitia landing site on Mars. The imagery data were acquired just as the Sun peaked over the horizon on the Lander's 631st sol (martian solar day). The picture at the bottom was taken by the Viking 1 Lander on August 20, 1976. Similar in appearance to the sunrise picture, it actually represents a sunset at Chryse Planitia, and wasn't acquired until the Sun had already dipped several degrees below the horizon. Pictures taken at dawn or dusk are quite dark except where the sky is brightened above the Sun's position. The glow in the sky results as light from the Sun is scattered and preferentially absorbed by tiny particles of dust and ice in the atmosphere. When the camera is calibrated for darker scenes, the "sky glow" tends to saturate its sensitivity and produce the bright regions seen here. The "banding" and color separation effects are also artifacts rather than real features, and are introduced because the cameras are not able to record continuous gradations of light. The cameras must represent such gradations in steps (bands) of brightness and color, and the process sometimes produces some "false" colors within the bands. The scattering of light closest to the Sun's position tends to enhance blue wavelengths. The narrowing sky-glow nearer the horizon above the Sun's position occurs as a result of light extinction. At that elevation, the optical path of sunlight through the atmosphere is at its longest penetration angle, and a substantial portion of the light is simply prevented from reaching the camera by the dust, ice particles, and other material in its way.

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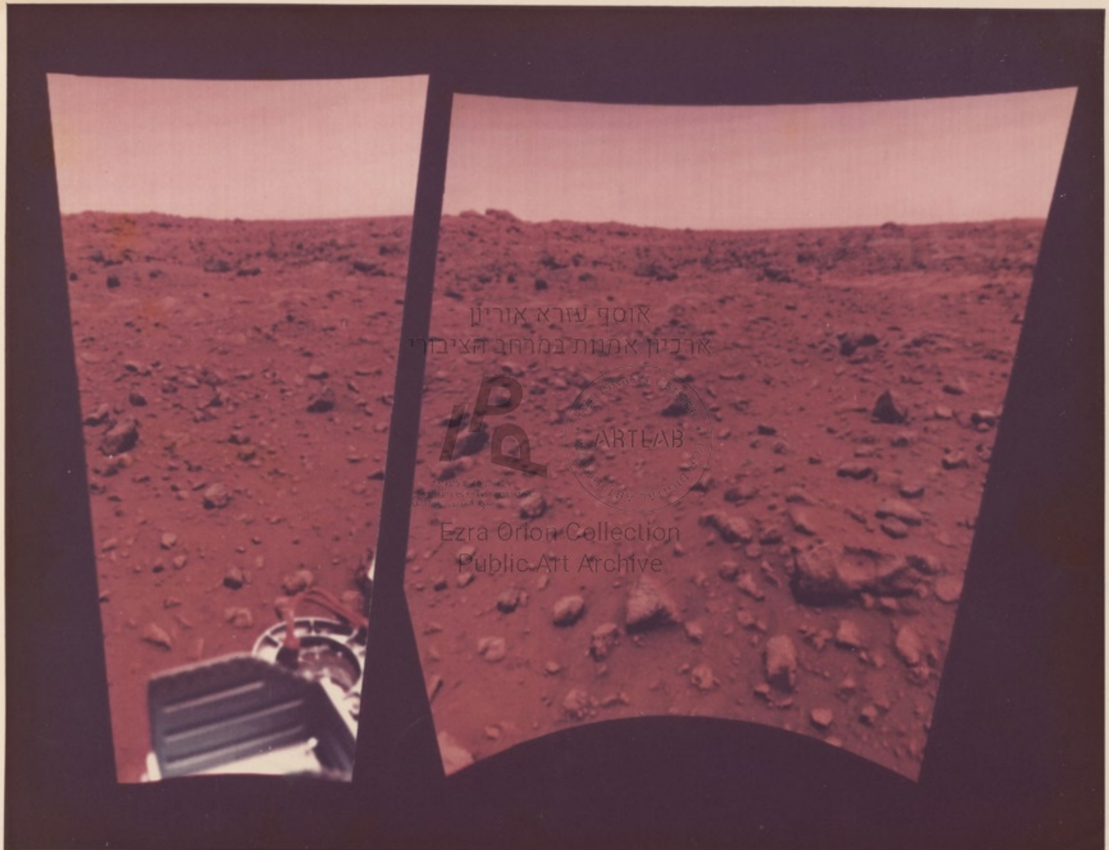

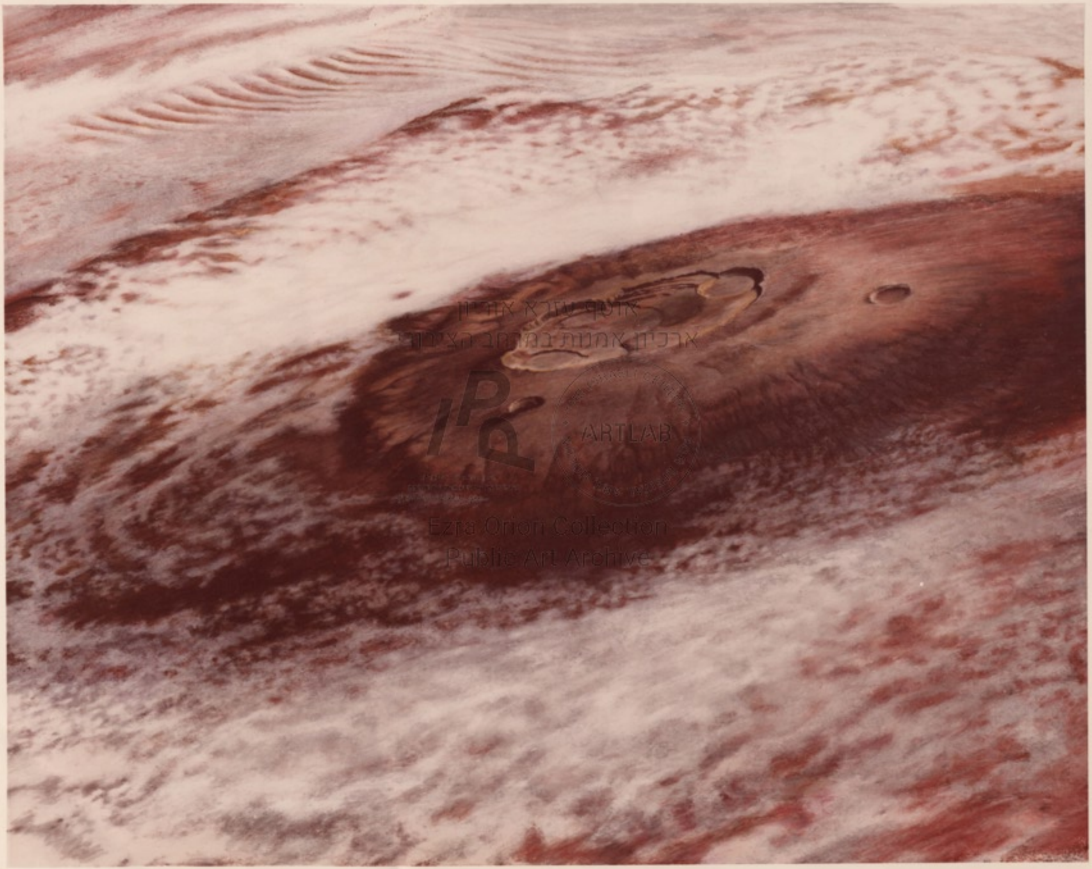

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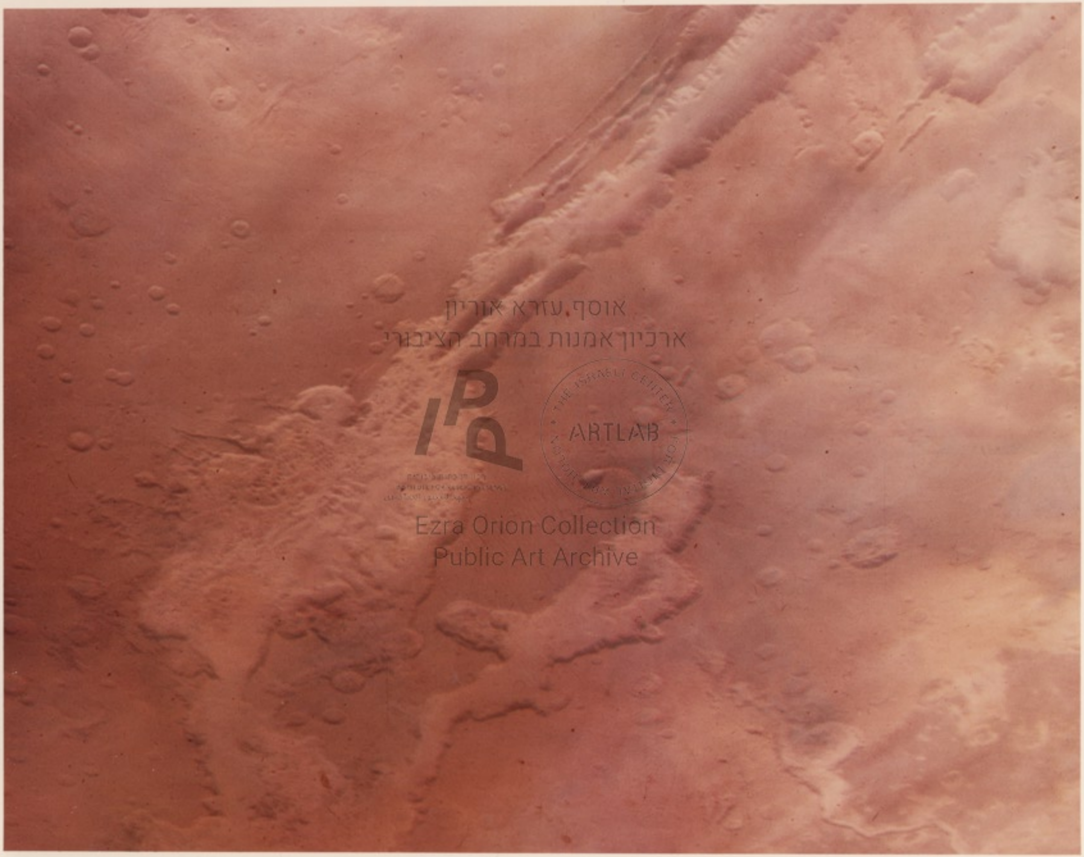
PASADENA, CALIFORNIA. TELEPHONE (213) 354-5011

PHOTO CAPTION

This artist's conception of the great Martian volcano, Olympus Mons, was prepared from photographs taken by the Viking 1 Orbiter on July 31, 1976, from a distance of 8000 kilometers (5000 miles). The 24-kilometer-high (15 miles) mountain is seen in mid-morning, wreathed in clouds that extend up the flanks to an altitude of about 19 kilometers (12 miles). The multi-ringed caldera (volcanic crater), some 80 kilometers (50 miles) across, pushes up into the stratosphere and appears cloud-free at this time. The cloud cover is most intense on the far western side of the mountain. A well-defined wave cloud train extends several hundred miles beyond the mountain (upper left). The planet's limb can be seen at upper left corner. It also shows extensive stratified hazes. The clouds are thought to be composed principally of water ice condensed from the atmosphere as it cools while moving up the slopes of the volcano. In the Martian afternoon, the clouds develop sufficiently to be seen from Earth, and it is known that they are a seasonal phenomenon largely limited to spring and summer in the northern hemisphere. Olympus Mons is about 600 kilometers (375 miles) across at the base and would extend from San Francisco to Los Angeles. The drawing was prepared by Gordon Legg of Graphic Films, Inc., Hollywood, CA. for a NASA film on Viking.



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VIKING NEWS CENTER
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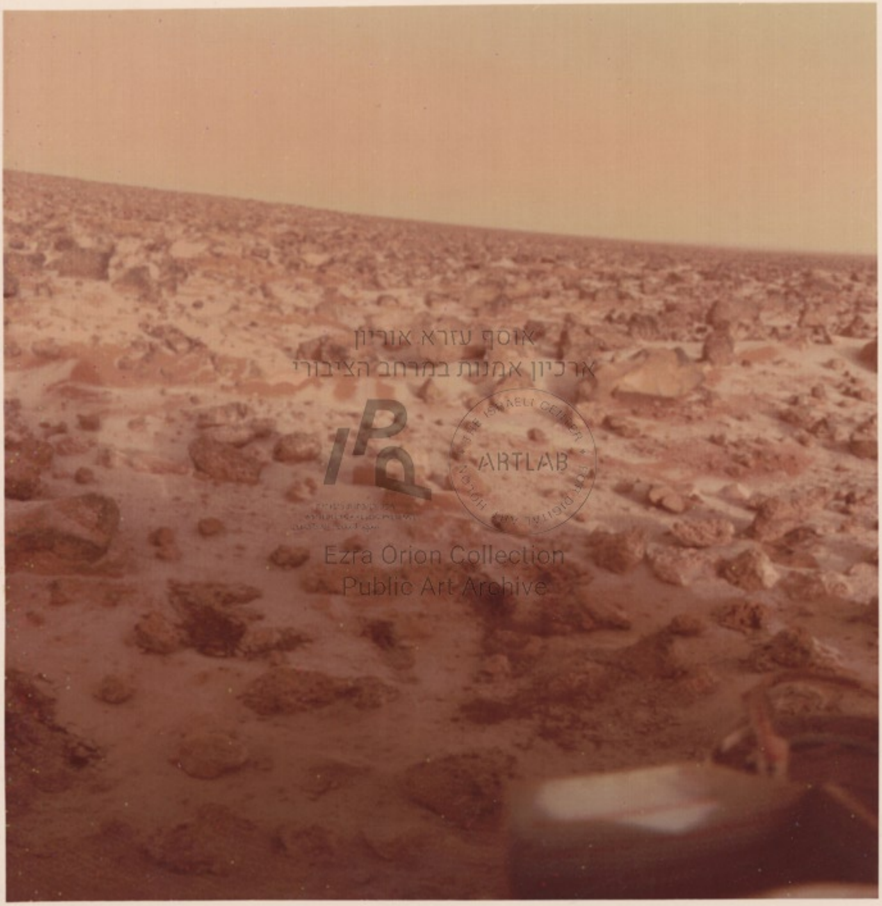
Viking 1-83
P-18078 (color Rev. 32)
OCTOBER 1, 1976

PHOTO CAPTION

From 31,000 kilometers (19,200 miles) above Mars, Viking Orbiter 1 took 15 black and white photos through three color filters--violet, green and red--to form this color mosaic of part of the so-called "Grand Canyon of Mars." The canyon, Valles Marineris, lies just a few degrees south of the equator and parallels it for some 5,000 kilometers (3,100 miles) from east to west. In this picture, the equator cuts across the top left corner. North is to upper left. Area covered is about (1,800 by 2,000 kilometers) (1,120 by 1,250 miles)--a little more than twice the area of Alaska. The 15 photos, taken near the highest point in the Orbiter's 32nd revolution of Mars (on July 22), were computer-processed and combined at the United States Geological Survey facility in Flagstaff, Arizona.



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National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Viking 1
P-22668

The Viking 1 Lander took this image of Mars August 8, 1978, 730 Mars days after landing. Parts of the Lander are visible in the foreground. The square structure on the left is the top of a landing leg; to its right are the wind and temperature sensor and a brush used for cleaning off the scoop that collects soil samples. On the surface can be seen a field of dust accumulation on the left and a rocky plain extending to the horizon, a few kilometers away. Most of the rocks measure around 50 centimeters (19.5 inches) across; the large one on the left, about 2.5 meters (8 feet) wide and 8 meters (26 feet) away from the Lander, has been nicknamed "Big Joe."

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Pasadena, California

Viking 2
P-22458

This late-winter picture, taken from the Viking 2 Lander on the 1050th Mars day, shows traces of the white condensate that covered most of the surface during both of the Lander's winters on Mars. The condensate, only a few microns thick, is composed of either water or carbon dioxide ice, or a combination of both, and could have come as either frost or snow. Some scientists believe it also could have risen out of the surface by a process called cryopumping. Several trenches can also be seen where the Lander's sampling arm reached out to gather surface material for its lifeseeking experiments; to their right lies the arm's protective cover, which was jettisoned shortly after landing. Most rocks are about 50 centimeters (19.5 inches) in size and were probably thrown out as the result of meteor impacts long ago. The small pits in some of them are either wind-eroded or were caused by trapped gas bubbles as the rocks formed. Also visible in the image are the rolled-up surface sampler arm housing (left) and the top of a landing leg (right).

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Viking 1-60
P-17254
July 28, 1976

PHOTO CAPTION

This image, received today, shows the trench excavated by Viking 1 surface sampler. The trench was dug by extending the surface sampler collection head in a direction from lower right toward the upper left and then withdrawing the surface sampler collector head. Lumpy piles of material at end of trench at lower right was pulled by plowing from trench by the backhoe which will be used to dig trenches later in the mission. Area around trench has ripple marks produced by Martian wind. The trench which was dug early on Sol 8, is about 3 inches wide, 2 inches deep and 6 inches long. Steep dark crater walls show the grains of the Martian surface material stick together (have adhesion). The doming of the surface at far end of the trench show the granular material is dense. The Martian surface material behaves somewhat like moist sand on Earth. Evidence from the trench indicate a sample was collected and delivered to the experiments after repeated tries. The biology experiment level full indicator indicates a sample was received for analysis. The X-Ray fluoresence experiment has no indication to show it received a sample. The GCMS experiment level full indicator suggests no sample was received but this matter is being investigated.

National Aeronautics and
Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Hubble's New Optics Probe Core of Distant Galaxy

Wide Field/Planetary Camera I Image
before servicing mission

Wide Field/Planetary Camera II Image
after servicing mission

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

Hubble's New Optics Probe Core of Distant Galaxy

On the front: This comparison of images of the core of the galaxy M100 shows the dramatic improvement in Hubble Space Telescope's (HST's) view of the universe. The new image, taken with the second-generation Wide Field/Planetary Camera II (WF/PC II) installed during the STS-61 HST First Servicing Mission, beautifully demonstrates that the camera's corrective optics compensate fully for the optical aberration in the telescope's primary mirror. With the new camera, Hubble will probe the universe with unprecedented clarity and sensitivity and fulfill the most important scientific objectives for which it originally was built.

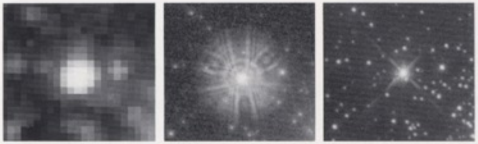
Front right: The core of the spiral galaxy M100, as imaged by WF/PC II in its high-resolution channel. WF/PC II's modified optics correct for Hubble's previously blurry vision, allowing the telescope, for the first time, to cleanly resolve faint structure as small as 30 light-years across in a galaxy tens of millions of light-years away. The image was taken December 31, 1993.

Front left: For comparison, a picture taken with the WF/PC I camera November 27, 1993, just a few days before the servicing mission. The effects of the optical aberration in HST's 2.4-meter primary mirror blur starlight, smear out fine detail and limit the telescope's ability to see faint structure.

Both Hubble images are "raw," that is, they have not been processed using computer image reconstruction techniques that sharpen aberrated images made before the servicing mission but which degrade the accuracy of the images.

The WF/PC II was developed by the Jet Propulsion Laboratory in Pasadena, California. Hubble is managed by Goddard Space Flight Center in Greenbelt, Md., for the Office of Space Science at NASA Headquarters in Washington, D.C.

The mission to service Hubble was carried out from the Space Shuttle Endeavour, which flew into space December 2, 1993, from Kennedy Space Center in Florida and returned to Earth on December 13. The 11-day mission featured a record five spacewalks to service HST.



Ground-based | WF/PC I | WF/PC II

IMAGE COMPARISON SHOWS POWER OF "NEW" HUBBLE

The three panes above show images of a very bright star, Melnick 34, in the giant star-forming region called 30 Doradus in the Large Magellanic Cloud. In the background are a number of fainter stars comparable in luminosity to our Sun.
Above left: The best available ground-based image of Melnick 34.
Above center: The same star imaged by the first Wide Field/Planetary Camera I. Even with its aberrated optics, the advantages of working in space above Earth's distorting atmosphere are immediately apparent.
Above right: The same star imaged by the newly installed Wide Field/Planetary Camera II. The new optics allow for sharper focus and reveal a large number of fainter stars in a crowded field.

For The Classroom*

In this activity, the student's eye is an analogy of the imaging processing computer that stores numerical image fragments, collected and radioed to Earth by the Hubble Space Telescope, and reassembles them for use.

Materials:
Paper tube
Index card
Pencil
Ruler
Scissors
Tape

Procedure:
1. Trace one end of the tube on the index card and cut out the circle.
2. Use the ruler to draw a straight line directly across the diameter of the circle.
3. Cut the circle in half along the straight line.
4. Tape each half of the circle on one end of the tube leaving only a narrow slit about 2 to 3 millimeters wide.
5. Look through the other end of the tube. Try to make out the image of what you are looking at. Slowly move the tube from side to side. Gradually increase the speed of the tube's movement.

Discussion:
This activity roughly demonstrates the imaging process used by the Hubble Space Telescope. By slowly moving the tube from side to side small fragments of the image are captured and directed down the tube ("radioed") towards the student's eye. Because the fragments are quickly forgotten, the addition of many more fragments as the tube continues to move confuses the image in the student's mind. However, as the tube is moved rapidly, each image fragment remains just long enough to combine with the others to form a recognizable image. This effect is known as "persistence of vision."

*From *Classroom Activities* available at NASA Teacher Resources Centers

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

Hubble Space Telescope First Servicing Mission

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

Hubble Space Telescope First Servicing Mission

On the front: Astronaut F. Story Musgrave, anchored on the end of the Remote Manipulator System (RMS) arm on the Space Shuttle Endeavour, prepares to be elevated to the top of the towering Hubble Space Telescope (HST) to install covers on magnetometers. Astronaut Jeffrey A. Hoffman, at bottom, teamed up with Musgrave to perform final servicing tasks on the telescope.

The nearly flawless 11-day mission to service Hubble included a record-breaking five spacewalks in which astronauts performed a number of tasks designed to improve the telescope and extend its life.

COSTAR

To compensate for HST's blurred vision, astronauts installed a phone booth-size device called the Corrective Optics Space Telescope Axial Replacement (COSTAR). Using 10 corrective mirrors ranging in size from a dime to a quarter, COSTAR improved the quality of data from three instruments: the European Space Agency (ESA) Faint Object Camera (FOC), the Faint Object Spectrograph (FOS) and the Goddard High Resolution Spectrograph (GHRS).

WIDE FIELD/PLANETARY CAMERA II

Astronauts also installed a second-generation camera known as the Wide Field/Planetary II Camera. This camera, already under construction when Hubble was launched on April 24, 1990, included its own corrective optics as well as a number of technological improvements. It replaced the original Wide Field/Planetary Camera I.

