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# LUNAR EXPEDITION PLAN

# LUNEX

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**MAY 1961**

HEADQUARTERS

SPACE SYSTEMS DIVISION

AIR FORCE SYSTEMS COMMAND

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AIR FORCE SPACE SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND

29 May 1961

FOREWORD

This document provides a plan for a manned Lunar Expedition. It was prepared to furnish more detailed information in support of the National Space Program proposed by a USAF committee chaired by Major General J. R. Holzapple. That report pointed out the dire need for a goal for our national space program. The Lunar Expedition was chosen as the goal since it not only provides a sufficient challenge to the nation, but also provides technical fall-outs for greatly improved space capabilities.

Previous editions of this plan have provided guidance and incentive to Air Force technical groups. Consequently, their efforts have established a broad technical base within the Air Force from which rapid advances can be made. This capability has been taken into account in laying out the accelerated schedules in this plan.

O. J. Ritland
O. J. RITLAND
Major General, USAF
Commander

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Stamped document
DATE 8/8/73 [illegible]

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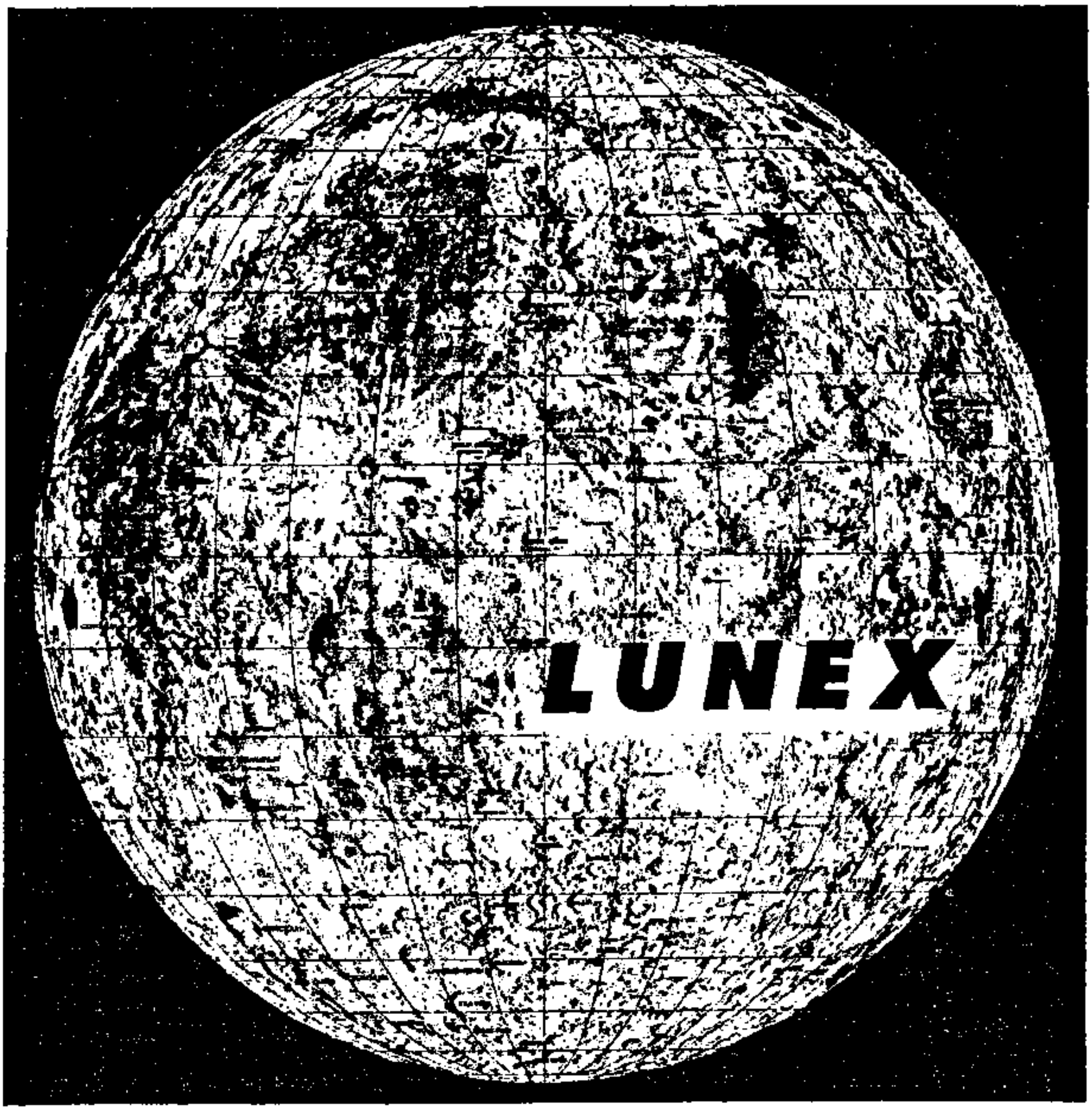