OTHER ENHANCEMENTS

Also replaced were ESA's two solar arrays, which gather sunlight to power Hubble; a Solar Array Drive Electronics (SADE) unit, which transmits commands to the array wings; two magnetometers, which measure the spacecraft's relative orientation to Earth's magnetic field; two gyroscope packages, which help point HST and track targets; a kit to improve the reliability of the Goddard High Resolution Spectograph; a 386 co-processor to augment the telescope's onboard DF-224 computer; and fuse plugs for the gyros and science instruments.

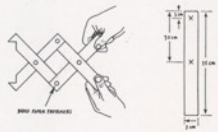
The STS-61 HST First Servicing Mission was carried out from the Endeavour following its flight into space December 2, 1993, from Kennedy Space Center in Florida. Endeavour returned to Earth on December 13, 1993. The seven-member crew included Richard O. Covey, commander; Kenneth D. Bowersox, pilot; Musgrave, payload commander; Hoffman, mission specialist; ESA's Claude Nicollier, the mission specialist who operated the RMS arm; and Tom Akers and Kathryn C. Thornton, mission specialists who formed the second spacewalking team.

Hubble is managed by Goddard Space Flight Center in Greenbelt, Md., for the Office of Space Science at NASA Headquarters in Washington, D.C.

For The Classroom

Scientists working in space and deep under the ocean often use remote manipulator arms. These manipulator arms come in different shapes and sizes. Have students construct a manipulator arm to help them understand how one works.

Materials:
Poster board
Scissors
Ruler
Brass Paper Fasteners
Hole punches
Scrap paper
Marbles

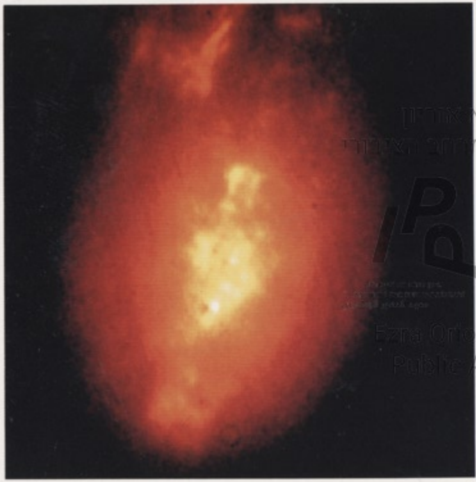


Procedure:
1. Distribute the materials.
2. Cut the poster board into four strips, each 15 centimeters long by 2 centimeters wide.
3. Make two holes in each strip of poster board. Place one hole in the center of the strip. Center the other hole about one centimeter from one end of the strip.
4. Use brass fasteners to assemble the accordion-like model as shown in the illustration.
5. Students will find that the manipulator does not grasp unless they cut "teeth" at the end as shown in the illustration.
6. Crumple several pieces of scrap paper into small balls and drop them onto the floor randomly.
7. Have students take turns using their manipulator arms to arrange the crumpled paper into a square and then into a circular pattern. Repeat the exercise using marbles. Students may need to redesign their manipulator arm to pick up the marbles.

Adapted by permission from *The Jason Core Curriculum*

National Aeronautics and
Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Hubble's Improved Vision Reveals Central Region of Active Galaxy



Faint Object Camera (FOC) image
before servicing mission

COSTAR-improved FOC image
after servicing mission

National Aeronautics and
Space Administration
Goddard Space Flight Center

Hubble Reveals Central Region of Active Galaxy

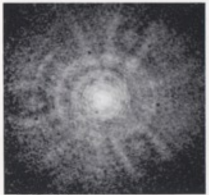
On the front: NASA's refurbished Hubble Space Telescope (HST) has provided this outstanding image of the nuclear region of the galaxy NGC 1068. This galaxy is about 60 million light-years away and is the prototype of a class of active galaxies known as Seyfert Type 2. An active galaxy's core shines with the brightness of a billion solar luminosities and fluctuates over the period of a few days, inferring that energy is being released from a region just a few light-days in size. The most likely source for this enormous amount of energy is a supermassive black hole with a mass of 100 million stars like the Sun.

Front left: Previous observations with HST's Faint Object Camera (FOC) showed a number of hot gaseous clouds ionized, or heated, by the intense radiation from the nuclear source. This diverging beam of emission, or "cone," is caused by the shadowing effect of the radiation of the active nucleus by opaque gas and dust clouds orbiting the suspected black hole.

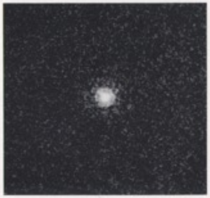
Front right: A view of the same field with the corrected FOC, whose vision has been improved by the mirrors in the Corrective Optics Space Telescope Axial Replacement (COSTAR) that astronauts installed during the STS-61 HST First Servicing Mission in December 1993. The new observations show with unprecedented clarity a much more extensive double cone of emission, believed to be shaped by radiation from the active nucleus. A wealth of new detail also is revealed in this core region. The knots and streamers of emission will enable the geometry of this core region to be understood and will offer new information on the nature of the clouds.

The FOC was provided by the European Space Agency (ESA). COSTAR was developed by Ball Aerospace of Boulder, Colo., under contract to Goddard Space Flight Center in Greenbelt, Md. Hubble is managed by Goddard for the Office of Space Science at NASA Headquarters in Washington, D.C.

The HST servicing mission was carried out from the Space Shuttle, Endeavour, which flew into space December 2, 1993, from Kennedy Space Center in Florida and returned to Earth on December 13. The 11-day mission featured a record five spacewalks to service HST.



Before COSTAR



After COSTAR

NEW OPTICS RESTORE HUBBLE'S VISION

Above left: An FOC image of a star taken prior to the HST servicing mission. Spherical aberration causes the broad halo around the star.

Above right: Following deployment of COSTAR, the FOC fully meets its pre-launch expectations. Most of the starlight now is concentrated at the center of the image, and the blurry "skirt" of light is completely gone. This gives HST dramatically improved sensitivity and ten times better resolution than ground-based telescopes.

For The Classroom

The Corrective Optics Space Telescope Axial Replacement (COSTAR) uses mirrors to correct the light from the telescope mirror before it reaches the scientific instruments.

Why would scientists use mirrors instead of lenses to make the corrections?

The mirrors in COSTAR are small, about the size of a nickel. One of each pair of mirrors (M1) is a relatively simple concave spherical shape. The other mirror of a pair (M2) is more complicated – it is described as similar to a potato chip.

Have students experiment with mirrors:

What happens to your image when you look into a concave mirror?
What happens to your image when you look into a convex mirror?
What happens to your image when you look into two mirrors taped at right angles to each other?

Have students try mirror writing: Write a word on a piece of paper. Stand a mirror on the paper so that the letters are reflected in the mirror. Copy the reflected word on another piece of paper. Ask a friend to read the word. This should prove difficult because the letters are upside down and back-to-front. Hold a mirror so that the word will be reflected and appear normal.

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VIKING NEWS CENTER
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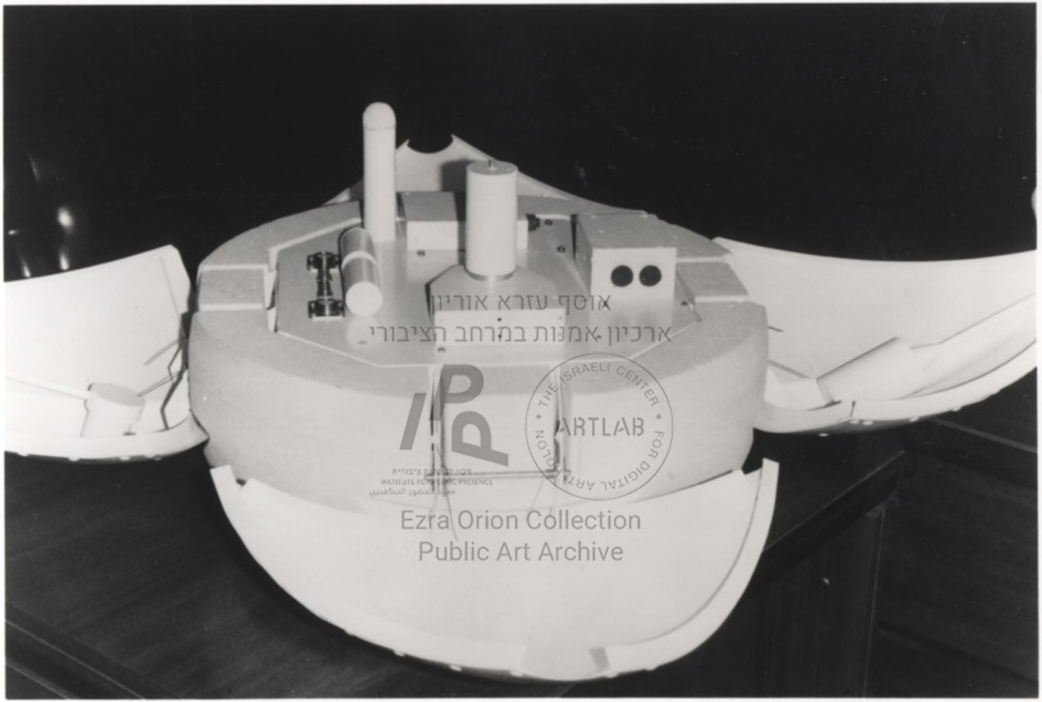
Viking 1-82
211-5159 (P62-65)
September 22, 1976

PHOTO CAPTION

More than 100 individual pictures taken by Viking Orbiter 1's TV cameras during revolutions 62 through 65 (August 23 to 26) form this photomosaic -- part of the systematic mapping of Valles Marineris, or Mariner Valleys, the huge complex of equatorial canyons on Mars. The mosaic is centered at 5° South Lat., 85° West Long. North is at top. At left is part of Labyrinthus Noctis from which two canyons, Tithonium Chasma (top) and Ius Chasma, extend to the east. A wide range of canyon morphology can be seen. In places, the walls appear to have been modified by huge landslides; in other places by headward erosion to form integrated tributary systems; and elsewhere faulting appears to have predominated. Main puzzle concerning the canyons: "Where is all the material which formerly occupied the regions of negative relief?"



Model of the Mars 94 small station: the station will be deployed from an entry shell above the planet's surface, parachuting down to land on Mars. Its landing configuration is as a ball that bounces and absorbs most of the shock. After coming to rest, the protective casing separates and exposes the small station. Then the station's petals open outward, permitting the instruments, including TV, to make measurements on the martian surface.

Photo Credit: IKI/JPL #41996A


NASA

P-19011

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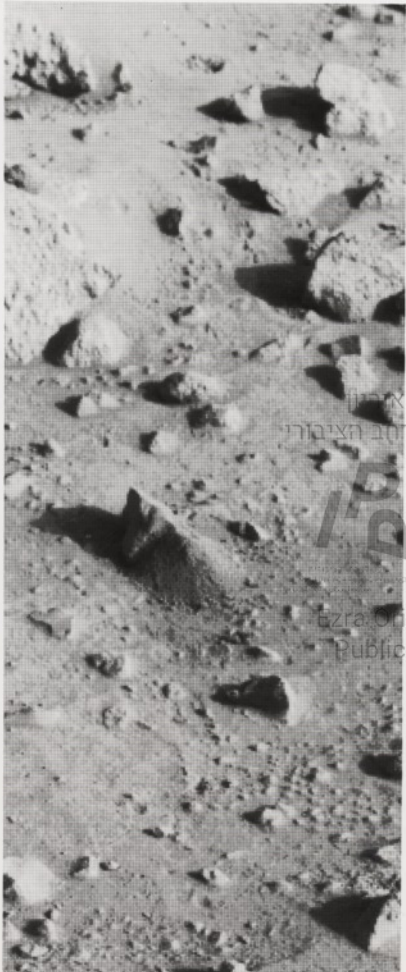
JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
PASADENA, CALIF. 91109. PHONE (818) 354-5011

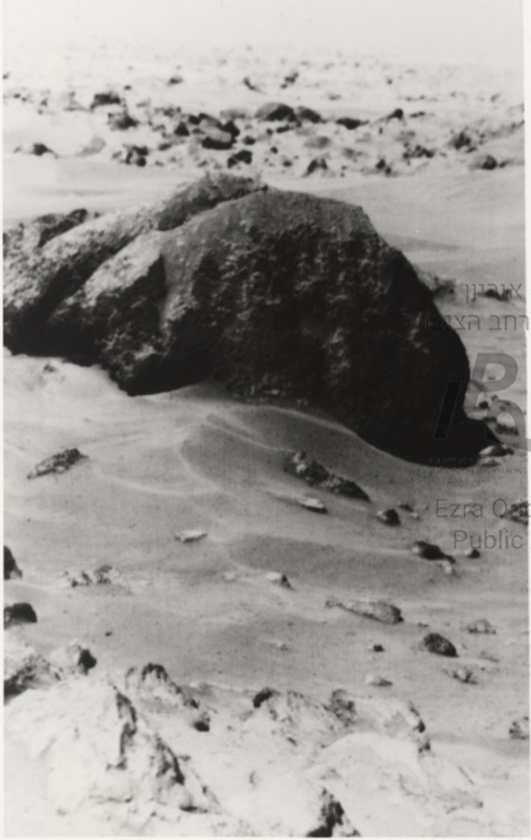
P-19011

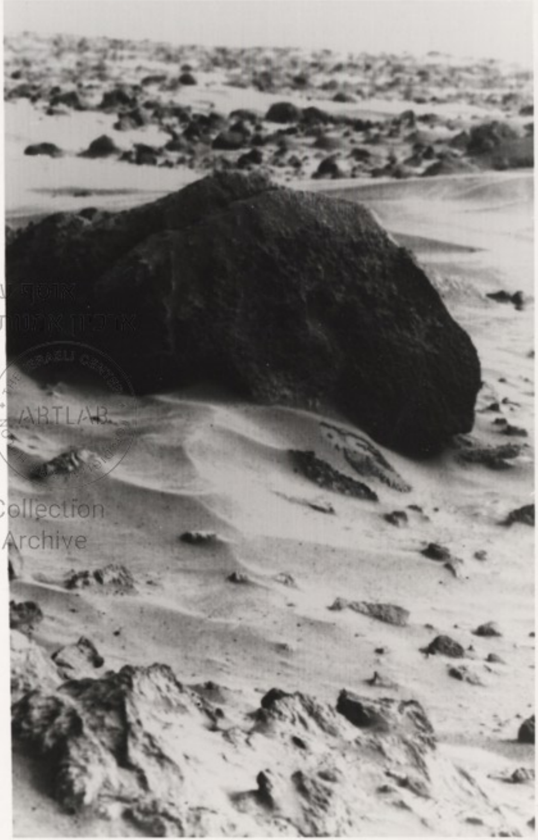
PHOTO CAPTION

A future mission to Mars using a roving vehicle is being studied at the Jet Propulsion Laboratory. The intelligent machines could land on the red planet and traverse at least 100 kilometers (62 miles) during a one-Martian-year mission. In this painting a rover is in the 4100-kilometer-long (2,500-mile) Valles Marineris. The rover, about the size of a large desk, has loop wheels, two stereo cameras (atop boom at front) and a manipulator arm. The vehicle could carry more than 100 kilograms (220 pounds) of scientific instruments to study the Martian surface and a 250-watt radioisotope thermoelectric generator for electric power. The rover would be able to survey surrounding terrain, detect obstacles and avoid them. It could be equipped with proximity sensors, stereo cameras, laser range-finding instruments and advanced computers. It would move around the surface of Mars independent of detailed instructions from Earth. The JPL study is for NASA's Office of Space Science and Application.



קצוני הטמאליה
מצולעת דמות אבן
טבולה על מדרון האבן
קימנית, כגביר...
פנת האבן ג' רוחות





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P19591 (Special)

This pair of pictures from Viking Lander 1 at Mars' Chryse Planitia shows the only unequivocal change in the Martian surface seen by either lander. Both images show the one-meter (3-foot) high boulder nicknamed "Big Joe." Just to the lower right of the rock (right photo) is a small-scale slump feature. The picture at left shows a smooth, dust-covered slope; in the picture at right the top surface layer can be seen to have slipped downslope. The event occurred sometime between Oct. 4, 1976, and Jan 24, 1977. (Pictures taken before Oct. 4 do not show the slump; the first picture in which it appears was taken Jan. 24.) The surface layer, between one-half and one centimeter (one-fifth to one-third inch) thick, is apparently less cohesive than the underlying material. The layer that slipped formed a 30-centimeter-long (11.8-inch) "tongue" of soil and a patch of exposed underlying material. The triggering mechanism for the event is unknown, but could have been temperature variations, wind gusts, a seismic event, or perhaps the lander's touchdown on July 20, 1976.

P19591

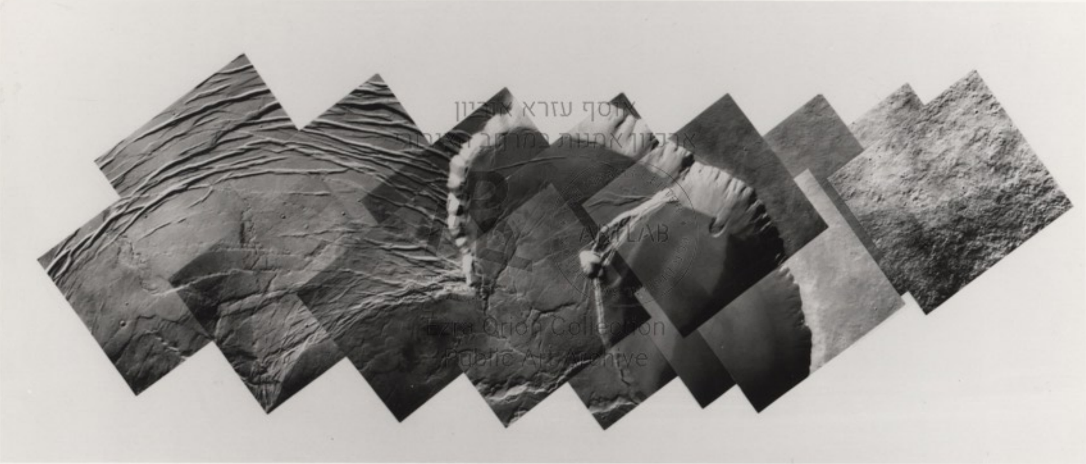

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PHOTO CAPTION

211-5928
Aug. 4, 1980

The summit caldera of Olympus Mons, largest volcano on Mars and in the solar system, was photographed from Viking Orbiter 1 on July 13, 1980. This mosaic shows geological features not visible in earlier pictures of the caldera:

Small impact craters, irregular volcanic vents and spatter cones are now visible at this resolution on the floor of the upper crater, some 25 kilometers (16 miles) across, containing the small landslide at the top of the picture. This crater floor thought to be the youngest feature in the scene, now appears older than had been thought, indicating that the last eruptive episode occurred earlier in Mars' history than had been believed.

More of the newly seen small impact craters and irregular volcanic structures described in the upper crater can be found in the central portion of the mosaic, in an area of intermediate age that has numerous "wrinkle ridges" (compressional fractures).

Also seen for the first time in this region, and of great interest, are the irregular, leveed channels or collapsed lava tubes near the juncture on the left of this unit with the oldest portion of the caldera which is collapsed and deeply fractured.

Seen from an altitude of 650 kilometers (415 miles), the detail of the structures is twice as good as in Viking's earlier pictures of the volcano. The resolution of the mosaic is 17 meters per pixel (55 feet per picture element).

Viking is managed for NASA by Jet Propulsion Laboratory Pasadena, Calif.

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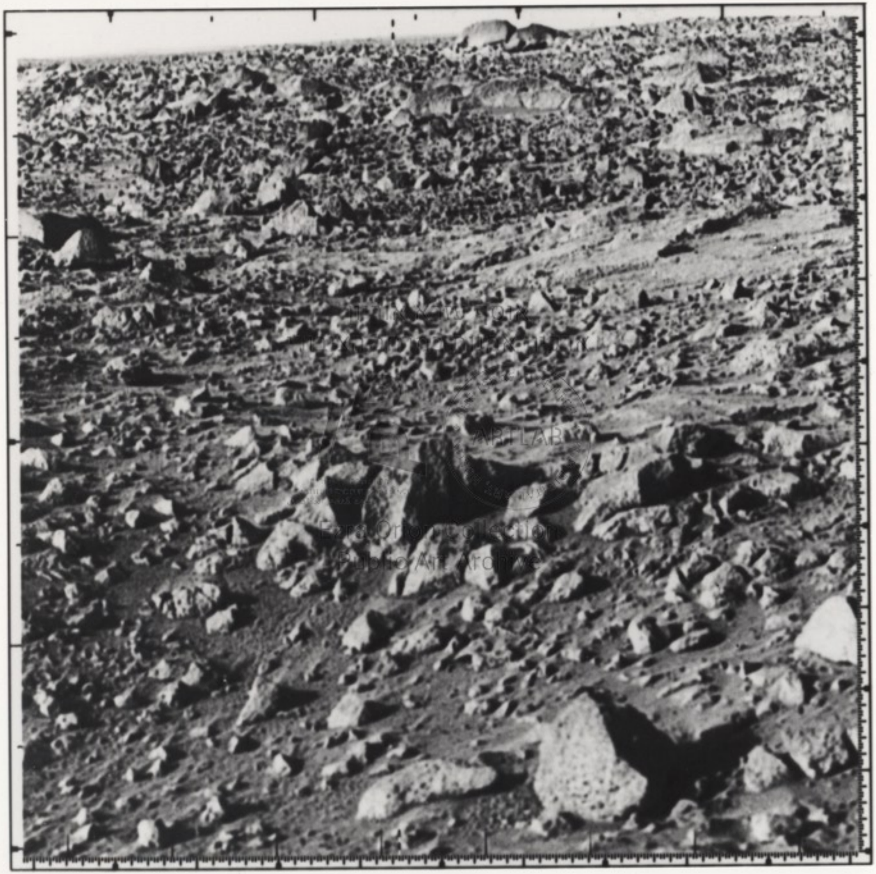
Viking 1-35
P-16984 (14A58/14A60)
July 8, 1976

PHOTO CAPTION

Fault zones break the Martian crust in this view obtained by Viking 1 of an area two degrees south of the equator and near a potential landing site for Viking 2 in September. The fault valleys are widened by mass wasting and collapse. Mass wasting is the downslope movement of rocks due to gravity and possibly hastened by seismic shaking (Mars quakes).



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Viking 1-48
P-17133 (Sol 2)
July 22, 1976

PHOTO CAPTION

Viking 1 took this high-resolution picture today--its third day on Mars. Distance from the camera to the near field (bottom) is about 4 meters (13 feet); to the horizon, about 3 kilometers (1.8 miles). The photo shows numerous angular blocks ranging in size from a few centimeters to several meters. The surface between the blocks is composed of fine-grained material. Accumulation of some fine-grained material behind blocks indicates wind deposition of dust and sand downwind of obstacles. The large block on the horizon is about 4 meters (13 feet) wide. Distance across the horizon is about 34 meters (110 feet).

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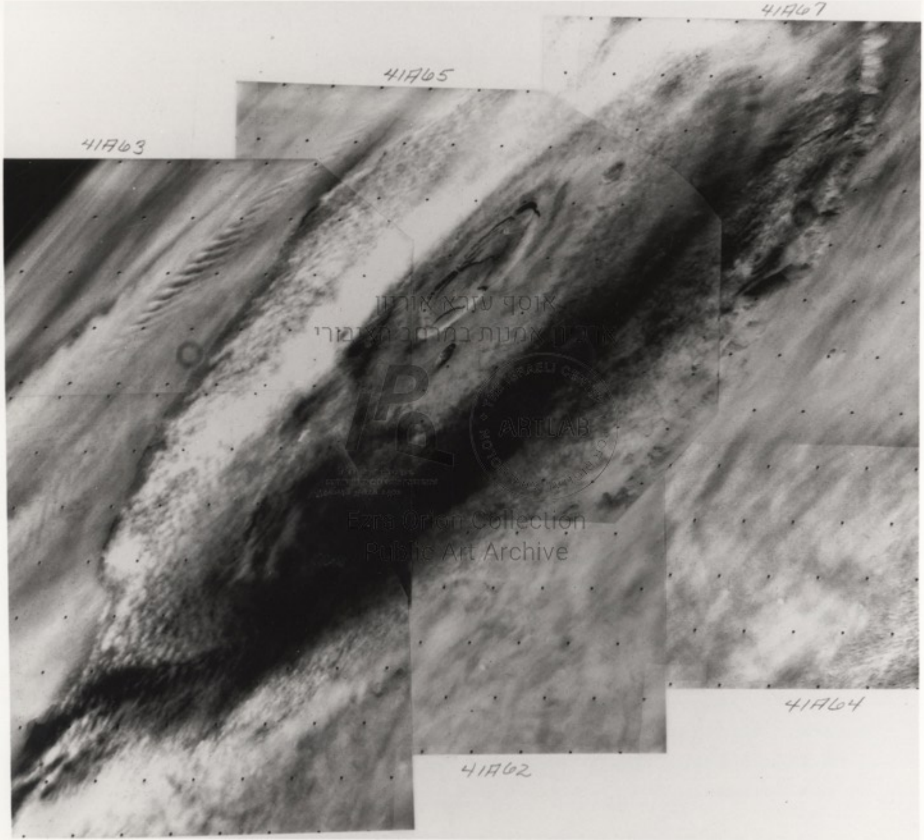
Viking 1-45
P-17044 (Sol 0)
July 20, 1976

PHOTO CAPTION

First panoramic view by Viking 1 from the surface of Mars. (Top): The out-of-focus spacecraft component toward left center is the housing for the Viking sample arm, which is not yet deployed. Parallel lines in the sky are an artifact and are not real features. However, the change of brightness from horizon towards zenith and towards the right (west) is accurately reflected in this picture, taken in late Martian afternoon. At the horizon to the left is a plateau-like prominence much brighter than the foreground material between the rocks. The horizon features are approximately three kilometers (1.8 miles) away. At left is a collection of fine-grained material reminiscent of sand dunes. The dark sinuous markings in left foreground are of unknown origin. Some unidentified shapes can be perceived on the hilly eminence at the horizon towards the right. Patches of bright sand can be discerned among the rocks and boulders in middle distance. In right foreground are two peculiarly shaped rocks which may possibly be ventifacts produced by wind abrasion on Mars. A horizontal cloud stratum can be made out halfway from the horizon to the top of the picture. (Bottom): At left is seen the low gain antenna for receipt of commands from the Earth. The projections on or near the horizon may represent the rims distant impact craters. In right foreground are color charts for Lander camera calibration, a mirror for the Viking magnetic properties experiment and part of a grid on the top of the Lander body. At upper right is the high-gain dish antenna for direct communication between landed spacecraft and Earth. Toward the right edge is an array of smooth fine-grained material which shows some hint of ripple structure and may be the beginning of a large dune field off to the right of the picture, which joins with dunes seen at the top left in this 300° panoramic view. Some of the rocks appear to be undercut on one side and partially buried by drifting sand on the other.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Viking 1-68
P-17444 (P-41)
August 09, 1976

PHOTO CAPTION

The great Martian volcano, Olympus Mons, was photographed by the Viking 1 Orbiter on July 31 from a distance of 8000 kilometers (5000 miles). The 24-kilometer-high (15 miles) mountain is seen in mid-morning, wreathed in clouds that extend up the flanks to an altitude of about 19 kilometers (12 miles). The multi-ringed caldera (volcanic crater), some 80 kilometers (50 miles) across, pushes up into the stratosphere and appears cloud-free at this time. The cloud cover is most intense on the far western side of the mountain. A well-defined wave cloud train extends several hundred miles beyond the mountain (upper left). The planet's limb can be seen at upper left corner. It also shows extensive stratified hazes. The clouds are thought to be composed principally of water ice condensed from the atmosphere as it cools while moving up the slopes of the volcano. In the Martian afternoon, the clouds develop sufficiently to be seen from Earth, and it is known that they are a seasonal phenomenon largely limited to spring and summer in the northern hemisphere. Olympus Mons is about 600 kilometers (375 miles) across at the base and would extend from San Francisco to Los Angeles.

SEFUL INFORMATION

REWELL BANQUET - THURSDAY, OCTOBER 13, 1994

kets can be purchased at the Information Desk at the cost of US$ 60.00 per person, until ednesday, October 12, 1994

PTIONAL TOURS FOR ACCOMPANYING PERSONS

UR 1 MASSADA AND THE DEAD SEA
DAILY: MONDAY, OCTOBER 10 - FRIDAY, OCTOBER 14, 1994 — 09.00-17.00 hours
Price per person: US$ 56.00

UR 2 NAZARETH, CAPERNAUM AND TIBERIAS
DAILY: MONDAY, OCTOBER 10 - WEDNESDAY, OCTOBER 12, 1994 — 09.00-17.00 hours
Price per person: US$ 47.00

UR 3 THE KIBBUTZ EXPERIENCE
MONDAY, OCTOBER 10, 1994 — 09.00-13.00 hours
Price per person: US$ 23.00

OUR 4 TEL-AVIV AND JAFFA
TUESDAY, OCTOBER 11, 1994 — 09.00-17.00 hours
Price per person: US$ 50.00 (including lunch)

OUR 5 JERUSALEM - THE CENTER OF THREE RELIGIONS
WEDNESDAY, OCTOBER 12, 1994 — 09.00-13.00 hours
Price per person: US$ 20.00

OUR 6 OLD JERUSALEM
THURSDAY, OCTOBER 13, 1994 — 09.00-13.00 hours
Price per person: US$ 20.00

OUR 7 BEDOUIN TRACKS
FRIDAY, OCTOBER 14, 1994 — 14.00-18.00 hours
Price per person: US$ 30.00

POST CONGRESS TOUR TO THE GALILEE (2 days/2 nights)

Saturday, October 15, 1994 - Monday, October 17, 1994

Prices:	Double Room (2 persons)	US$ 550.00
	Single Room (1 person)	US$ 390.00

PROFESSIONAL VISITS

The following professional visits will be offered:

Israel Aircraft Industries — Tuesday, October 11, 1994
Price per person: US$ 20.00

The Technion - Institute of Technology — Wednesday, October 12, 1994
Price per person: US$ 25.00

Please register for these tours at the Information Desk.

LOCATIONS AND TELEPHONE NUMBERS OF OFFICES AT THE CONVENTION CENTER

IAF EXECUTIVE SECRETARY	(Room 101)	Telephone No. (02) 558559
IAF PRESIDENT	(Room 104)	Telephone No. (02) 558514
IAF SECRETARIAT	(Room 102)	Telephone No. (02) 558506
IAA PRESIDENT	(Room 116)	Telephone No. (02) 558556
IAA SECRETARIAT	(Room 108)	Telephone No. (02) 558548
PROGRAM COMMITTEE	(Room 109)	Telephone No. (02) 558549
IISL PRESIDENT	(Room 115)	Telephone No. (02) 558555
PROCEEDINGS ROOM	(Room 105)	Telephone No. (02) 558521
PRESS ROOM	(Room 210)	Telephone No. (02) 382494
PREPRINT ROOM	Entrance Level	Telephone No. (02) 558513

45th INTERNATIONAL ASTRONAUTICAL CONGRESS

JERUSALEM, ISRAEL, OCTOBER 9 - 14, 1994

POCKET PROGRAM

* CONGRESS HOTELS

1. ***I.C.C.**
1. ***HOLIDAY INN CROWNE PLAZA (Adjacent to the Convention Center)**
2. ***SONESTA**
3. ***PARADISE**
4. ***JERUSALEM RENAISSANCE**
5. HOLYLAND
6. SHALOM
7. ***JERUSALEM GATE**
8. CAESAR
9. LEV JERUSALEM
10. JERUSALEM TOWER
11. TIRAT BAT SHEVA
12. ZION SQUARE
13. SHERATON PLAZA
14. KINGS
15. YMCA
16. KING DAVID
17. KING SOLOMON
18. MORIAH PLAZA
19. ***WINDMILL**
20. LAROMME
21. MT. ZION
22. ARIEL
23. MITZPE RACHEL
24. AMERICAN COLONY
25. HYATT REGENCY

CALENDAR

Jerusalem, Israel - 6-14 October 1994

Federation Meetings	Academy Meetings	Congress Sessions
HALL	HALL	**Thursday, 6 October** HALL **a.m.** 9.00 UN/IAF Workshop on Developing Nations (HI1)
		Friday, 7 October **a.m.** 9.00 UN/IAF Workshop on Developing Nations (HI1)
Saturday, 8 October **a.m.** 9.00 Technical Activities Ctee (HI2) 11.30 Publications Ctee (HI2)	**Saturday, 8 October** **a.m.** 9:00 Publications Ctee (R1) 10:30 Awards/Membership Ctee (R2)	**Saturday, 8 October** **a.m.** 9.00 UN/IAF Workshop on Developing Nations (HI1)
p.m. 2.00 Finance Ctee (HI2) 4.00 Bureau I (HI2)	**p.m.** 12:00 Safety and Rescue Ctee (R3) Art & Literature Ctee (R4) 1:30 SETI Ctee (R1) Quality Subctee (R3) 11th Man in Space Ctee (R4) 3:00 Small Satellites Ctee (R1) Space Debris Ctee (R2) Mars Exploration Ctee (R3) Space Activities & Society Ctee (R4) 4:30 Scientific Legal Ctee (R1) Interstellar Exploration Ctee (R2) EVA Protocols Ctee (R3) 5:30 Scientific Prog. Ctee (R4)	**p.m.** 8.00 **CONGRESS REGISTRATION** (HI)

The room assigned for the meeting is listed in parentheses. Convention Center = **CC** - Holiday Inn = **HI**. Jerusalem Renaissance = **R**

Federation Meetings	Academy Meetings	Congress Sessions / CC
Monday, 10 October HALL	**Monday, 10 October** HALL	**Monday, 10 October** HALL
a.m.	**a.m.**	**a.m.**
11:30 EURISY (HI3)		8.30 Opening Ceremony **(CC Ussishkin Hall)** (CC)
p.m.	**p.m.**	**p.m.**
2:00 Space Station Ctee (HI1)	4:30 Int'l Space Plans & Pol. Ctee **(HI2)**	2.30 General Assembly 1 **(HI5)**
2.30 General Assembly I (HI5)		2.00
		I.1. Mater.& Struct. - Space Structuree - Development & Verification (E)
		M.1. Satellite Communications - Policy & Regulatory Issues (C)
		R.1. Space Power - Nuclear Solar Power & Propulsion Systems (D)
		U.1. Space Systems - Space Systems Technology Plans to Meet Regional Needs (F)
		V.1. Space Transportation - Launch Systems (G)
		W.1. Student Conference 1 (K)
		IAA.6.1. Safety & Rescue - Space System Safety & Crew Rescue (B)
		IAA.6.2. Safety & Rescue - Space Debris & Satellite Constellations (B)
		IAA.8.1. Space Activ. & Soc. - A Comprehensive Rationale for Astronautics (I)
		IAA.9.1. SETI - SETI:Science & Technology (H)
		IAA.11.1 Small Satellites Missions - Low Cost Scientific Missions in Earth-Orbiting & Planetary Programs (A)
		5.15 Plenary 1

The room assigned for the meeting is listed in parentheses. Convention Center = **CC** - Holiday Inn = **HI**. Jerusalem Renaissance = **R**

Federation Meetings			Academy Meetings			Congress Sessions		
Sunday, 9 October		**HALL**	**Sunday, 9 October**		**HALL**	**Sunday, 9 October**		**HALL**
a.m.			**a.m.**			**a.m.**		
9:00	Earth Observations Ctee	(HI1)	9.00	Academy Day (Academy of Sciences)		9.00	UN/IAF Workshop on Developing Nations	(HI6)
	Astrodynamics Ctee	(HI2)						
	Space Power WG 1	(HI3)						
	SYRE Subctee	(HI4)						
	Space Propulsion Ctee	(HI5)						
11:00	Microgravity Ctee	(HI1)						
	Education Ctee	(HI2)						
	Space Power WG3	(HI3)						
	Communications Ctee	(HI4)						
p.m.			**p.m.**					
1:00	Management Ctee	(HI1)	6:00	IAA Board of Trustees I	(HI2)			
	Space Transportation Ctee	(HI2)		Economics in Space Operations	(HI1)			
	Liaison with Int'l Organ. & Devel. Nations Ctee	(HI3)						
	Solar Sail Sub-Ctee	(HI4)						
2:00	Materials & Structures Ctee	(HI1)						
	Space Power WG 2	(HI2)						
	Student Activities Subctee	(HI3)						
	Space Exploration Ctee	(HI4)						
3:00	Space Systems Ctee	(HI3)						
	Space & Nat. Disaster Red. Ctee	(HI2)						
5:00	Int'l Program Ctee 1994	(CCA)						

The room assigned for the meeting is listed in parentheses. Convention Center = **CC** - Holiday Inn = **HI**. Jerusalem Renaissance = **R**

Federation Meetings			Academy Meetings			Congress Sessions / CC		
Tuesday, 11 October		HALL	**Tuesday, 11 October**		HALL	**Tuesday, 11 October**		HALL
			a.m.			**a.m.**		
			9.00	Board of Trustees II	(HI1)	8.30		
				Planetary Missions Sub-Ctee	(HI3)	A.1.	Astrodynamics - Natural Trajectories	(H)
			10:30	Developing Nations Sub-Ctee	(HI2)	B.1.	Earth Observations - International Earth Observations Coordination	(A)
			12.00	Academy Luncheon	(HI)	G.1.	Life Sciences - Space Physiology & Medicine	(I)
						H.1.	Management - Management of International Space Programs	(B)
						J.1.	Microgravity Facilities - Improved Capabilities & Future Needs	(J)
						M.2.	Satellite Communications - Future Systems and Technologies	(C)
						P.1.	Space & education - "Hands-on" Education	(L)
						Q.1.	Space Exploration - Lunar Exploration	(D)
						R.2.	Space Power - Power from Space - Prospects for the 21st Century	(K)
						S.1.	Space Propulsion - In-Space Propulsion	(G)
						T.1.	Space Stations - Overview	(E)
						IAA.1.1.	Economics in Space Operations - Cost Reduction in Space Transportation	(F)
						11.45	Plenary 2	
p.m.						**p.m.**		
2:00	AIAA Standards Ctee	(HI3)				2:00		
5.00	IISL Board of Directors	(HI1)				B.2.	Earth Observations - Future Earth Observations Missions	(A)
6:15	History Ctee	(HI3)				G.2.	Life Sciences - Space Biology and Biophysics	(I)
						I.2	Materials & Structures - Space Structures - Dynamics & Microdynamics	(J)
						U.2.	Space Systems - Tools for Systems Analysis, Ground Simulation Design	(F)
						V.2.	Space Transportation - Transfer & Re-Entry Systems	(G)
						W.2.	Student Conference 2	(K)
						IAA.2.1.	History of Astronautics 1	(H)
						IAA.3.1.	International Space Plans & Policies - Human Space Exploration	(C)
						IAA.5.1.	Multilingual Astronautical Terminology - General Topics and International Cooperation	(L)
						IAA.6.3.	Safety & Rescue - Risk Management	(B)
						IAA.11.2	Small Satellite Missions - Small Satellite Programs in Developing Countries	(D)
						IISL.1. IISL	New Legal Developments in Satellite Communications	(E)
						5:15	Plenary 3	

The room assigned for the meeting is listed in parentheses. Convention Center = **CC** - Holiday Inn = **HI**. Jerusalem Renaissance = **R**

Federation Meetings	Academy Meetings	Congress Sessions / CC
Thursday, 13 October HALL	**Thursday, 13 October** HALL	**Thursday, 13 October** HALL

Congress Sessions / CC — Thursday, 13 October

a.m.

8:30

		HALL
A.4.	Astrodynamics - Guidance & Control	(H)
B.4.	Earth Observations - Data Processing & Management	(A)
J.3.	Microgravity - Micrograv. Experiments - Scientific Results of Recent Missions	(J)
M.4.	Communication Satellites - Non-Geostationary Orbits	(C)
P.3.	Space & Education - Communicating with the Public (with IAA)	(L)
S.3.	Space Propulsion - Non Chemical & Advanced Propulsion	(G)
T.3.	Space Stations - Operations	(E)
U.4.	Space Systems - Technology for Planetary & Solar Missions	(F)
IAA.1.3.	Space Plans & Pol. - Cost Methodologies & Remote Sensing	(B)
IAA.4.1.	Interstellar Space Exploration - Outer Solar Syst. & Extra Solar Exploration	(K)
IAA.5.2.	Multilingual Astronautical Terminology - Data Systems Technology	(I)
IAA.11.3	Small Sat. Missions - Low Cost Scient.Missions in Earth-Orbit & Planetary Programs	(D)
IISL.4.	Other Legal Matters	(HI1)
11:45	Plenary 6	

Federation Meetings — p.m.

2.00 Manfred Lachs Space Law Moot Court Competition **(Hebrew Univ.)**

Congress Sessions / CC — p.m.

2:00

		HALL
A.5.	Astrodynamics - Navigation & Positioning	(B)
B.5.	Earth Observations - Disaster Prevention & Management	(A)
G.4.	Life Sciences - Biotechnology & Life Support	(I)
I.4.	Materials & Structures - Smart Materials & Adaptable Structures	(H)
J.4.	Microgravity - Microgravity Research - New Experiments in Fluid Physics, Physical Chemistry & Materials Sciences	(J)
Q.4.	Space Exploration - Mission Operations & Technologies Systems	(D)
R.4.	Space Power - Advanced Space Power Systems & Technologies	(K)
T.4.	Space Stations - Utilization	(E)
U.6.	Space Systems - Robotics, Telescience, & Data Management Systems	(F)
V.4.	Space Transportation - Advanced Concepts - Technologies	(G)
IAA.3.3.	Space Plans & Policies - Global Environment Monitoring	(C)
IAA.6.5.	Safety & Rescue - Space Debris: Eng. Solutions	(L)

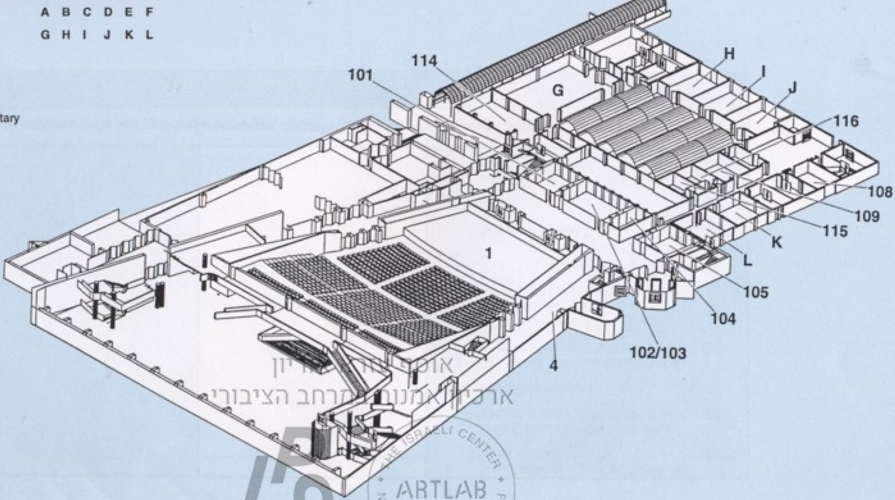
The room assigned for the meeting is listed in parentheses. Convention Center = **CC** - Holiday Inn = **HI**. Jerusalem Renaissance = **R**

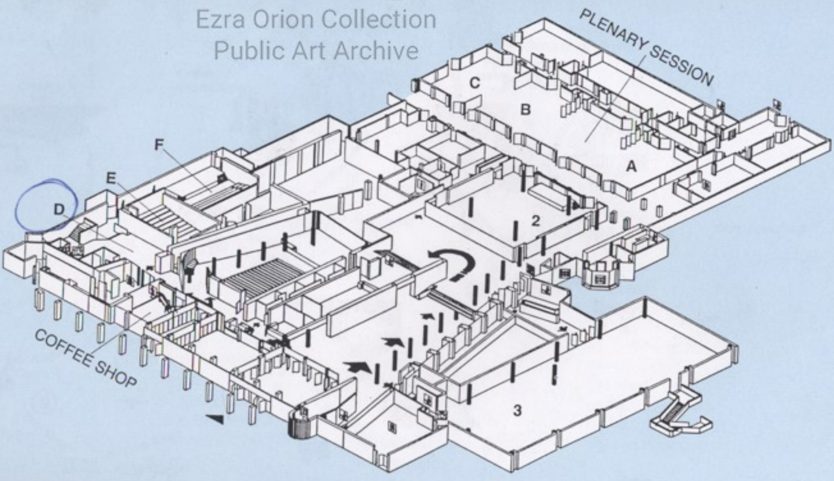
Federation Meetings		Academy Meetings		Congress Sessions / CC		
Friday, 14 October	**HALL**	**Friday, 14 October**	**HALL**	**Friday, 14 October**		**HALL**
				a.m.		
				8:30		
				A.6.	Astrodynamics - Mission Design	(B)
				B.6.	Earth Observations - Global Change & Environment Monitoring	(A)
				G.5.	Life Sciences - Simulation of Humans in Space	(I)
				I.5.	Materials & Structures - Environmental Effects & Structural Protection	(J)
				J.5.	Microgravity - Microgravity Environment - Numerical Modelling & Simulation	(E)
				M.5.	Communication Satellites - Fixed & Broadcast Services	(C)
				Q.5.	Space Exploration - Solar Systems Exploration	(D)
				S.4.	Space Propulsion - Hypersonic & Combined Cycle Propulsion	(G)
				U.7.	Space Systems - Spin-Offs & Technology Transfer	(F)
				IAA.2.2.	History of Astronautics 2	(I)
				IISL.5.	Discussion of all IISL Sessions and General Assembly	(H)
				V.5.	Space Transportation - Surface & Flight Operations	(G)
p.m.				11:45	Plenary 7	
4.00 Bureau II	(HI2)			**p.m.**		
				1:30	IAF General Assembly II	(HI5)
				2.00		
				U.5.	Space Systems - Payloads: Challenges & Technology Solutions	(F)