## GENERAL LUNAR DATA

| | |
|---|---|
| Distance from earth | |
| moon (miles) | 239,000 |
| (kilometers) | 387,000 |
| Diameter | |
| miles | 2160 |
| kilometers | 3480 |
| Temperatures | |
| sun at zenith | 101°C to 130°C |
| night | −153°C |

## GRAPHIC INFORMATION

**Names**
The feature names selected were adopted from the 1935 International Astronomical Union nomenclature system with minor changes by Yerkes Observatory in 1959.

**Projection**
An orthographic projection portrays the moon as a sphere in the true perspective created by viewing from an infinite distance.

**Control**
This is a controlled mosaic. Position was determined through the use of selenographic control established primarily from the measures of J. Franz and S.A. Saunders. A collated listing of these positions was published under the auspices of the International Astronomical Union in 1935.

**Photography**
The mosaic is comprised of photographs taken at Yerkes, Mc Donald and Mt. Wilson Observatories. Photographs with high consistant sun angles were selected to maintain uniform portrayal of lunar craters and prominences and discernible maria regions.

**Orientation**
Cardinal directions have been established to conform with cartographic tradition, north to top and east to right, rather than astronomical convention. This orientation positions the moon in its true relationship to the earth. 180° of the visible disc at mean libration is shown.

## NAMES LEGEND

| | |
|---|---|
| Craters | |
| (diameters in miles) | |
| 100 and over | CLAVIUS |
| 50 to 100 | TYCHO |
| less than 50 | [illegible] |
| Mountain Ranges | |
| (length in miles) | |
| 400 and over | APENNINE MOUNTAINS |
| less than 400 | PYRENEES MTS |
| Mountain Peaks, Valleys, Walls and Rilles | HYGINUS RILLE |
| Oceans, Gulfs, Bays, Seas, etc | |
| (length of major axis in miles) | |
| 600 and over | *MARE IMBRIUM* |
| 200 to 600 | *MARE NUBIUM* |
| less than 200 | *SINUS BORIS* |

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| X. | INTELLIGENCE |

Appendix #1 Glossary of Terms


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# PROPOSED SYSTEM PACKAGE PLAN

# FOR

# LUNAR EXPEDITION


Prepared by Support Systems Plans Division

Approved by Norair M. Lulejian
Norair M. Lulejian
Colonel, USAF
Director, Advanced
Systems Plans And Analysis


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# SECTION I

## SUMMARY

## LUNAR EXPEDITION (U)

## (LUNEX)

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ATTACHMENTS

CHART I-A LUNAR EXPEDITION PROGRAM MILESTONE SCHEDULE

CHART I-B LUNAR EXPEDITION MANAGEMENT MILESTONES FY62 - FY63

# 1.0 SUMMARY

## 1.1 PURPOSE

The Lunar Expedition has as its objective manned exploration of the moon with the first manned landing and return in late 1967. This one achievement if accomplished before the USSR, will serve to demonstrate conclusively that this nation possesses the capability to win future competition in technology. No space achievement short of this goal will have equal technological significance, historical impact, or excite the entire world.