The room assigned for the meeting is listed in parentheses. Convention Center = **CC** - Holiday Inn = **HI**. Jerusalem Renaissance = **R**

CONVENTION CENTER DIRECTORY

1	Opening Ceremony	Sessions Halls
2	Registration Hospitality Slide Corner	A B C D E F G H I J K L
3	Exhibition	
4	Preprint Room	
101	IAF Executive Secretary	
102/103	IAF Secretariat	
104	IAF President	
105	Proceedings Editor	
108	IAA Secretariat	
109	Program Committee Chairman	
114	Rehearsal Room	
115	IISL President	
116	IAA President	





Federation Meetings

Wednesday, 12 October		HALL
a.m.		
9:00	Space Systems Ctee	(H2)
	Life Science Ctee	(HI3)
9.30	Allan D. Emil Memorial Award Subctee	(HI1)
11.45	Student Jury	(HI2)
p.m.		
2.00	IAF Bureau II	(HI2)
3.00	Int'l Program Ctee 1995	(HI5)
4:00	Space Power Ctee	(HI1)

Academy Meetings

Wednesday, 12 October		HALL
a.m.		
9:00	Space Phys. & Medicine Subctee	(HI3)
	Human Factors Subctee	(HI4)
	Space Planetary Biology Subctee	(HI1)
	Biotechnology Subctee	(HI2)
11:00	Life Sciences Ctee	(HI3)
12:00	IAA Man in Space 1995	(HI1)
p.m.		
4:30	Multilingual Terminology Ctee	(HI3)

Congress Sessions / CC

Wednesday, 12 October		HALL
a.m.		
8.30		
A.2.	Astrodynamics - Optmization	(A)
H.2.	Management - Experiences in the Management of International Space Programs	(B)
I.3.	Materials & Structures - New Materials & Structural Applications	(J)
M.3.	Communication Satellites - Mobile & Personal Communications	(C)
Q.2.	Space Exploration - Space Based Astronomy	(D)
R.3.	Space Power - Solar Power Technologies	(K)
S.2.	Space Propulsion - Earth to Orbit	(G)
IAA.6.4.	Safety & Rescue - Space Debris: Measurements & Modeling	(F)
IAA.8.2.	Space Activ. & Soc. - The Impact of the Space Age on our Culture	(I)
IAA.9.2.	SETI - SETI: Interdisciplinary Connections	(L)
IAA.10.1.	Eva & Space Suits - Technology & Operation	(H)
11:45	Plenary 4	
p.m.		
2.00		
A.3.	Astrodynamics - Attitude Motion	(B)
B.3.	Earth Observations - Earth Observations Sensors & Technology	(A)
G.3.	Life Sciences - Human Factors	(I)
J.2.	Microgravity - Microgravity Instrumentation - Advanced Diagnostic & Expert Systems	(J)
P.2.	Space & Education - Education Structures	(K)
Q.3.	Space Exploration - Mars Exploration	(D)
T.2.	Space Stations - Design, Verification & Integration	(E)
U.3.	Space Systems - Technologies for Enhancing Small Satellite Systems	(F)
V.3.	Space Transportation - Advanced Concepts - Systems	(G)
IAA.1.2.	Economics in Space Operations - Commercialization of Space Activities	(L)
IAA.3.2.	Space Plans & Policies - International Cooperation	(C)
IISL.2.	Definition Issues in Space Law	(H)
IISL.3.	Liability in Commercial Space Actvities	(H)
5:15	Plenary 5	

The room assigned for the meeting is listed in parentheses. Convention Center = **CC** - Holiday Inn = **HI**. Jerusalem Renaissance = **R**


LUNAR OUTPOST

Transportation Node

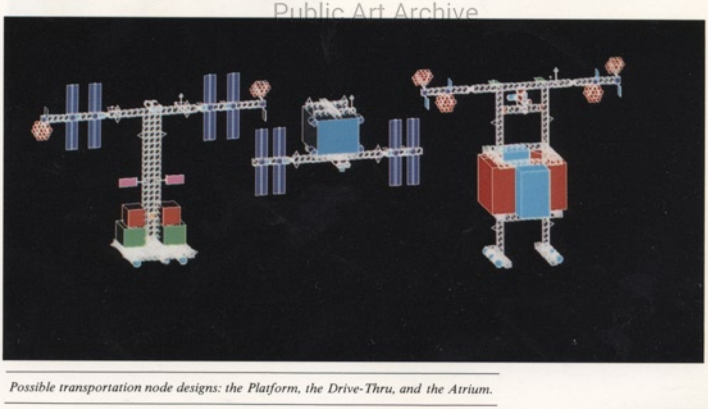
The lunar transportation vehicles are assembled and serviced at a space platform in low Earth orbit: the transportation node (TN). This platform acts as the connecting link between Earth transportation vehicles and the lunar transportation vehicles. The mission to the Moon is an ongoing operation with four to eight flights to the Moon and back each year using reusable vehicles. A facility is needed to store and service the lunar spacecraft between flights.

The TN is assumed to be separate from, although possibly co-orbiting, Space Station Freedom. A TN supporting the Lunar Base Program must store large quantities of propellant and handle frequent vehicle interactions. These interactions include docking of vehicles, transfer of propellant, mating of payloads and vehicle elements, and deployment of lunar transfer vehicles. The intensive servicing operations and frequent spacecraft traffic associated with the TN would disturb Space Station Freedom functions and experiments, increasing the microgravity environment and contaminating the near-station vacuum.

The TN is sized and characterized by all aspects of the lunar base scenario, including the mission frequency, type and size of delivered payloads, crew rotation schedule, and the selected vehicle configurations.

Three configurations are presented. The first was designed with an emphasis on spacecraft processing inside the TN. A primary objective of this design was to minimize the overall size of the configuration. The other two configurations have as their primary design goal the overall operation and maintenance of the TN itself, including its attitude control and stability. These configurations considered interior operations secondarily.

It is important to consider both internal and external factors in the design of a TN. Internal functions include the movement of payload, fueling, and assembly—the pathways and sequence of operation. External functions are those involving the operation of the TN in space: for example, its attitude control and reboost schemes. The TN's useful life will be measured in decades; therefore, both factors are important items to consider in its initial design.



Possible transportation node designs: the Platform, the Drive-Thru, and the Atrium.

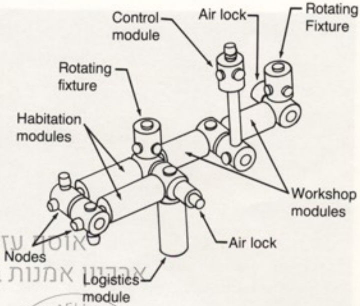
Space Shuttle Orbiter docked to the Drive-Thru transportation node.

Drive-Thru Configuration

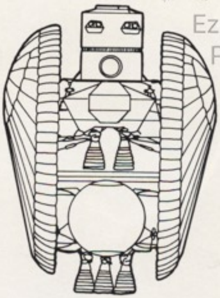
On the preceding page, the Drive-Thru configuration is illustrated with a departing lunar stack and an arriving heavy-lift propellant tanker. An orbital maneuvering vehicle is attached to the truss just inside the front door. The Drive-Thru configuration is designed to support mission stack buildup, refurbishment, and propellant loading within one large unpressurized hangar. The dry mass of this TN, without propellants or vehicles, is approximately 400 metric tons. Fully loaded with two fueled lunar vehicle stacks and propellant storage modules filled, the Drive-Thru has a mass of almost 1000 metric tons.

The hangar measures 50 m long by 35 m wide by 25 m high, providing an enclosed volume of 43,750 m³. This volume contains two mission stacks which can be serviced concurrently. The stack consists of an orbital transfer vehicle (OTV), a lunar ascent/descent vehicle, a lunar payload, and up to two aerobrakes. Initially, the lunar spacecraft pieces are delivered from Earth and enter the hangar through the back door. Each stack is docked to a fixture that provides 360-degree rotation and allows pressurized access to the lunar crew module (or payload) from the TN interior.

Typically, the lunar stack is moved to the forward fixture for propellant loading and departs through the front door. This leaves room for a second lunar stack to be assembled on the back fixture. The second stack will be used for an emergency rescue, if necessary.

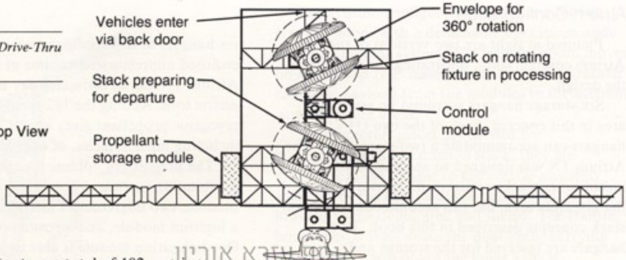


Pressurized module arrangement.



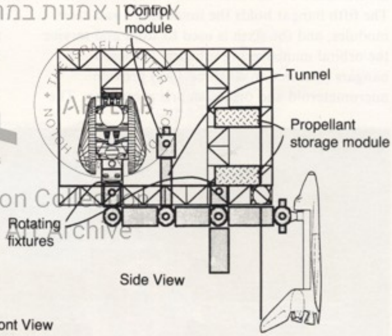
The Drive-Thru configuration was designed to service this lunar vehicle stack.

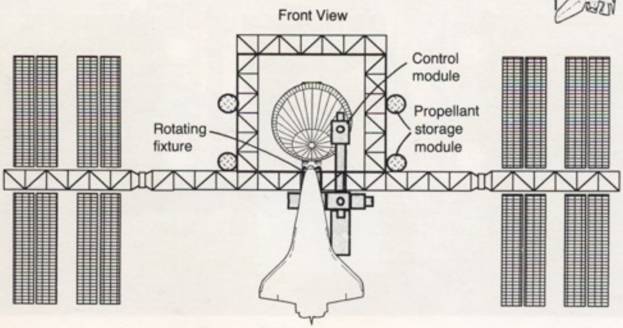
Three views of the Drive-Thru configuration.



Four tank sets store a total of 182 metric tons of cryogenic hydrogen and oxygen propellant. Additional propellant can be stored in the lunar stacks and in a heavy-lift tanker docked to the top of the hangar.

The assembly operations control module, extending vertically into the hangar, serves as a viewing platform from which the TN crew directs the activities within the hangar. Two habitation modules house a total of 13 crew: 6 permanent TN crew, 3 visiting Shuttle orbiter crew, and 4 visiting lunar crew. Two workshop modules, two air locks, and a logistics module linked by a number of resource nodes complete the pressurized area.





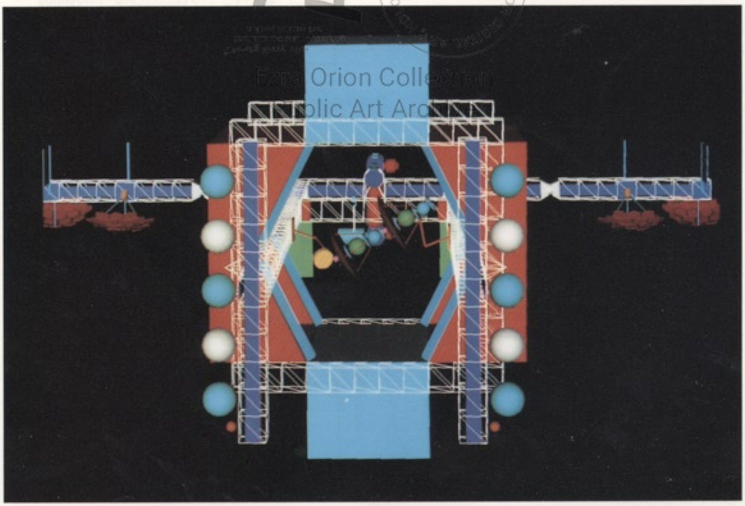
Atrium Configuration

Pictured at right are two versions of the Atrium configuration, illustrating the evolution of the design.

Six storage hangars surround an assembly area in this concept. Each of the two OTV hangars can accommodate a two-stage OTV. The Atrium TN was designed to accommodate the linked lunar stack arrangement, shown below in the assembly area, but can accommodate all lunar stack concepts described in this book. Two hangars are reserved for the storage and maintenance of the lunar ascent/descent vehicles. The fifth hangar holds the lunar cargo and crew modules, and the sixth is used to store and service the orbital maneuvering vehicles. Enclosed hangars (featured in all three TNs) provide micrometeoroid and orbital debris protection. The six hangars of this configuration comprise a total enclosed unpressurized volume of 88,000 m^3. The Atrium TN has an estimated dry mass of 320 metric tons. Adding the 182 metric tons of stored cryogenic propellant gives a total TN mass, not including lunar vehicles, of over 500 metric tons.

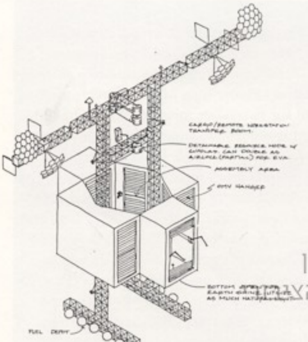
The pressurized volume is contained within a habitation module, a command operations module, two interconnect modules, two air locks, a logistics module, and a remote operations node. One habitation module is able to provide facilities for six permanent and seven temporary crew, because the health maintenance facility has been relocated to an interconnect module.

Atrium configuration, viewed from below, with lunar vehicle stack being assembled.

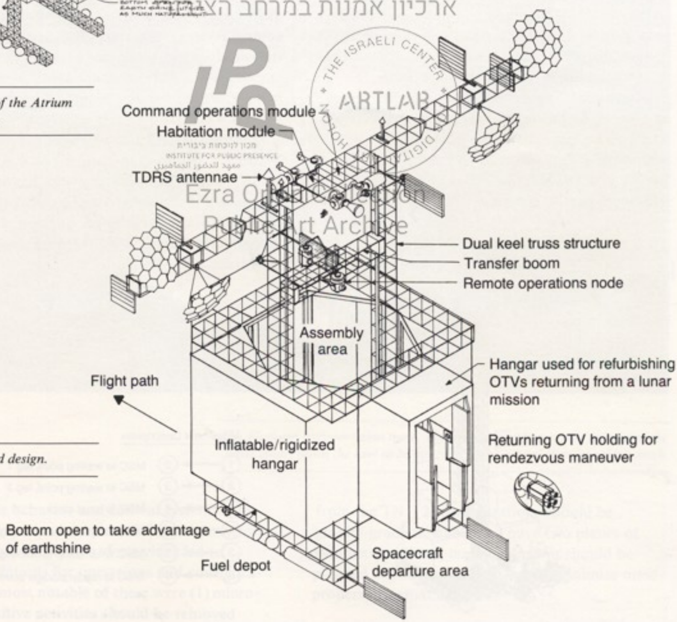


The Atrium configuration includes a mobile transfer boom with a detachable operations node and manipulator system. The transfer boom moves on a "tracked rail" inside the dual keels to transfer crew and payload from the modules to the assembly and departure areas.

As spacecraft pieces are needed for buildup of the lunar mission stack, they are moved from the hangar to the central assembly area. When the lunar stack is complete, it is lowered to the depot area and fueled. The transfer boom then travels down the dual keels, carrying the crew who will board the lunar vehicle.



Early sketch of the Atrium configuration.



The improved design.

Platform Configuration

The Platform configuration represents an evolution of Phase 1 Space Station Freedom. The vertical keel, assembly platform, and hangars have been added to facilitate transportation-related activities. An increased power supply is provided by adding two solar dynamic dishes to the four existing photovoltaic solar panels. The dry mass of this configuration is estimated to be 300 metric tons.

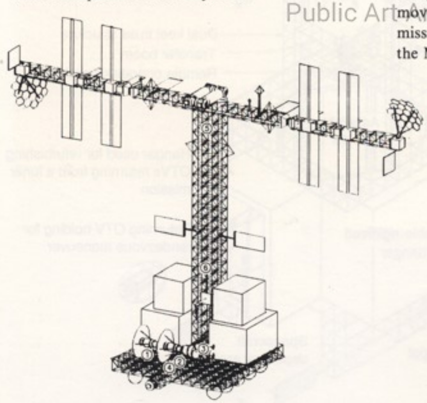
A second docking ring was attached to the assembly platform for the delivery of cargo. This method of delivery noticeably decreases payload transfer times and disturbances. Payload delivery to the upper docking module would necessitate a long transfer down the vertical keel to a storage hangar, disturbing the TN's attitude.

Designed to be gravity-gradient stable, the Platform configuration has its storage hangars and fuel tanks located at the bottom of the keel. This arrangement allows the TN to take advantage of the stabilizing torque provided by Earth's gravitational field, thereby gaining an additional passive control system.

Facilities are provided to prepare two complete lunar mission stacks. Four hangars provide 25,000 cubic meters of volume to store the stacks; the 364 metric tons of fuel provide enough propellant for two lunar missions. Dual-mission fueling reduces dependence on the Earth-launched resupply schedule, desirable for contingency planning of emergency missions. The drawback is that it increases the inert mass of the TN due to the greater number of fuel storage tanks required.

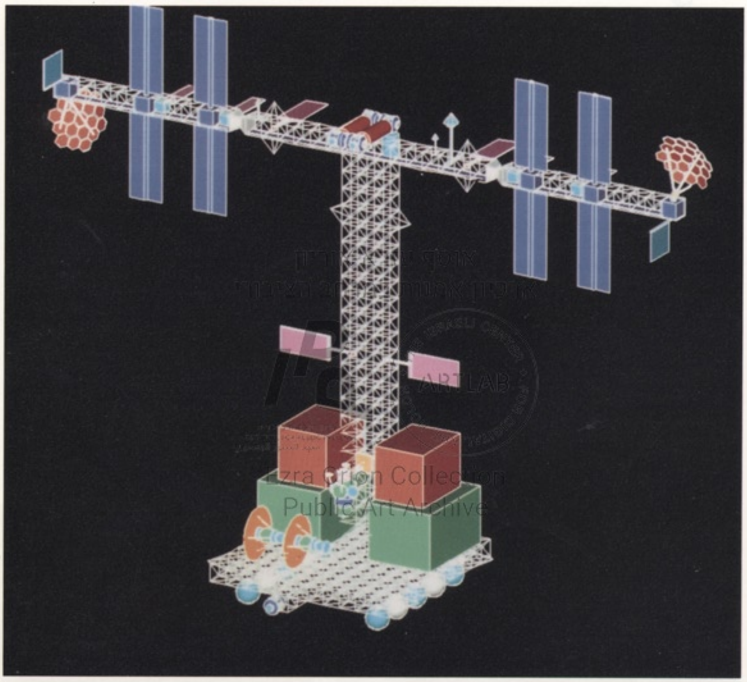
An on-orbit spacecraft simulation developed by the Advanced Programs Office at JSC was used to calculate the forces and torques on the TN due to propellant motion, vehicle docking, and control system reactions, plus the contributions of the aerodynamic, solar, and gravity gradient environments. Many configurations were analyzed in an effort to identify the characteristics of an optimum TN.

One of the activities performed on the Platform TN during the analysis is illustrated below. After lunar stack assembly has been completed, the mobile servicing center (MSC) moves the stack to the upper docking ring. The mission crew boards, then the stack departs for the Moon.



Movement Description

① → ②	MSC to waiting point, leg 1
② → ③	MSC to waiting point, leg 2
③ → ④	MSC to lunar stack
④ → ③	MSC/lunar stack to docking node, leg 1
③ → ⑤	MSC/lunar stack to docking node, leg 2
⑤ → ⑥	MSC to ready/storage point



The Platform transportation node. The mobile servicing center transports the lunar lander down the keel to be attached to the orbital transfer vehicle stack.

Attitude behavior and control system responses experienced by the TN due to environmental forces and onboard activities led to recommendations for operations and configurations. The most notable of these were (1) micro-gravity-sensitive activities should be removed from the TN, (2) configurations should be gravity-gradient stable and have two planes of symmetry, (3) and mass movement should be planned about paths which would minimize mass property fluctuations.

Space Transportation

Several concepts for the spacecraft which will transport people and cargo to the lunar outpost are described here within the framework of potential mission scenarios.

Transport Missions

The transportation system elements, such as the orbital transfer vehicle (OTV), aerobrake, and landing craft, are assembled at the transportation node in low Earth orbit.

After a crew or cargo module is attached, propellant is loaded into the OTV and landing craft tanks. Finally, any passengers board and the vehicle departs.

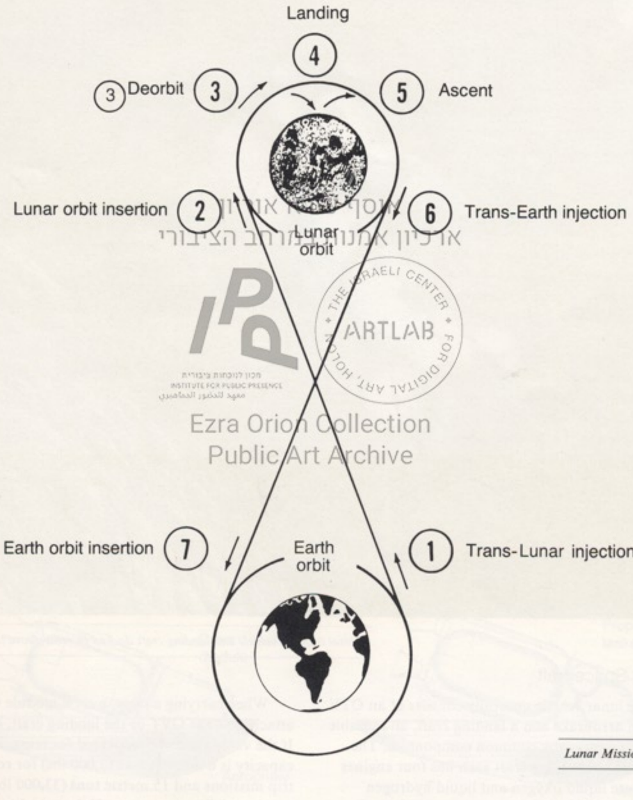
After leaving the transportation node, the OTV fires its engines for the trans-lunar injection maneuver, which swings the vehicle out of low Earth orbit onto a path to intercept the Moon. Near the Moon, the OTV engines fire again to insert the vehicle into lunar orbit.