## 1.2 BACKGROUND

Extensive studies by Air Force-Industry teams during 1958, 1959, and 1960 examined all facets of the problem and techniques of sending men to the moon and resulted in a feasible concept which is attainable at an early date and is economical and reliable. Laboratories within the Air Force participated in this effort, thus establishing a broad technological base which can react quickly to an expanded high priority program.

## 1.3 DESCRIPTION

The lunar mission would be initiated by the launching of the lunar payload by a large, three-stage liquid or solid propellant booster to escape velocity on a lunar intercept trajectory. The payload, consisting of a Lunar Landing Stage, Lunar Launching Stage and a manned vehicle, would use a lunar horizon scanner and a doppler altimeter for orientation prior to a soft landing using the Lunar Landing Stage. Terminal guidance using prepositioned beacons would be required for landing at a preselected site. The Lunar Launch Stage would provide the necessary boost for the return to earth of the manned Lunex Re-entry Vehicle. Using mid-course guidance and aerodynamic braking, the vehicle would effect re-entry and a normal unpowered aircraft landing at a ZI base.

In addition to the manned vehicle a cargo payload is included in this plan. The cargo payload would utilize the same three-stage earth launch booster and the same lunar landing techniques. However it would not be returned to earth and would be used only to transport supplies and cargo to the expedition on the moon.

The primary concept recommended in this plan is the "direct shot" method since studies have indicated it could be available at an earlier date and it would be more reliable. Another concept is also suggested which consists of the rendezvous and assembly of components in an earth orbit before injection into a lunar trajectory. The techniques and development required for this latter concept are documented under a separate SSP titled, SAINT. Therefore, no details of this concept are presented in this plan. All schedules relating the two plans have been coordinated to insure compatibility and to take advantage of mutual advances. Since neither rendezvous techniques nor large boosters have been demonstrated, both approaches must be pursued until it becomes obvious that one of them has clear advantages over the other.

The following developments are required in order to accomplish the lunar expedition:

a. A three-man Lunex Re-entry Vehicle. This vehicle must be capable of re-entry into the earth's atmosphere at velocities of 37,000 ft/sec. It must also be capable of making a conventional aircraft landing. Control and improved guidance for entering the earth's atmosphere at the proper place and angle is needed as well as improved materials to withstand the high surface temperatures. Adequate life support equipment is also required. The development of this vehicle is the key to the accomplishment of the LUNEX program and is one of the pacing development items. A detailed schedule for its development is included.

b. A Lunar Landing Stage for decelerating and landing the entire payload. This stage must have the capability to decelerate 134,000 pounds from a velocity of almost 9,000 ft/sec to 20 ft/sec at touchdown. A doppler altimeter is required to provide information for ignition and control of the engine. Horizon scanners must be used to orient the payload to the local vertical.

c. A Lunar Launch Stage capable of launching the manned Lunex Re-entry Vehicle from the lunar surface. Lunar ascent guidance is required to place the vehicle on the proper trajectory.

d. A three-stage earth launch booster, referenced as a space launching system. The first stage will use either $LOX/LH_2$ with six million pounds of thrust or a solid fuel with an equivalent launch capability. The second and third stages will use $LOX/LH_2$. The development of this space launching system is considered the pacing development item for the LUNEX program. Because of the magnitude of the booster program and the applicability of the booster to other programs, the plan for its development is being presented separately.

In addition to the above listed hardware developments, additional information is required about the lunar surface such as its physical and roughness characteristics. High resolution photographs of the entire lunar surface may provide this information. Present NASA plans if expedited could provide the information for this LUNEX program. NASA's SURVEYOR (soft lunar landing) program could also incorporate radio-light beacons which would be used later in conjunction with a terminal landing system. A core sample of lunar material is required as soon as possible so that design of lunar landing devices and lunar facilities can be accomplished.