Once in lunar orbit, the OTV and landing craft separate. The landing craft engines fire briefly to begin the descent. Then, while approaching the surface, the engines fire continuously to accomplish a soft landing. After completing its mission on the surface, the landing craft ascends to meet the OTV waiting in orbit.

On many missions, when the OTV reaches lunar orbit, it will meet a reusable landing craft based on the lunar surface. Payloads and passengers can be transferred in lunar orbit, and the landing craft can be refueled.

The return to Earth orbit begins when the OTV fires its engines for the trans-Earth injection maneuver. The spacecraft coasts back on a path which is targeted to skim through the upper atmosphere of the Earth. During this aerobraking phase, the OTV, which must be protected by a heat shield, slows down due to air friction and is captured in an elliptical orbit. The aerobraking maneuver conserves enough propellant to make the extra mass of the heat shield worthwhile. After aerobraking, the OTV fires its engines briefly to circularize its orbit and begins a rendezvous sequence which eventually returns it to the transportation node, where the journey began.

Orbital transfer vehicle performing aerobraking maneuver.



Lunar Mission.

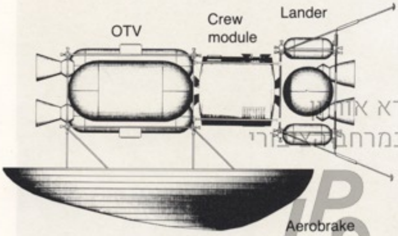
Lunar Outpost

John Alred, Ph.D.
Ann Bufkin
Kriss J. Kennedy
Andrew Petro
Michael Roberts
Jonette Stecklein
James Sturm

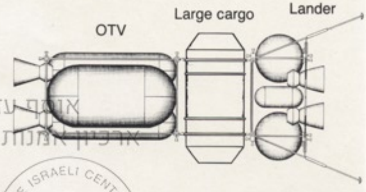
Systems Definition Branch
Advanced Programs Office
Johnson Space Center
1989

Mission Configurations

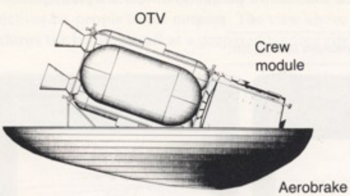
Exploration - An OTV and a landing craft, with a crew module, are used for a short-duration mission. The OTV and crew module return to Earth orbit with the crew. The landing craft is left in lunar orbit.



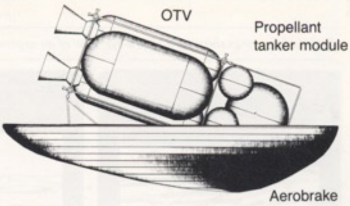
Large Cargo Delivery - An expendable OTV carries a landing craft and a large cargo module to lunar orbit. The OTV has no aerobrake and is left in lunar orbit. The landing craft descends with the cargo and remains on the lunar surface.

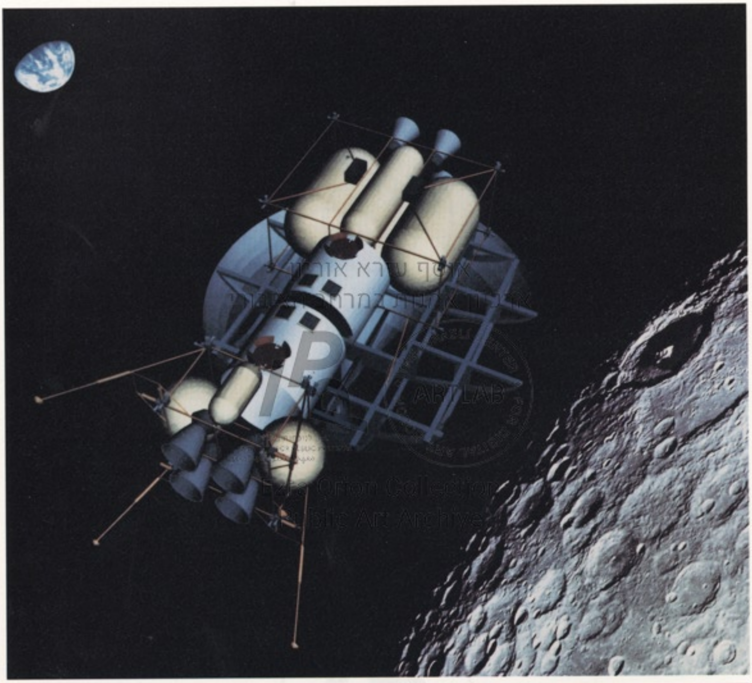


Crew Rotation - An OTV carries one crew module to lunar orbit where it meets a landing craft with its own crew module. The departing crew from the landing craft and the arriving crew from the OTV switch places. The landing craft is refueled from the OTV tanks, then returns to the surface; the OTV returns to Earth orbit.



Propellant Tanker - An OTV carrying extra propellant tanks as cargo delivers 40 metric tons of propellant to lunar orbit. This is enough propellant to refuel two landing craft. After performing its refueling mission, the OTV returns to Earth orbit.



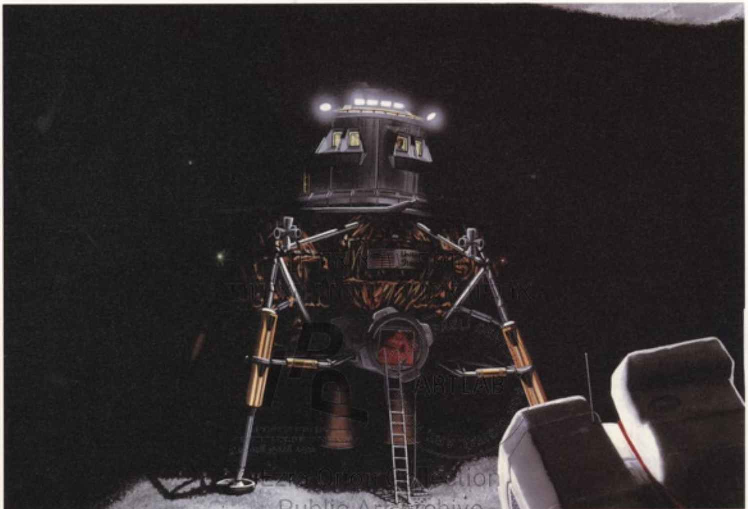


Orbital transfer vehicle and landing craft docked in orbit above the Moon.

Lunar Spacecraft

The lunar vehicle generally consists of an OTV with an aerobrake and a landing craft, all reusable elements with many common components. The OTV and the landing craft each has four engines which use liquid oxygen and liquid hydrogen propellants. The vehicle can carry a variety of payloads and can operate with or without a crew.

When carrying a crew, a crew module will be attached to the OVT or the landing craft, or both. If the vehicle is to be recovered for reuse, its cargo capacity is 6 metric tons (13,000 lbs) for round-trip missions and 15 metric tons (33,000 lbs) for one-way delivery missions. If the vehicle elements are expended, a one-way payload of 25 metric tons (55,000 lbs) is possible.

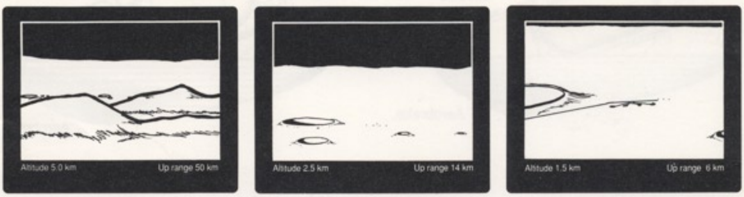


Landing craft on a exploration mission to a polar region of the Moon.

Lunar Landing

The landing craft can be used for exploration missions with four people on the lunar surface for about one week. These missions could be destined for a variety of locations including potential outpost sites. The landing craft is shown above on the surface in a polar region. Once a permanent

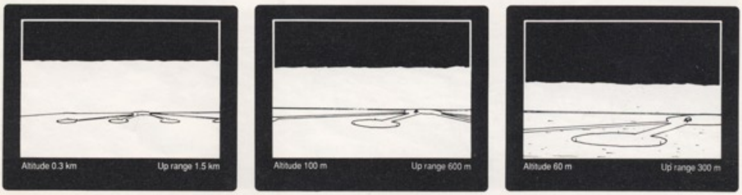
Series of drawings showing a pilot's-eye view of an approach to a permanent landing site.



Landing craft being unloaded at the lunar outpost.

outpost is established, landing craft might be used for suborbital flights to explore remote locations.

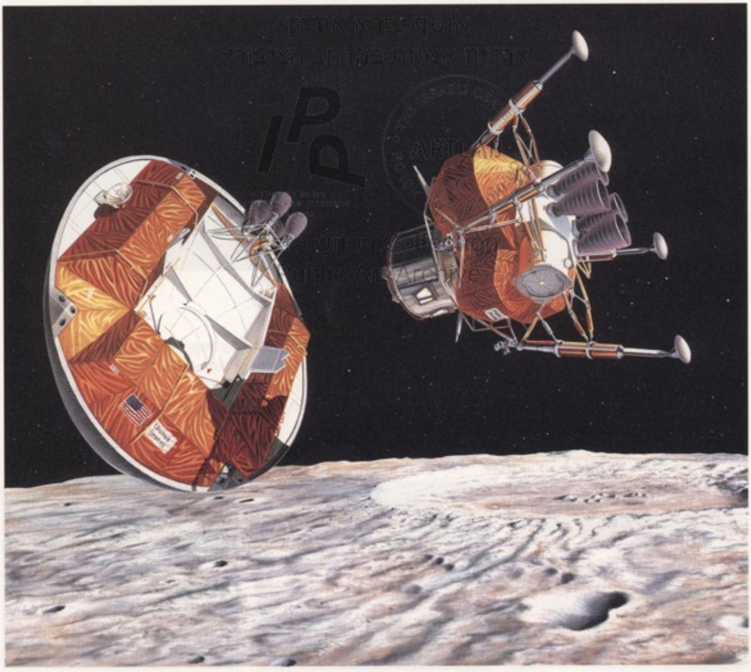
When used for routine crew rotation, the landing craft and crew module will be able to deliver six people to the outpost. The view above shows the landing craft at a prepared landing site. It is surrounded by support vehicles, including a pressurized rover connected to the landing craft by a flexible tunnel. The rover will transport the crew to the outpost habitat, a few kilometers away.



Alternative Spacecraft Concepts

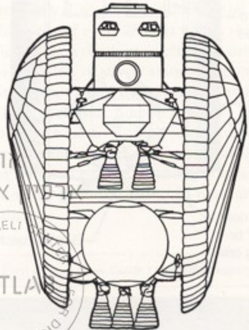
The vehicle below is an alternative to the one already described. The major differences are that the OTV is part of the aerobrake structure and the landing craft is returned to Earth orbit at the end of each mission. The landing craft fits behind the aerobrake, between the OTV propellant tanks. When connected, the landing craft engines can be used to propel the entire vehicle using propellant from the OTV tanks. This OTV is highly specialized for the lunar mission and the cargo envelope is limited in size.

Alternative lunar vehicle concept. Orbital transfer vehicle and landing craft separating in lunar orbit.

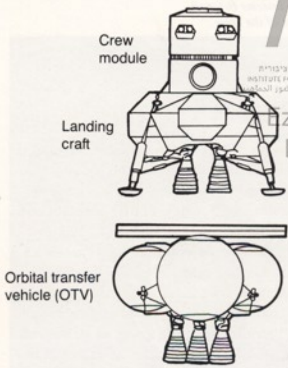


In another alternative concept, the landing craft is also returned to Earth orbit. However, the landing craft and OTV each has its own aerobrake; a configuration which provides greater flexibility in arranging the vehicle elements and payloads. The OTV is not part of the aerobrake structure and can be flown in an expendable mode, with little modification.

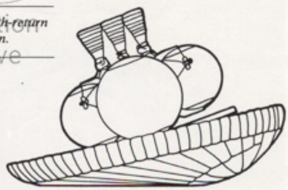
Landing craft and orbital transfer vehicle with their aerobrakes.



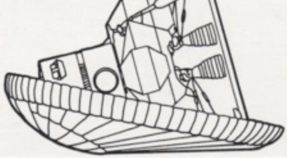
Landing craft and orbital transfer vehicle.

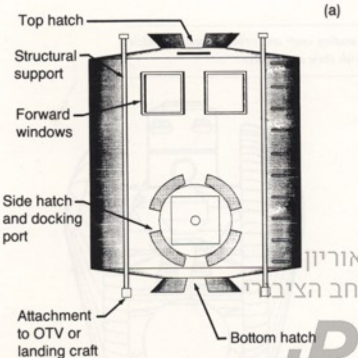


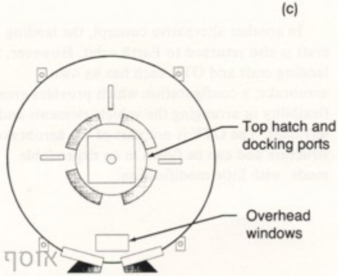
OTV in Earth-return configuration.



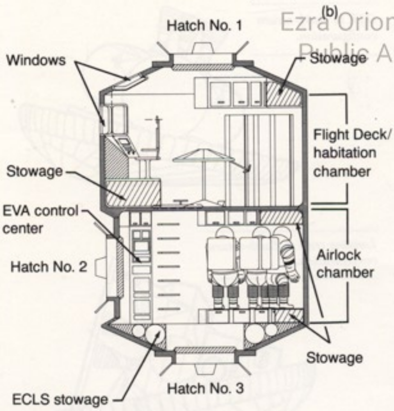
Landing craft in Earth-return configuration.







Exterior (a), Interior (b), and Top (c) views of the crew module.



Crew Module

The crew module is a self-sufficient payload which supports people in transit and for short durations on the lunar surface. It is a cylinder with a diameter of 4.5 meters (15 ft), a height of 6 meters, and a mass of 6 metric tons (11,000 lbs). The same basic module would be used on the OTV and the landing craft.

The module is divided by a bulkhead into two cylindrical chambers, the upper serving as a flight deck and habitation area, the lower as an air lock and storage area. There is a hatch at each end of the cylinder and one on the side. The top hatch is for docking with other modules. The side hatch provides access at the transportation node. The bottom hatch is the primary means of entry and exit on the lunar surface. Crews would descend on a ladder from the bottom of the module to a platform on the landing craft.

Site Selection

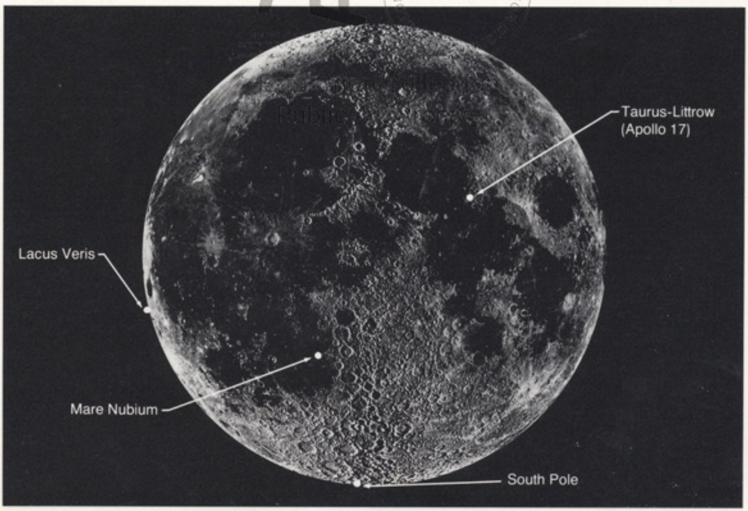
The primary site selected for the lunar outpost at Lacus Veris, on the western limb, is one of four locations suggested by the Solar System Exploration Division at JSC. The other potential sites are Mare Nubium, Taurus-Littrow (the Apollo 17 landing site), and the South Pole.

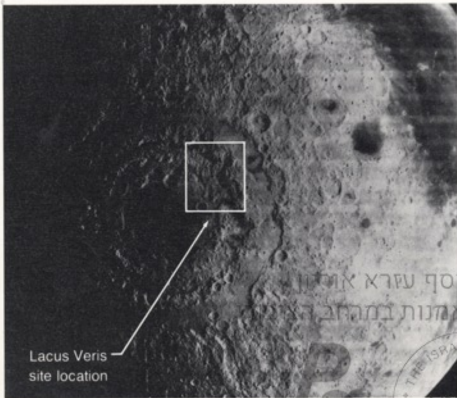
Lacus Veris, in the northwest quadrant of a mare region at 87.5° W., 13° S., is part of a multiple ringed structure known as Mare Orientale. Site selection was based primarily on proximity to features of scientific interest. Other influencing factors include the ruggedness of the terrain, access to the lunar far side, soil chemistry (availability of oxygen-yielding minerals), Earth visibility, and lighting.

Lacus Veris' location on the western limb of the Moon provides valuable access to the far side for observatories. Earth-bound astronomy is hampered in two ways: the full Earth shines sixty times more brightly than the full Moon, washing out the nighttime sky for optical astronomers, and man-made electromagnetic interference affects radio astronomy. Lacus Veris is actually on the far side for 8 out of every 28 days due to the Moon's libration, a result of its elliptical orbit.

Lacus Veris is a relatively smooth region, good for landing pads, surface transportation and habitat site preparation. Since it is a mare region, there should be a relatively high concentration of the mineral ilmenite, which can be extracted and processed for lunar oxygen. Lighting conditions at this location are good because of its proximity to the equator.

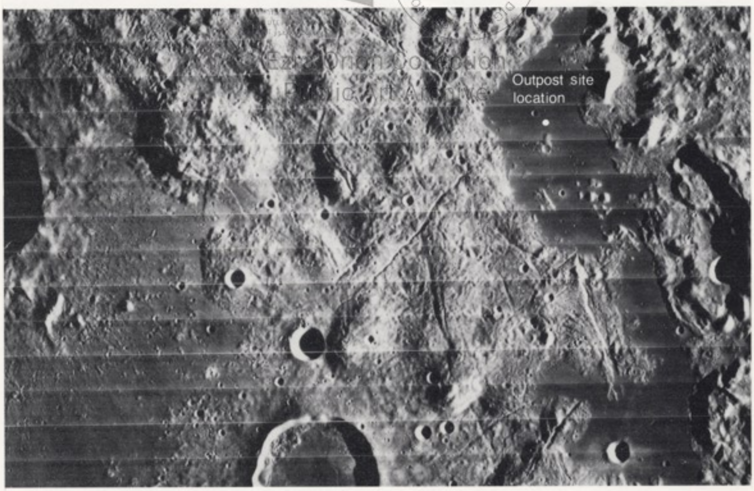
Location of Lacus Veris as seen from Earth. (Lick Observatory photo)





Mare Orientale. Since Lacus Veris was not photographed during the Apollo missions, these images are from Lunar Orbiter IV, with a resolution of 60 m.

Lacus Veris.



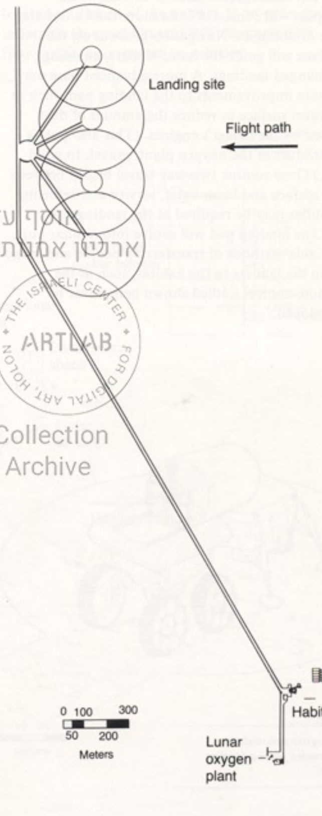
The Outpost

This master plan depicts a mature lunar outpost designed for the Lacus Veris site. However, the design principles can be applied to other sites as well. The outpost, the forerunner to a permanently inhabited lunar base, is comprised of a landing site, habitat facility, and lunar oxygen pilot plant.

The landing site is located 2.5 km north-northwest of the base, and the landing pads are aligned in a north-south orientation to accommodate descent of a lunar lander from the east. The landing site's distance from the outpost will minimize impacts from exhaust blast ejecta and chemical contamination from rocket plumes and will reduce the potential for damage if a crash or explosion should occur. The solar power field is particularly vulnerable to degradation from the byproducts of routine lunar landing operations.

The habitat provides living and working facilities for 12 crewmembers on the surface of the Moon. It is a pressurized, thermally controlled, and radiation-protected environment.

The oxygen pilot plant will test various techniques for oxygen production from lunar minerals. This facility could operate virtually autonomously, requiring only servicing and maintenance. The oxygen produced will be used to refuel the lunar landers and to supplement the outpost's oxygen supply.



The outpost master plan.

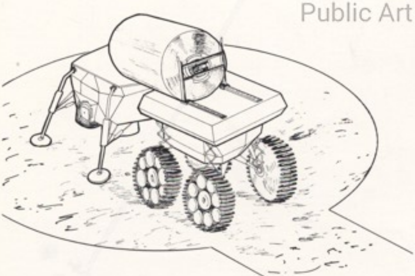
The concepts depicted in this publication were developed during the Lunar Base Systems Study undertaken by the Advanced Programs Office, in the Engineering Directorate of the Johnson Space Center, during the period 1986-88. The study was performed by Advanced Programs personnel with contractor support from Eagle Engineering, Inc. (NASA Contract NAS9-17878) and Lockheed Engineering and Sciences Co. (NASA Contract NAS9-17900).

The following individuals also contributed to the study: Laura Bass, Kyle Fairchild, John Graf, Eric Graham, John Patterson, and Deborah Sinow.

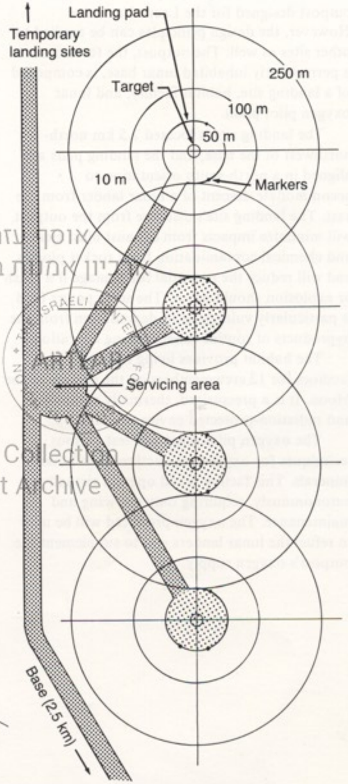
Landing Pad

The landing facilities for an early lunar outpost will consist of little more than a flat area free of obstacles. Navigation beacons on the surface will guide the lunar landers, enabling unmanned landings. A more advanced base may require improvements to the landing pad, such as a gravel surface to reduce the amount of dust raised by the lander's engines. (This also puts a byproduct of the oxygen plant, gravel, to good use.) Once routine two-way travel begins between the surface and lunar orbit, service and refueling facilities may be required at the landing site.

The landing pad will evolve into a lunar port. Reliable methods of transferring people and cargo from the landers to the habitat, such as the remote-control flatbed shown here, must be developed.



A logistics module is unloaded from a landing craft.



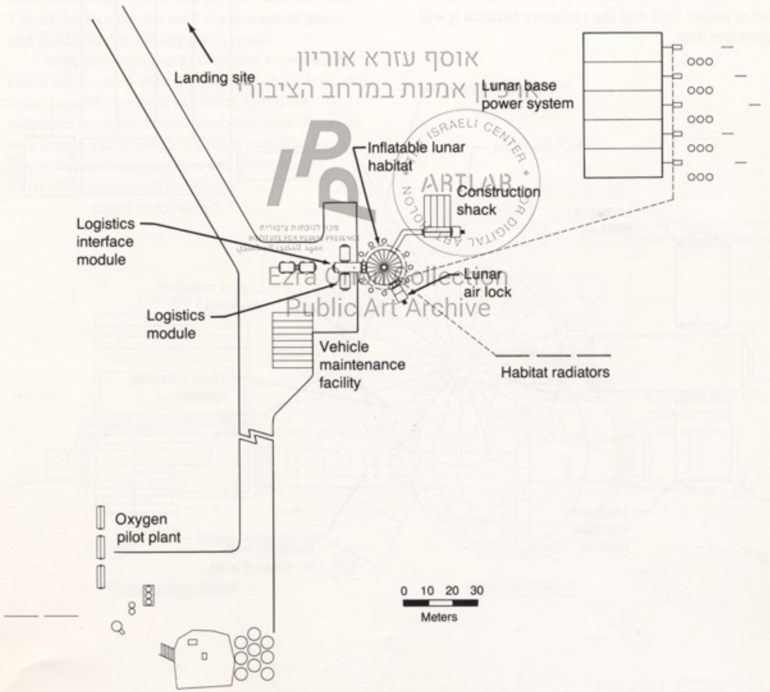
The landing complex.

The Habitation Site

Selection of the specific site for the habitat will be based chiefly on convenience. If a suitable crater can be found for the habitat, the base will be located there; otherwise, an excavation will be required. In any event, the terrain around the inflatable habitat should be smooth for easy access and mobility.

The vehicle maintenance facility, to be located southwest of the habitat, is an open-ended inflatable Quonset hut that will accommodate four surface transportation vehicles.

The outpost site plan.

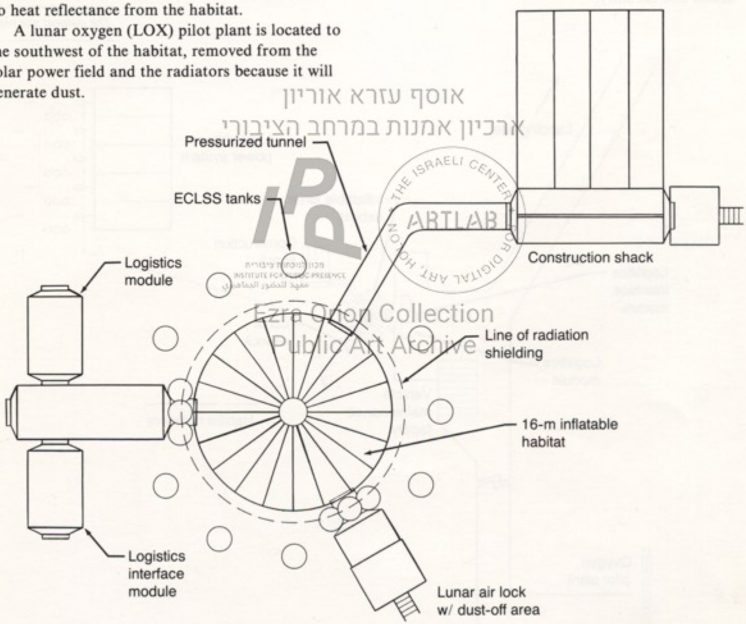


A solar power field will be located northeast of the habitat to allow an unobstructed view of the Sun and to separate the solar arrays from dust raised by surface vehicles.

The habitat heat rejection system is a series of vertical heat pipe radiators oriented parallel to the solar ecliptic. Located to the southeast, the radiators are far enough away that there will be no heat reflectance from the habitat.

A lunar oxygen (LOX) pilot plant is located to the southwest of the habitat, removed from the solar power field and the radiators because it will generate dust.

The habitation complex.

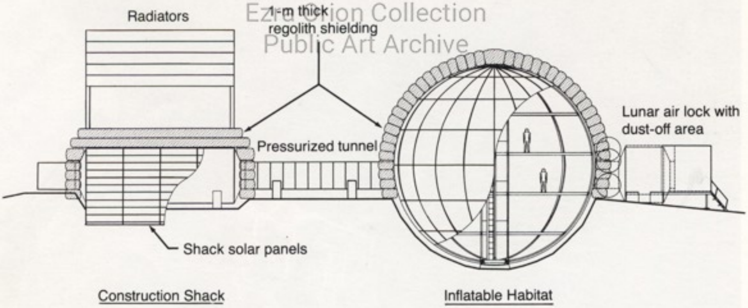


The habitation complex consists of a construction shack, inflatable lunar habitat, lunar air lock, logistics interface module, environmental control and life support system (ECLSS) tanks, and radiation shielding.

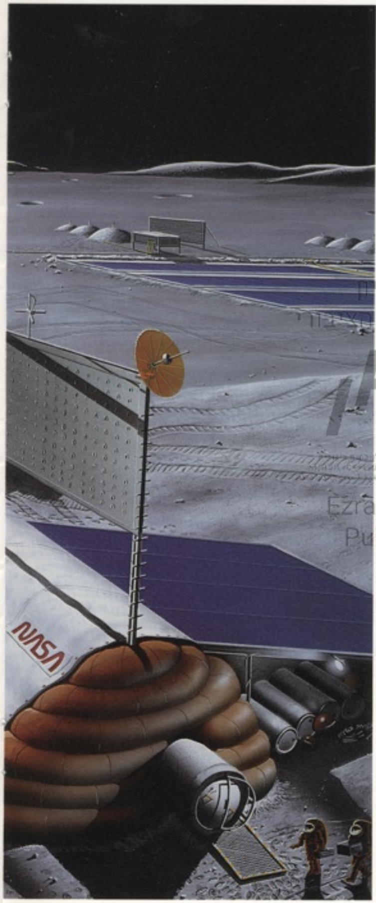
The logistic interface module has berthing ports for the pressurized rovers and logistics modules. It is used as a "loading dock" for crew and cargo. The air lock supports lunar extravehicular activity (EVA), providing redundancy with the construction shack air lock. The ECLSS tanks are used for storage of gases and fluids for the life support system.

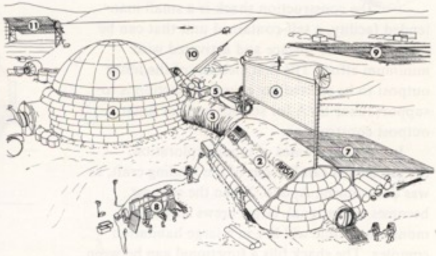
The inflatable lunar habitat and construction shack are covered with a one-meter-thick layer of lunar regolith, a shield sufficient to reduce radiation from the largest recorded solar flares to safe levels. The regolith is shown contained in a continuously filled bag that coils around the inflatable habitat and the shack.

Habitat elevation/section.




USA





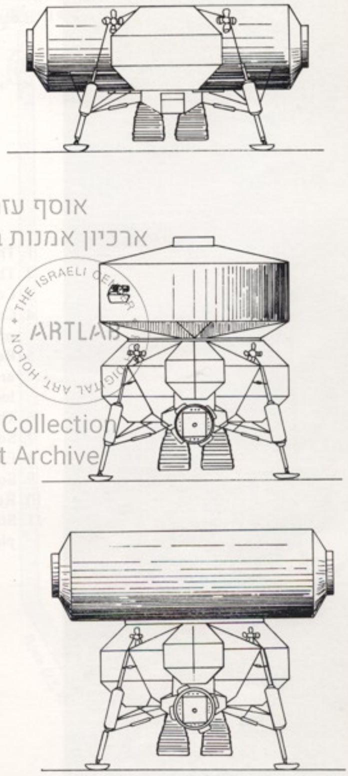
1. The inflatable habitat
2. The construction shack
3. Connecting tunnel
4. Continuous, coiled regolith bags for radiation protection
5. Regolith bagging machine, coiling bags around the habitat while bulldozer scrapes loose regolith into its path
6. Thermal radiator for shack
7. Solar panel for shack
8. Experimental six-legged walker
9. Solar power system for the outpost
10. Road to landing pad
11. Solar power system for the lunar oxygen pilot plant

The Lunar Construction Shack

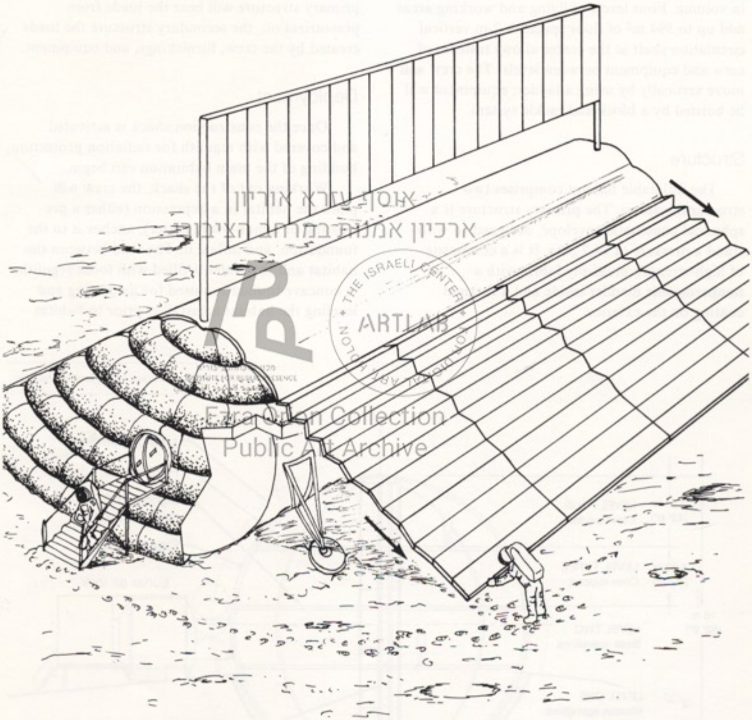
The construction shack is a small man-tended facility, a self-contained unit that can be set down on the surface and activated with minimum effort. The first element of the lunar outpost to be erected, its primary function is to support lunar EVA for science and for lunar outpost construction.

In the early phases of lunar exploration, the astronauts can live out of the landing craft, as was done during Apollo. When the outpost becomes operational, larger crews staying for months at a time will live in a large habitation complex. The shack fills a functional gap between lunar landers and a permanent lunar outpost. Lunar landers are limited in size because extra mass requires greater propellant consumption at every stage of the journey. Lander stay times will be on the order of a few days to a week, with minimal facilities to accomplish specific mission tasks. Yet construction of a permanent outpost will require many man-hours of productive EVA time and involve unforeseen problems that demand flexibility on the part of the construction crew and their facilities. The construction shack will allow longer stay times and a less constrained timetable.

Another role for the construction shack might be that of a scientific base camp. A number of shacks distributed across the lunar globe could support a broad lunar exploration initiative.



Alternative construction shack configurations, with landing craft.



The construction shack solar panel is deployed. (cutaway shows stabilizing footpad.)

The Inflatable Habitat

An inflatable lunar habitat will provide a living and working environment for a crew of 12. It is a 16-m-diameter spherical envelope, 2145 m^3 in volume. Four levels of living and working areas add up to 594 m^2 of floor space. A 2-m vertical circulation shaft at the center allows transfer of crew and equipment between levels. The crew will move vertically by using a ladder; equipment will be hoisted by a block and tackle system.

Structure

The inflatable habitat comprises two structural systems. The primary structure is a spherical pneumatic envelope, designed to withstand a pressure of 14.7 psia. It is a composite of high-strength multi-ply fabric with a nonpermeable bladder inside and a thermal coating on the exterior.

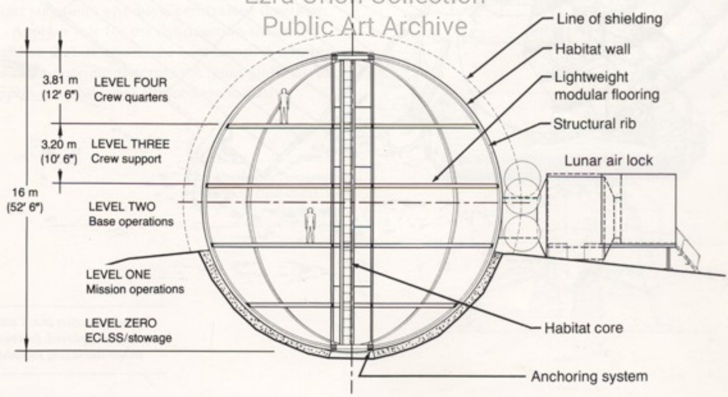
The secondary structure is composed of a spherical rib-cage, core columns, radial floor beams, and a modular flooring system. The primary structure will bear the loads from pressurization, the secondary structure the loads created by the crew, furnishings, and equipment.

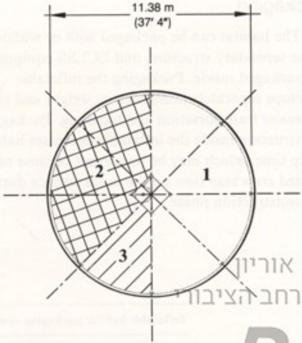
Deployment

Once the construction shack is activated and covered with regolith for radiation protection, building of the main habitation can begin.

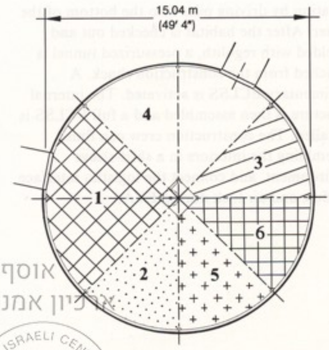
Working out of the shack, the crew will place the habitat in a depression (either a pre-existing or a man-made crater), anchor it to the foundation, and inflate it. The void between the habitat and the crater is filled with loose regolith. A concave foundation used for anchoring and leveling the habitat is installed prior to habitat

Cross-section of inflatable habitat.

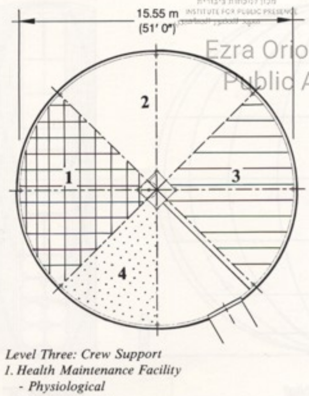




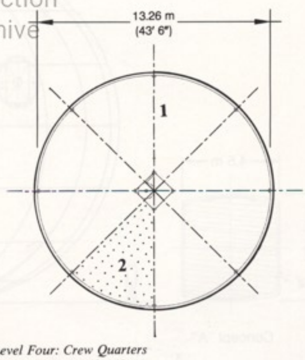
Level One: Mission Operations
1. Lunar Experiment Laboratory
2. Scientific Data Processing Facility
3. Maintenance Facility



Level Two: Base Operations
1. Surface Operations Workstations
2. Data and Communications Center
3. Base Activities Wardroom
4. Landing Operations Center
5. Library/Quiet Space
6. Waste Management Facility



Level Three: Crew Support
1. Health Maintenance Facility
- Physiological
- Psychological
2. Recreation Facility
3. Galley (Kitchen, Dining Area)
4. Laundry/Housekeeping



Level Four: Crew Quarters
1. Crew Quarters for 12
2. Personal Hygiene Facility

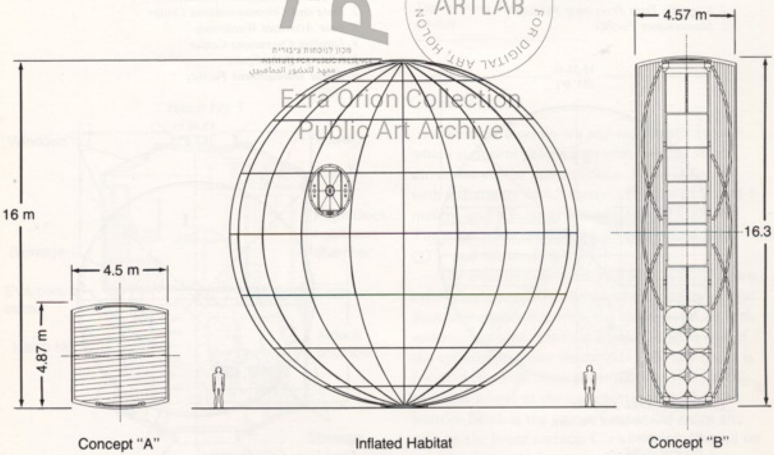
Contents

inflation by driving piles into the bottom of the crater. After the habitat is checked out and shielded with regolith, a pressurized tunnel is attached from the construction shack. A rudimentary ECLSS is activated. The internal structure is then assembled and a full ECLSS is installed. The construction crew can finish assembling the interiors in a shirt-sleeve environment, and connect the logistics interface module and air lock during EVA.

Packaging

The habitat can be packaged with or without some secondary structure, and ECLSS equipment prepackaged inside. Packaging the inflatable envelope separately minimizes its weight and size for easier transportation and handling. Packaging the structure inside the inflatable decreases habitat setup time, which may be important because of the limited crew stay time on the lunar surface during the construction phase.

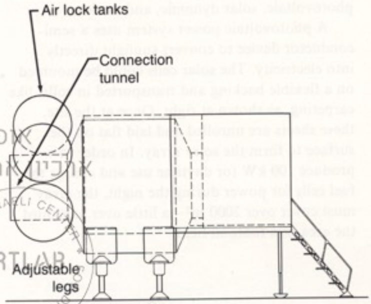
Inflatable habitat packaging concepts.



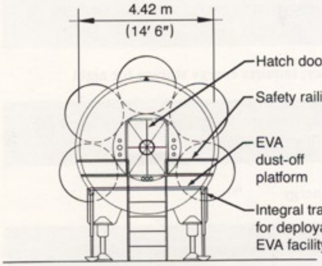
Air Lock

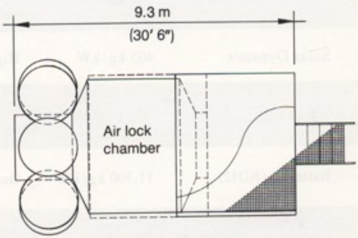
The purpose of a lunar air lock is to handle the transition of crew from intravehicular activity (IVA) to EVA and vice versa. Depending on the lunar suits used and the habitat pressure, a short oxygen pre-breathe may be required to clear nitrogen from the crewmember's body before leaving the habitat. The air lock can accommodate two crewmembers at one time, and store four suits.

The air lock is composed of purging tanks, a crew chamber, a connection tunnel and berthing interface, adjustable legs for leveling, and a dust-off facility. The air lock chamber will have a grated floor to allow lunar dust and soil to settle into a collection area, which is emptied by trapdoor when it is full.



Three views of the air lock.





The Power System

The early lunar outpost will need about 100 kW of electricity to maintain the environmental control system, power laboratory equipment, and provide energy for tools and vehicles outside. The three most promising options for power generation are solar photovoltaic, solar dynamic, and nuclear.

A photovoltaic power system uses a semiconductor device to convert sunlight directly into electricity. The solar cells could be mounted on a flexible backing and transported in rolls, like carpeting, as shown at right. Once at the site, these sheets are unrolled and laid flat on the surface to form the solar array. In order to produce 100 kW for daytime use and charge the fuel cells for power during the night, the array must cover over 2000 m^2—a little over one-third the area of a football field.

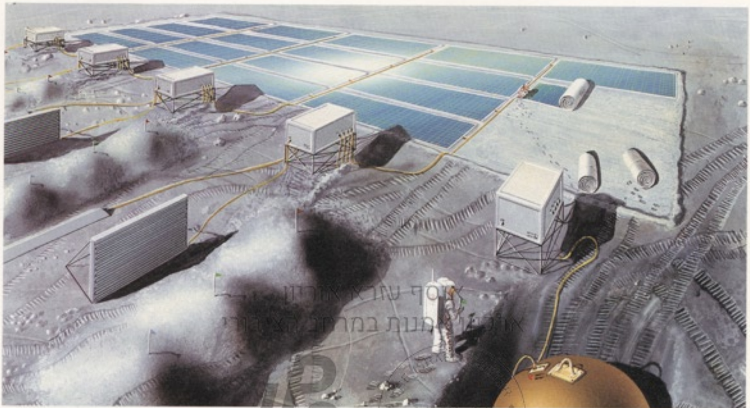
A solar dynamic power system typically uses a thermodynamic cycle to convert the heat from concentrated sunlight into work, which is then converted to electrical energy. Currently, the dynamic solar systems have higher conversion efficiencies than the photovoltaics, but are more massive. A dynamic system is also inherently more complex than a photovoltaic array, which has no moving parts.

Solar power systems produce power only during the day; thus some other form of energy storage system is required to provide power at night. Regenerative fuel cells are the leading candidate to fill this energy storage role.

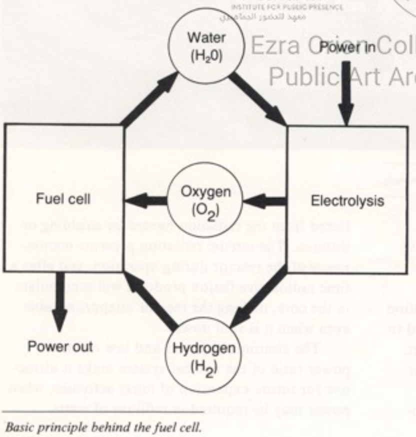
Fuel cells chemically combine oxygen and hydrogen to form water and release energy. Energy is stored by electrolyzing the water back into its components. The system can be

Power systems comparison table.