## 1.4 MAJOR PROBLEM AREAS

The development of techniques for re-entering the earth's atmosphere at 37,000 ft/sec is one of the major problems. Guidance equipment must be very accurate to insure that the re-entry angle is within $\pm 2^{\circ}$. Too steep an entry angle will cause overheating and untolerable G loads, while too shallow an entry angle may permit the Lunex Re-entry Vehicle to skip out of the atmosphere into a highly eccentric earth orbit. If this happens, the vehicle may spend several days in the trapped radiation belts and may exceed the time limits of the ecological system.

The Lunar Landing Stage will be a difficult development because of a requirement for orientation with the local vertical when approaching the moon. It must also be guided to the selected landing site. Many tests will be required to develop the necessary equipment.

The Lunar Launching Stage will be another difficult development. The prelaunch countdown must be performed automatically and, if the launching booster is not vertical upon launch, corrections must be made in order to attain the required moon-earth trajectory.

Although the foregoing developments are difficult, no technological break-through will be required. All designs can be based on extrapolation of present technology.

## 1.5 MILESTONES

Major milestones in the program are:

a. Recovery of a manned re-entry vehicle from 50,000 miles in 1965.

b. Manned circumlunar flight in 1966.

c. Manned lunar landing and return in 1967.

These and other significant events are shown on Chart I-A.

1.6 CAPABILITIES DEVELOPED

The development of large boosters, rendezvous techniques and maneuverable space vehicles, all required for the Lunar Expedition, will also provide a capability for many new and advanced space achievements. For example, the Space Launching System which will boost 134,000 pounds to escape velocity will boost approximately 350,000 pounds into a 300 nm orbit, or will launch a manned vehicle on a pass around either Mars or Venus.

1.7 MANAGEMENT ACTIONS REQUIRED

The major Management Milestones for FY62 and FY63 are shown on Chart I-B. Immediate attention by Management to obtain Program Approval and Funding by July 1961 is necessary if the United States is to put a "man on the moon" by August 1967.

Throughout the LUNEX program time allocated for management and Air Force technical evaluations has been kept to a minimum. This is essential to meet the schedules, and delays in providing funding as indicated, or in receiving notification of required decision, will have the direct effect of delaying the program end objective.

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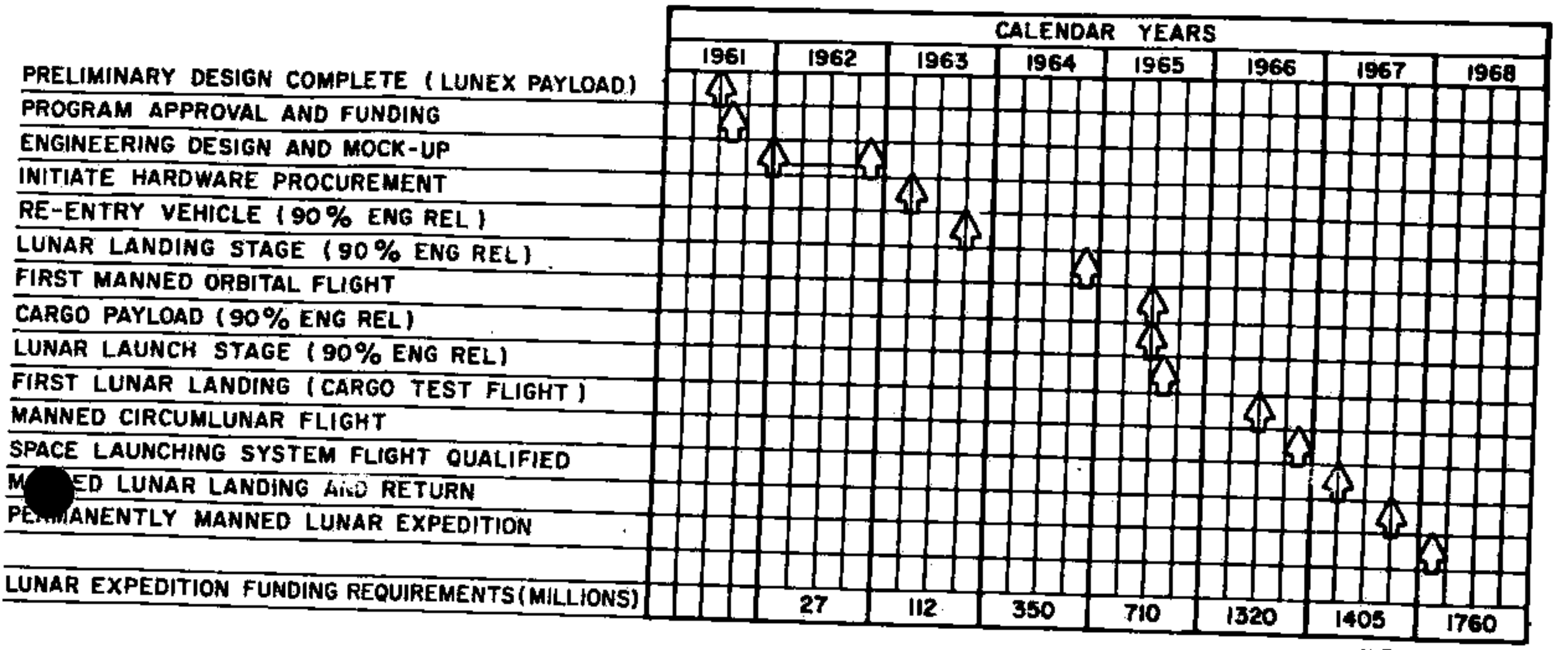
CHART I - A