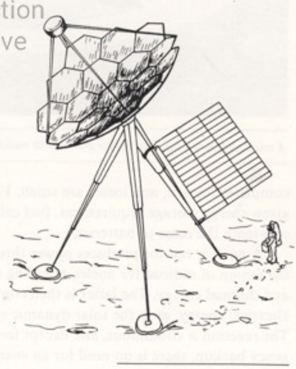
System	Unit Mass	Comment
Solar Photovoltaic	40 kg/kW	No moving parts: requires energy storage system for night
Solar Dynamic	405 kg/kW	High efficiency; requires energy storage for night
Fuel Cells	450 kg/kW	High operating pressures; only stores energy; sized for operation during lunar night
Batteries (NiH2)	11,300 kg/kW	Only stores energy
Nuclear	30 kg/kW	Continuous power—no energy storage required; intense radiation



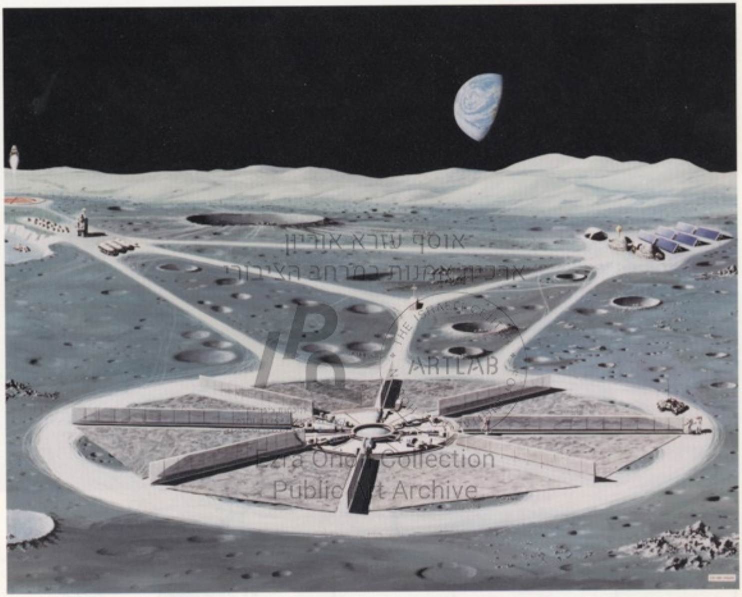
A photovoltaic power supply with regenerative fuel cells.



Basic principle behind the fuel cell.



A 25 kW solar dynamic unit, with radiator.



A multi-megawatt nuclear power plant, with radiating panels.

completely closed, and losses are small. For a given energy storage requirement, fuel cells have one-tenth the mass of batteries.

A nuclear reactor produces power through the fission of radioactive nuclei, releasing radiation and thermal energy. The latter is then converted to electrical energy, as in the solar dynamic system. The reaction is continuous, and except for emergency backup, there is no need for an energy storage system. However, the crew must be protected from the radiation hazard by shielding or distance. The intense radiation prevents maintenance of the reactor during operation, and after a time radioactive fission products will accumulate in the core, making the reactor unapproachable even when it is shut down.

The continuous power and low mass/power ratio of the nuclear system make it attractive for future expansion of lunar activities, when power may be required in millions of watts.

Thermal Control

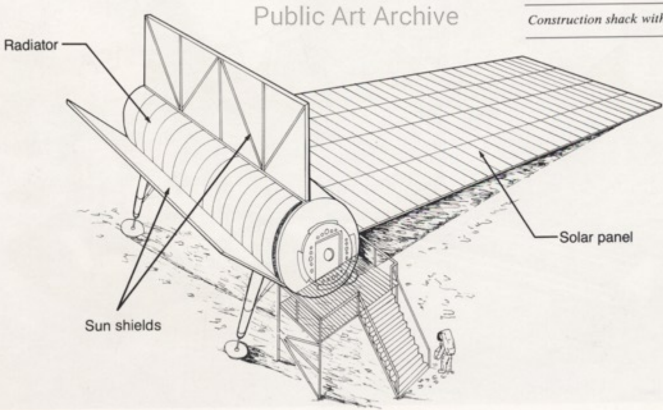
Thermal control of the lunar base is difficult due to the extreme environment on the Moon. Many factors must be considered before a heat dissipation system can be implemented. Problems with the atmosphere, the lunar soil, and micrometeoroids all must be accounted for before an extended human presence can be realized.

Conventional heat dissipation is accomplished through conduction and convection, but on the airless Moon the heat must be radiated to space. The direct sunlight causes exposed items to have a high temperature, while those items in the shade have a very low temperature. The difficulty arises in trying to radiate heat from the radiator when it is surrounded by the hot lunar surface during the day. The radiator will tend to absorb heat from the surroundings, increasing the habitat's internal temperature. At night the opposite will be true, and the radiator will dissipate more heat than the habitat can afford to lose.

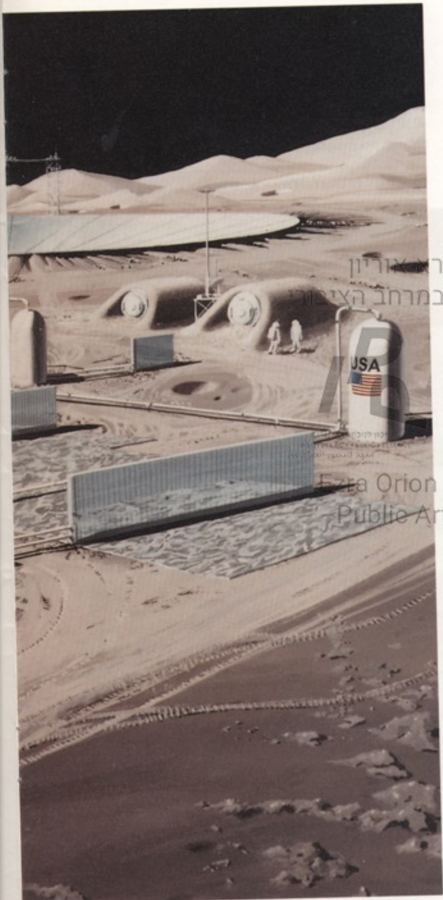
Two principal methods to maintain an even heat flux out of the habitat are to increase the radiating temperature as the lunar surface heats up or to shield the radiators so that they experience, or "see," a constant temperature. The figure below shows the proposed configuration for the lunar shack, and one way to shield a radiator from the large temperature changes.

Another item of concern is the lunar regolith. It has an infrared emissivity of about 96 percent, and a tendency to stick to objects. The high emissivity means that most of the heat arriving at the lunar surface from the Sun is reradiated. In addition to the 1000 W/m^2 the habitat produces, the radiators have to dispose of a 1335 W/m^2 from the Sun. The regolith has such a low thermal conductivity that it acts very much like an insulator. Coupled with its tendency to coat objects, this can seriously diminish the radiator's performance. Therefore, any radiation method chosen will have to be shielded and occupy a large area to ensure sufficient dissipation. A concept developed by NASA's Lewis Research Center which makes use of a large field of radiators is depicted on the following page.

Construction shack with radiator.




NASA



The Moon is constantly being bombarded with micrometeorites, strikes of which against the radiating surface will reduce the efficiency of the radiator. A conventional radiator makes use of a closed system containing an evaporating liquid. A puncture by a micrometeorite will allow the liquid to evaporate, diminishing performance. Eventually all the fluid will evaporate and the radiator will cease to function. Fortunately, the flux of micrometeorites is inversely proportional to their size: there are large numbers of tiny ones and very few of the relatively larger sizes.

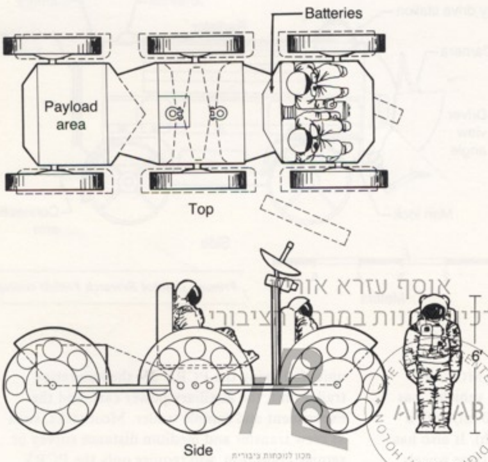
Large thermal radiator field.

Surface Transportation

Lunar surface transportation is designed to move people and equipment to accomplish local objectives and perform long distance missions including the mapping and surveying of future mining and resource sites. Other construction tasks, such as excavation or large equipment assembly, will be accomplished by specially designed construction equipment.

The operating conditions for surface vehicles will be very different from terrestrial travel conditions. The Moon has one-sixth the gravity of Earth, practically zero atmosphere, extreme temperature swings (102 K to 384 K, or -250° F to +257° F, at the Apollo 17 site), and almost no magnetic field to provide protection

MOSAP and LOTRAN vehicles on a scouting mission.



LOTRAN conceptual design.

from radiation. The vehicles required for lunar operation must not only survive this environment but do so over the course of many years.

When humans return to the the Moon, the surface vehicles will be designed with the help of past experience—Apollo missions 11, 12, and 14 through 17, and the unmanned Soviet Lunokhod 1. Such knowledge has already been incorporated into designs for missions planned, but not flown, in the Apollo program, and for the Mars Rover Sample Return Mission currently being planned.

Two types of transportation vehicle will be required during the buildup phase of the lunar outpost: an unpressurized rover for local transportation, and a pressurized vehicle for long-range travel.

Local Rover (unpressurized)

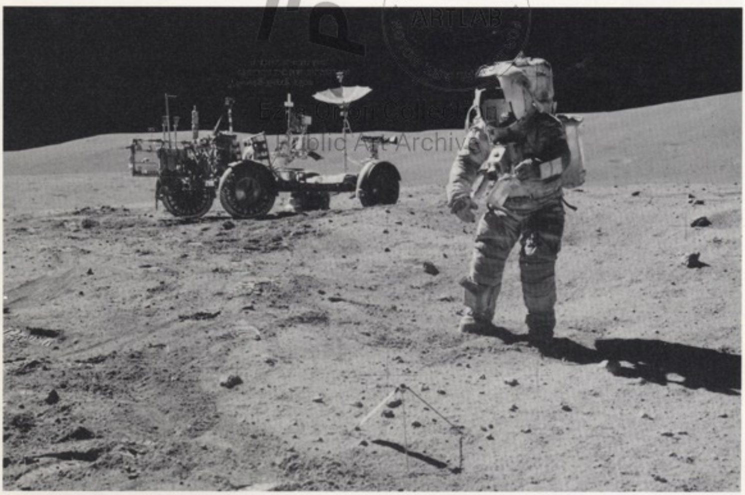
The local rover, LOTRAN (local transportation vehicle, unpressurized), is designed for a range of 100 km (62 mi) with a maximum speed of 15 km/h (9.3 mi/h). Its passive suspension in the form of metal-elastic wheels simplifies the design by reducing the number of moving parts and opportunities for failure. The vehicle is fully articulated at two joints, allowing for obstacle avoidance and/or negotiation. It can carry two crewmembers plus 850 kg of payload or two additional crewmembers, depending on the task requirements. The second joint can be disconnected for trips not requiring the trailer section.

Introduction

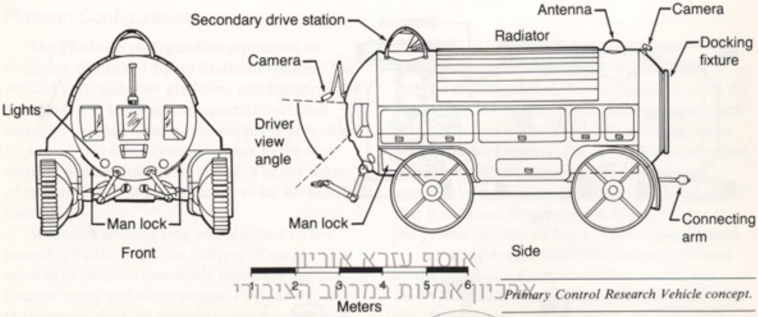
The human race began its exploration of the solar system in earnest with the July 1969 lunar landing of Neil Armstrong and Edwin Aldrin. Six additional Apollo missions followed this historic endeavor. Twenty years later, a group of scientists and engineers at the Lyndon B. Johnson Space Center (JSC) are considering the return to the Moon, not just to explore, but to learn to live and work on another planetary surface. The Moon becomes another stepping stone in the human path from the oceans to the stars, from home to the unknown.

In the past two years, a number of concepts for going to the Moon, living on its surface, and adapting to its unique environment have been developed at JSC by designers who drew on experience reaching many years into the past. Though the study is completed, the work is not.

The spacecraft concepts presented here may not be the ones that will eventually fly; habitation systems and stay times may be different than described; some of the elements described here may not even be built. The actual scenarios and elements will be based on long-term strategies of the civilian space program, technological advances, and, finally, public and Congressional support. The purpose of this overview is not to present a preferred path or "road map" to the Moon, but to enlighten the reader on the needs of lunar exploration and development, and to challenge the reader to formulate new ideas and concepts.



Apollo signaled the opening of the lunar frontier.



Primary Control Research Vehicle concept.

Pressurized Vehicle System

The pressurized vehicle system, MOSAP (mobile surface application traverse vehicle), has a maximum range of 3000 km (1860 mi) with a nominal speed of 10 km/h (6.2 mi/h). It also has a passive suspension in the form of cone wheels. The complete system is a four-piece modular design to allow flexibility in mission planning. Each of the four units can be individually operated or connected in the train configuration shown below and controlled by the first unit, the primary control research vehicle (PCRV). The units following the PCRV are the habitation trailer unit, the auxiliary power cart, and the experiment and sample trailer. Most tasks, such as crew transfer and medium distance survey or sample collection, will require only the PCRV.

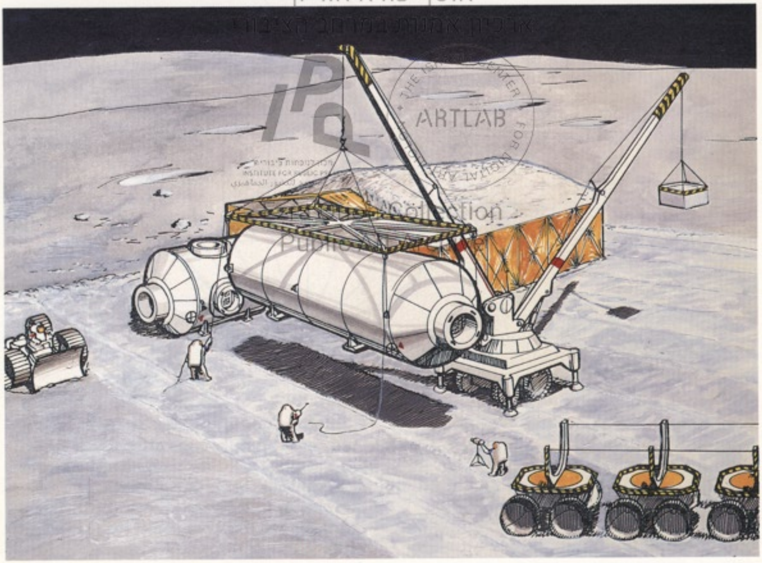
Extremely long traverses will be accomplished by using a landing craft with crew module flying round trip from lunar orbit. Basing the landing craft at the outpost and "hopping" from site to site would not be as energy efficient.

MOSAP overlooking Schroteri valley.

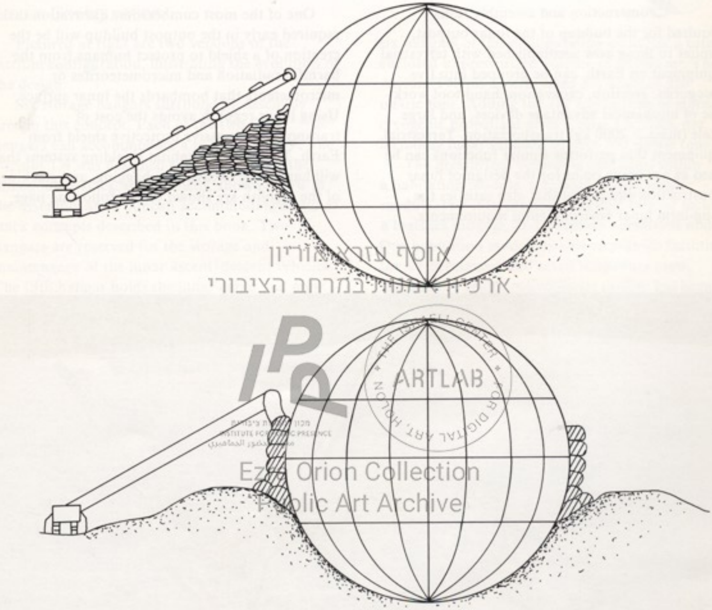
Construction and Assembly

Construction and assembly tasks required for the buildup of the lunar outpost, similar to those now accomplished with terrestrial equipment on Earth, can be grouped into five categories: erection, excavation, hand tool work, use of mechanical advantage devices, and large scale (mass $>$ 2000 kg) transportation. Terrestrial equipment that performs similar functions can be used as a starting point for the design of lunar construction equipment that also satisfies the long-term lunar environmental requirements.

One of the most cumbersome excavation tasks required early in the outpost buildup will be the creation of a shield to protect humans from the harmful radiation and micrometeorites or micrometeors that bombards the lunar surface. Using lunar regolith avoids the cost of transporting a massive protective shield from Earth. Two possible habitat shielding systems that will handle the excavation, bagging, and stacking of the regolith are shown on the following page.

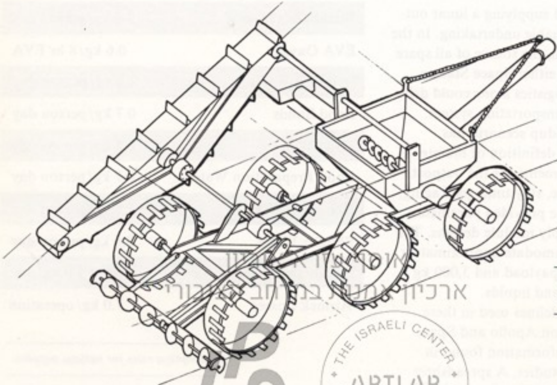


Erection and transportation equipment concepts. One task from the erection and transportation categories is the unloading, movement, and placement of large components.

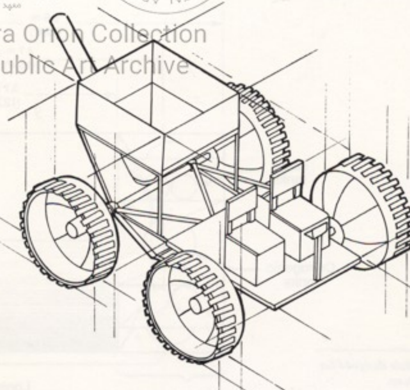


Two concepts for shielding the habitat.

Another task planned is the setup and operation of a small oxygen plant. Operation of this plant will require the excavation of lunar soil on a continuous basis. Two machines, a bucket excavator and a lunar truck to accomplish the excavation and transportation of soil to the plant, were conceptually designed for efficiency of size—they are not so big as to preclude their use in earlier stages of the lunar base.



A lunar bucket excavator conceptual design.



Lunar truck concept.

Maintenance and Supply

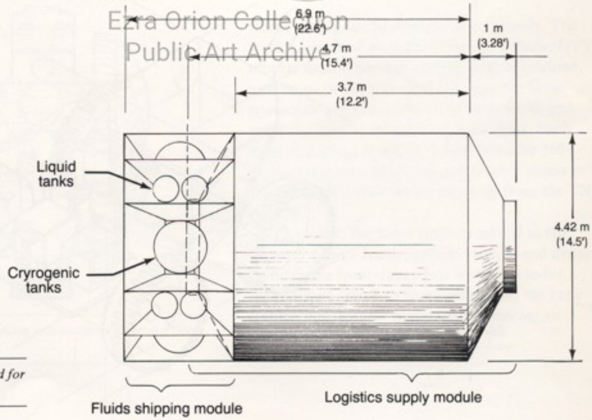
Maintaining and supplying a lunar outpost is a complex and variable undertaking. In the early phases of occupation, the source of all spare parts and supplies will be either Space Station Freedom or Earth. The logistics alone could drive the design of the lunar transportation system.

Formulation of a buildup scenario has provided the preliminary definition of maintenance and supply requirements for the outpost. Trade studies on crew size, stay time, packaging, and shipping options have provided parameters required for logistics supply module designs. The concept below can accommodate approximately 11,000 kg (24,000 lbs) of payload and 3,000 kg (7,000 lbs) of cryogenics and liquids.

Assumptions and guidelines used in these trade studies were based on Apollo and Space Shuttle experience and information found in Space Station Freedom studies. A spreadsheet program based on inputs of stay time and crew size has been used to calculate supplies and spares required for a lunar outpost.

Metabolic Oxygen	0.8 kg/person day
EVA Oxygen	0.6 kg/8 hr EVA
Drinking Water	1.9 kg/person day
Food Solids	0.7 kg/person day
Food Water	0.5 kg/person day
Food Preparation Water	0.7 kg/person day
Handwash Water	1.8 kg/person day
Shower Water	3.6 kg/person day
Membrane Leakage Air	1.0 kg/day
Airlock Losses	7.0 kg/operation

Consumption rates for various supplies.



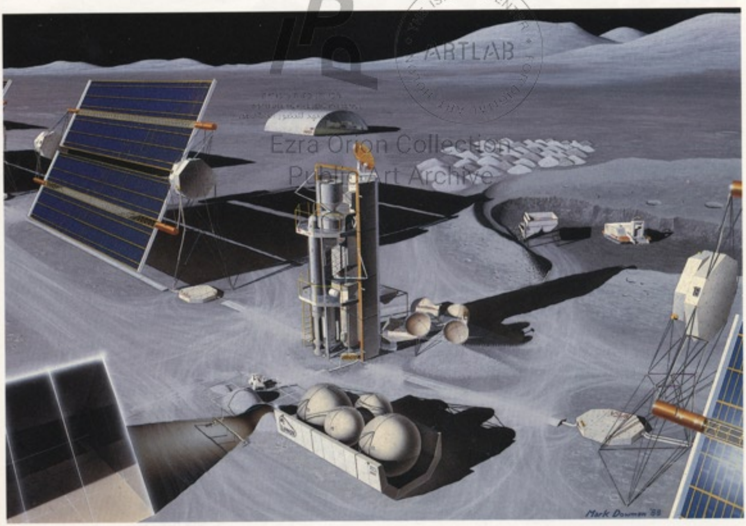
Logistics module designed for 180-day missions.

The Oxygen Plant

The oxygen pilot plant facility, designed to prove the technologies necessary to produce oxygen on the surface of the Moon, is intended to test different concepts and determine which method produces oxygen most efficiently. It is expected that the facility will produce only limited amounts of oxygen: approximately 2000 kg a month. Shown below is an artist's rendition of a large-scale oxygen plant. At the beginning of the lunar outpost, during the buildup phase, there will be several small plants nearby, each proving a different technology.

The complexity of a resource production plant will mandate a high level of automation. Because the human effort necessary to find a problem in such a system would make the plants uneconomical, fault detection and diagnosis will be built into the plants, both pilot and full scale. The facility will thus provide the problem diagnosis, then humans will intervene to remove the faulty component and repair it. Should full automation be impractical, telerobotic operation of the plants will be the second choice.

The oxygen production plants receive bulk lunar regolith from a nearby mining facility, which might resemble the mining operations shown below. The soil is scraped up, loaded on large soil movers, and transported to the production facility. A more direct approach is also possible, as shown in the figure on the next page.



Lunar oxygen production plant.

Three-drum slusher mining operation.

Once the regolith is transported to the plant or plants, it must be concentrated to ensure a sufficient quantity of oxygen, found as a component of minerals in the soil, is present. For an efficient process, those minerals containing the oxygen must be concentrated.

In the production plant illustrated, ilmenite, an oxygen-bearing mineral, is mixed with hot hydrogen, breaking the mineral down into water, iron oxide, and titanium oxide. The water is then electrolyzed, producing oxygen and hydrogen. The oxygen is liquefied and pumped to underground storage tanks near the plant; the hydrogen is put back into the system and the process begins again. In the early stages, the pilot plant is powered by a solar photovoltaic power source. When full-size production plants are built, power requirements will be sufficient to justify a nuclear reactor.

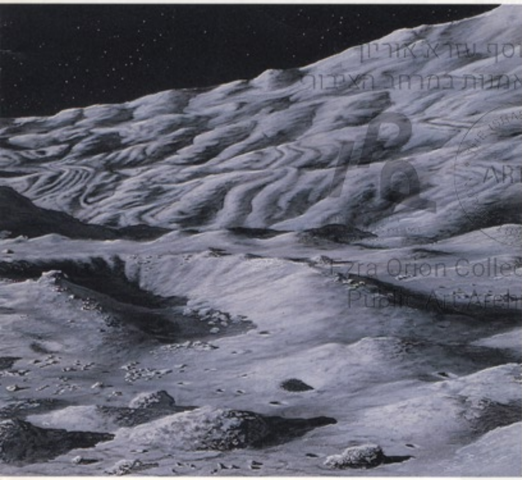
The production plant shown is just one of several potential processes for the removal of oxygen from the lunar soil. The required technology is not yet available for some of the processes; thus advances in technology projections may disclose a more efficient type of processing.

Surface scraper towed by lunar truck.

Obviously, one of the most exciting aspects of a lunar outpost is its ability to support detailed and long-term exploration of the lunar surface. Here a surface exploration crew begins its investigation of a lava tunnel to determine if it could serve as natural shelter for the habitation units of the lunar outpost. One member of the expedition is standing in the lip of the rille, near the point where the original tunnel disgorged its lava into an open channel. The two crewmembers in the foreground are standing in the lava channel. As indicated by the lack of meteorite erosion and debris burial, a section of the original tunnel's roof has collapsed, perhaps struck by the object that made the 15-m-diameter crater behind the crewmember at the rille's edge. The collapse has exposed the layering in the volcanic rocks and has displaced the mouth of the tunnel some 50 m upstream of its original position.

Entrance to a small lava tube.

Another expedition on the lunar surface could be a 2-week sojourn away from the outpost. In this scene, the expedition has stopped to drill for deep core samples in support of petrological studies in the floor of the young crater known as Aristarchus, 36 km in diameter and 4200 m deep. The peak of Aristarchus can be seen a few kilometers south of the drill rig. This view from the the crater floor shows the prominent slump terraces of the crater walls and the solidified impact melt rivulets which flowed down the steep inner wall immediately after the crater was formed. Because Aristarchus is very young, the rivulets, the volcanic-like features, and the cooling cracks of the impact melt floor unit are only slightly muted by meteorite erosion and ejecta blanketing. The drilling activities are taking place at 23.7° N. and 47.5° W., 80 kilometers to the southeast of the traversing crew in Valis Schroteri depicted in the Surface Transportation section.



Expedition in Crater Aristarchus.

Precursors

Before a lunar outpost can be constructed, topological and cartographic data on the Moon must be obtained. Such data can be collected from lunar orbit using imaging satellites in the same manner that the U.S. Landsat and French SPOT collect data on the Earth. In addition, sample collection missions may be desirable to assure the proper location and design of the outpost.

A small return stage of an unmanned sample collection vehicle is shown accelerating toward lunar escape velocity at the beginning of its 3-day journey to Earth. During its few hours stay time on top of the 25-km-diameter highland volcanic dome Gruithuisen Delta, the teleoperated rake of the probe collected up to 3 kilograms of lunar soil and walnut-sized rocks. Because these domes are made of volcanic rocks, they may also be the sites of valuable ores which could be used in the development of a lunar outpost. In this view looking toward the northwest, the return stage is 60 km above the surface of Gruithuisen Delta, seen in the lower right. The sister dome, Gruithuisen Gamma, is in the center of the scene. These two prominent volcanic domes are located at 36° N. and 40° W., on the northwest shore of Mare Imbrium. The light highlands material in the upper left is ejecta from the Mare Imbrium basin.

A sample-return craft departs Mare Imbrium.

The Future

The technology for the habitation and transportation systems just described is well within our grasp. Once a commitment is made to lunar development, the outpost could grow into a network of lunar bases and eventually evolve into a self-sufficient lunar colony.

A lunar colony would employ more advanced technology, such as the electric propulsion vehicle shown below. With its low-thrust engines, this space freighter will take months to complete its journey from the Earth to the Moon. But it will deliver over a hundred tons of material on each trip and carry a similar amount of lunar exports back to Earth orbit.

Such lunar exports might be used to construct enormous solar power satellites in Earth orbit, providing clean energy to the entire planet. Lunar-derived propellants could power spacecraft throughout the solar system and beyond.

Self-supporting inflatable being erected in a lava tube.

Nuclear-electric low-thrust vehicle.

Future inhabitants of the lunar colony might live and work inside the cavernous lava tubes below the surface of the Moon. Lunar agriculture and a closed life support system could eventually make the colonists self-sufficient.

The Moon is many things: a stepping stone into the solar system, a laboratory for exotic research, a source of natural resources, and possibly the birthplace of a new human civilization. The technology needed to start realizing this great potential is here. All that is required is the will to exercise it.

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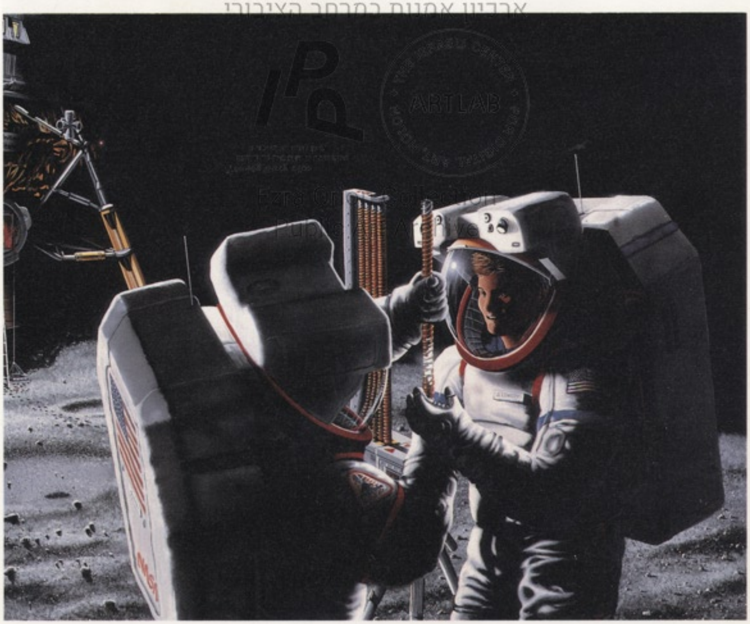
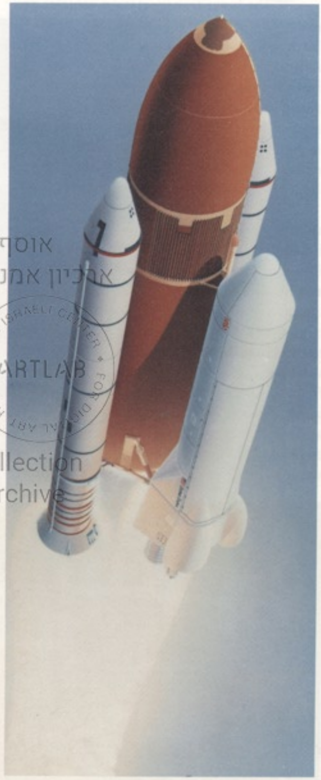
Piloted missions back to the Moon before the beginning of construction of a lunar outpost will be useful. Their findings will significantly influence the outpost. For example, some lunar scientists feel that water in the form of ice may be located at the south pole of the Moon. Gamma-ray and neutron spectrometers on a lunar polar orbiter could search for ice that might be present in permanently shadowed craters in that region. Since water, a basic human commodity, was absent in samples from the previously explored lunar sites, such a find would greatly enhance the ability of the outpost to reduce its imports from Earth. Below, two jubilant scientist-astronauts on an ice prospecting mission, are examining an ice-encrusted drill stem as they stand in the frigid (60 K), permanently shadowed area of a south pole crater. If the ice is relatively abundant, a lunar outpost could be located near such polar deposits.

Exploring the south pole of the Moon.



Launch from Earth

All of the spacecraft, propellant, cargo, and people begin the journey to the Moon by launching from Earth to an orbiting transportation node. To operate a lunar outpost, the mass that must be launched from Earth will eventually total several thousand tons per year. About 80 percent of that mass will be rocket propellant. New launch vehicles with greater capacity will be needed to meet this demand. One launch vehicle concept shown is a derivative of the Space Shuttle which has been modified to carry only cargo.



Concept for a future cargo launch vehicle.

JPL FACT SHEET

VIKING

NASA

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National Aeronautics and Space Administration
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MARS FACTS:

Diameter:	6,664 kilometers (4,240 miles)
Surface gravity	0.39 (Earth = 1)
Mean distance from Sun	227.7 million kilometers (141.5 million miles)
Number of satellites	Two -- Deimos and Phobos
One year	669 Mars days or 687 Earth days
	(Earth = 365.25 days)

Seasons	Northern hemisphere	Southern Hemisphere	Earth
Spring	194 days	143 days	92.9 days
Summer	178 days	154 days	93.6 days
Autumn	143 days	194 days	89.7 days
Winter	154 days	178 days	89.1 days

Updated: 5/24/82DB

FACT SHEET PROJECT VIKING

Project Viking was the culmination of a series of missions to explore the planet Mars; they began in 1964 with Mariner 4, and continued with the Mariner 6 and 7 flybys in 1969, and the Mariner 9 orbital mission in 1971 and 1972.

Viking was designed to orbit Mars and land and operate on its surface. Two identical spacecraft were launched -- Viking 1 on Aug. 20, 1975, and Viking 2 on Sept. 9, 1975. Each consisted of an orbiter and a lander. The landers were sterilized before launch to prevent contamination of Mars with terrestrial organisms.

Langley Research Center, Hampton, Va., had management responsibility for the Viking project from its inception in 1968 until April 1, 1978, when the Jet Propulsion Laboratory assumed management responsibility. The landers were developed under contract by Martin Marietta Aerospace, Denver, Colo. Lewis Research Center had responsibility for the Titan-Centaur launch vehicles. JPL's initial assignment was development of the orbiters, tracking and data acquisition, and the Mission Control and Computing Center.

Both spacecraft were launched from Cape Canaveral and spent nearly a year cruising to Mars. Viking 1 reached Mars orbit June 19, 1976; Viking 2 began orbiting Mars Aug. 7, 1976. After studying orbiter photos, the Site Certification Team considered the original landing site for Viking 1 unsafe. Nearby sites were examined, and the first landing on Mars occurred July 20, 1976, on the western slope of Chryse Planitia at 22.3°N, 48.0°W.

The planned landing site for Viking 2 was also considered unsuitable when high-resolution pictures became available. Certification of a new landing site was accomplished in time for a Mars landing Sept. 3, 1976, at Utopia Planitia, 47.7°N, 225.8°W.

At the time of their launches, the Viking spacecraft were the most complex planetary spacecraft developed. Each orbiter and lander operated far beyond its design lifetime with few anomalies or failures. Viking Orbiter 1 exceeded four years of active flight operations in Mars orbit.

The end of mission for Orbiter 2 was July 25, 1978, due to exhaustion of gas in the attitude-control system. That system kept the craft's solar panels pointed at the Sun to power the orbiter. When the spacecraft drifted off the Sun line, the power to its transmitter was shut off.

The Viking Project's primary mission ended Nov. 15, 1976, 11 days before Mars passed behind the Sun (superior conjunction). After conjunction, in mid-December 1976, telemetry and command communications were re-established, and extended mission operations began. Orbiter 1 began to run short of attitude-control gas in 1978, but through careful planning to conserve the remaining supply, it proved possible to continue acquisition of scientific data at a reduced level for another two years. The gas supply was finally exhausted and the spacecraft's electrical power was turned off on Aug. 7, 1980, after 1,489 orbits of Mars. Orbiter 1 has continued working into the summer of 1980. The last data from Lander 2 were received on April 11, 1980, but Lander 1 is programmed to operate through 1994, sending data consisting of meteorology information and pictures to Earth weekly.

Both Viking missions were extremely successful. With a single exception, the science instruments acquired more data than expected. Only the seismic experiment was a disappointment: The seismometer on Lander 1 could not be brought into operation after landing, and the other detected only one event that may have been a Marsquake.

The three biology experiments discovered unexpected and enigmatic chemical activity in the Martian soil, but no clear evidence of living organisms. The gas chromatograph/mass spectrometer found no sign of organic chemistry to its level of sensitivity, but it did provide a precise and definitive analysis of the composition of the atmosphere and found previously undetected trace elements. The elemental composition of the Martian soil was also measured by the X-ray fluorescence spectrometer.

Measurements of some physical and magnetic properties of the soil were made. The composition and physical properties of the upper atmosphere were also measured during the entry of the landers.

Nearly continuous monitoring of weather at the landing sites was carried out. The weather in the Martian midsummer was found to be repetitious, but in other seasons it became variable and more interesting. Cyclic variations in weather patterns (probably the passage of alternating cyclones and anticyclones) were observed. Atmospheric temperatures at the southern landing site were as high as -31°C (-24° F) at midday, with the predawn summer temperature being -86°C (-187° F). By way of contrast, the diurnal temperatures at the northern landing site during the midwinter dust storm varied as little as 4°C (7.2° F) on some days. The lowest predawn temperature was -124°C (-191°F), approximately the frost point of carbon dioxide. A thin layer of water frost covered the ground around Lander 2 during most of both the first and second winters.

The semiannual variation of barometric pressures resulting from condensation and sublimation of atmospheric carbon dioxide on the polar caps was found to be unexpectedly large; the maximum and minimum mean daily pressures observed by Lander 1 were 6.8 and 9.0 millibars. Another surprise was the generally small magnitude of wind velocities; neither lander has recorded a gust in excess of 120 kilometers (74 miles) an hour, and mean velocities were much lower. Nevertheless, more than a dozen small dust storms were observed by orbiter instruments. During the first southern summer, two global dust storms occurred, about four Earth months apart. Both obscured the Sun at the landers for a time and hid most of the planet from the orbiter cameras.

Photographs from the landers and orbiters surpassed expectations in quantity and quality. The total number of pictures exceeds 4,500 from the landers and 52,000 from the orbiters. The landers provided the first close-up look at the surface, monitored variations of atmospheric opacity over three full Martian years so far, and have determined the mean size of the aerosols. The orbiter cameras observed new and often puzzling terrain and provided clearer detail on known features, including some color and stereo observations, and mapped about 97 per cent of the surface.

The infrared thermal mappers and the atmospheric water detectors on the orbiters acquired data almost daily through the lifetime of the orbiters, observing the planet at high and low resolution. This massive quantity of data will require considerable time for analysis and understanding of the global meteorology of Mars. It was also definitely determined that the residual north polar ice cap that survives the summer is composed of water ice.

Analysis of radio signals from landers and orbiters, including Doppler, ranging and occultation data, and the signal strength of the lander-to-orbiter relay link provided a variety of valuable information. The program still continues with Lander 1.

Other significant discoveries of the Viking missions include:

o Nitrogen, not previously detected, is a significant component of the Martian atmosphere, and the enrichment of the heavier isotope of nitrogen and argon relative to the lighter implies that atmospheric density was much greater in the distant past.

o Changes in the Martian surface occur extremely slowly, at least at the two landing sites. Only two very small changes were observed in four years.

o The greatest concentration of water vapor in the atmosphere is near the edge of the north polar cap in midsummer. From summer to fall, the peak concentration moves to the equator, with about a 30 per cent decrease in global abundance. In the southern summer, the entire planet is dry, probably also an effect of the dust storms.

o The density of both Mars' satellites is low -- approximately 2 grams per cubic centimeter -- perhaps implying an asteroidal origin. The surface of Phobos is marked with at least two families of parallel striations, probably fractures caused by a large impact that may nearly have broken it apart.

o Measurements of the round-trip time of passage of radio signals between Earth and the Viking spacecraft made while Mars was beyond the Sun (near the two solar conjunctions) have determined the amount of the delay of the signals caused by the Sun's gravitational field. The result confirms the prediction of Albert Einstein to an estimated accuracy of 0.1 per cent -- twenty times greater than any previous test.

o Mars is seismically much less active than Earth.

o The atmospheric pressure varies by 30 per cent during the Martian year because of the condensation and sublimation of atmospheric carbon dioxide in the polar caps.

o The permanent north cap is water ice; the south cap probably retains some carbon dioxide throughout the summer.

o Water vapor is relatively abundant only in the far north during the summer but subsurface water in the form of permafrost covers much if not all of the planet.

o The northern and southern hemispheres are drastically different climatically because of the effect of global dust storms that originate in the south in summer.

o The Martian surface is a type of iron-rich clay that contains a highly oxidizing substance that releases oxygen when wetted.

o The surface contains no organic molecules detectable at the parts-per-billion level.

o No clear evidence of the presence of living microorganisms in the soil near the landing sites was discovered; the question of life on Mars remains open.

# # # #

Updated: 5/24/82DB

VIKING FACTS

Event	Viking 1	Viking 2
Launch	Aug. 20, 1975	Sept. 9, 1975
Arrival	June 19, 1976	Aug. 7, 1976
Landing	July 20, 1976	Sept. 3, 1976
Site	Chryse Planitia	Utopia Planitia
Coordinates	22.3°N, 48.0°	47.7°N, 225.8°
Orbiter in orbit	1,509.9 days	718.8 days
Lander on surface	2,100 days (4/20/82)	1,316.1 days
End lander operations	(predicted) 1994	April 11, 1980
End Orbiter operations	Aug. 7, 1980	July 25, 1978
Orbiter photos	51,539	
Lander photos	More than 4,500	
Photo coverage	97 percent of planet with resolution of 300 meters (1,000 feet) or better. 25 percent of planet with resolution of 25 meters (82 feet) or better.	
Lander weather reports	2 million	More than 1 million

Orbiter infrared observations   More than 1 million

Orbiter weight   5,125 pounds

Lander weight 1,260 pounds

Orbiters built by Jet Propulsion Laboratory

Lander built by Martin Marietta Aerospace

The

PLANETARY REPORT

Volume XIV Number 5 September/October 1994

Clementine Maps the Moon

On the Cover:

The Moon has long been a proving ground for spacecraft from its nearby planet. The latest to visit was *Clementine*, the "smaller, cheaper, faster" mission launched by the Ballistic Missile Defense Organization. *Clementine* completely mapped the surface of the Moon, and this mosaic was made from the data collected of the Aristarchus plateau. Named for the large, bright Aristarchus crater, the plateau was probably uplifted, tilted and fractured by the giant impact that formed the Imbrium basin. Data like these from *Clementine* are helping fill out scientists' understanding of the Moon's history.

Image: Naval Research Laboratory
Processing: United States Geological Survey, Flagstaff

Table of Contents

Volume XIV
Number 5
September/October 1994

Features

Departments

From The Editor

Two recent programs supported by Planetary Society members have deeply affected the futures of both the American and Russian space programs.

As you may remember, late last year we asked Society members to fund a study on ways the Russian space program could assist NASA in launching a mission to Pluto. You responded enthusiastically, and two specific proposals from that study—to launch with a *Proton* rocket and to add a small probe into Pluto—made their way into an agreement signed by the vice president of the United States and the prime minister of Russia.

About the same time, we held a workshop for innovators in Mars exploration to brainstorm ways the spacefaring nations could combine their efforts to produce a realistic, continuing spacecraft program. Those results closely mirror the new "Mars Together" study also endorsed by the two political leaders.

Neither of these accomplishments would have been possible without your support. Planetary exploration is moving forward again, and our members can take pride in their contributions. Let's keep up the momentum!

—Charlene M. Anderson

The Planetary Report (ISSN 0736-3680) is published bimonthly at the editorial offices of The Planetary Society, 65 North Catalina Avenue, Pasadena, CA 91106-2301, (818) 793-5100. It is available to members of The Planetary Society. Annual dues in the US or Canada are $25 US dollars or $30 Canadian. Dues outside the US or Canada are $35 (US). Printed in USA. Second-class postage pending at Pasadena, California, and at an additional mailing office. Postmaster: Send address changes to The Planetary Society, 65 North Catalina Avenue, Pasadena, CA 91106-2301. Canada Post Agreement Number 87424.

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A Publication of
THE PLANETARY SOCIETY

Mysterious Pluto is the smallest and coldest planet in our solar system. It also has the most eccentric orbit and a very large moon half its size. In "Pluto and Charon," by David Egge, that moon, Charon, is a silvery crescent above the horizon. Pluto's orbit is now taking it farther from the Sun, and the planet is becoming colder as it goes. If no spacecraft visits this tiny world in the next 25 years, before its thin atmosphere freezes onto its surface, we may have to wait another two centuries.

David Egge is an astronomical artist who lives in Minneapolis, Minnesota. His work has appeared in *Omni*, *Astronomy, Science Digest* and other publications, and on the *Cosmos* television series.

THE PLANETARY SOCIETY
65 North Catalina Avenue
Pasadena, CA 91106-2301

Printed in USA

MARS: THE NORTH POLAR SAND SEA AND RELATED WIND PATTERNS

Haim Tsoar, Ronald Greeley, and Alan R. Peterfreund

Journal of Geophysical Research, vol. 84, no. B14, December 30, 1979