LUNAR EXPEDITION PROGRAM MILESTONE SCHEDULE

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S

| I B | LUNAR EXPEDITION | CY 60 | CY 61 |
|---|---|---|---|

MANAGEMENT MILESTONES FY62 - FY63

J F M A M J J A S O N D J F M A M J J A S

START PRELIMINARY DESIGN (LRV)

COMPLETE PRELIMINARY DESIGN (LRV)

PROGRAM APPROVAL AND FUNDING

ENGINEERING DESIGN COMPETITION
AND MOCK-UP

Contractor No. 1 (Lunex Payloads)

Contractor No. 2 (Lunex Payloads)

DEVELOPMENT - PRODUCTION FUNDING

DESIGN CONCEPT DECISION

APPROVAL FOR HARDWARE GO-AHEAD

CONTRACT AWARD

LUNAR TRANSPORT VEHICLE PROGRAM

LUNAR EXPEDITION
PROGRAM

REQUIRED FUNDING (MILLIONS)

FY-62

FY-63

FY-64

LRV - Lunex Re-entry Vehicle

J F M A M J J A S O N D J F M A M J J A S

FY 61

SECR

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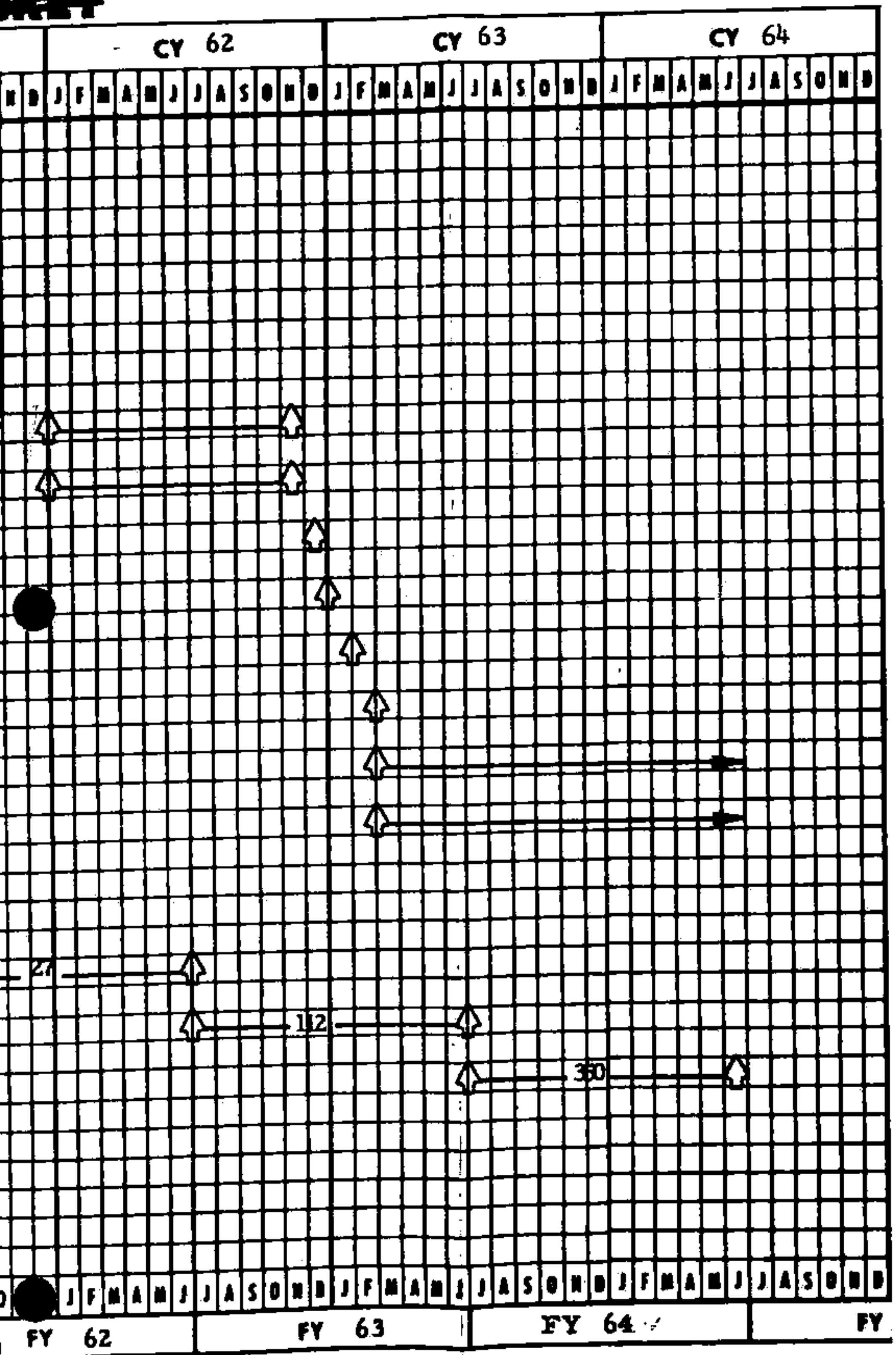


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# SECTION II

## PROGRAM DESCRIPTION

## LUNAR EXPEDITION (U)

## (LUNEX)

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# RECORD OF CHANGES

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| CHANGE NO. | DESCRIPTION OF CHANGE | DATE OF CHANGE | REFERENCE TO BASIC PART |
|---|---|---|---|
| | | | |

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## 2. PROGRAM DESCRIPTION

### 2.0 BACKGROUND

Shortly after the first Sputnik was launched in October 1957, Headquarters, ARDC initiated a series of studies to examine the military potential of space operations. These studies were accomplished by Industry-Air Force teams each working independently. Two of these studies which were the forerunners of this Lunex plan were "Lunar Observatory" and "Strategic Lunar System." The objective of the first study was to examine an economical, sound and logical approach for establishing a manned intelligence observatory on the moon, and the second study examined the military potential of lunar operations. These studies showed that it is technically and economically feasible to build a manned lunar facility.

A third study titled, "Permanent Satellite Base and Logistic Study" is presently under way and will be completed in August 1961. This study will provide a conceptual design of a three-man re-entry vehicle which will carry men to and from the moon. The three-man vehicle is the key item in the lunar transportation system as its weight will dictate the booster sizes. For this reason it is given special attention in this plan.

### 2.1 LUNEX PROGRAM OBJECTIVE

The objective of the Lunar Expedition program is the manned exploration of the moon with the first manned lunar landing to occur as soon as possible. The execution of this plan will land three men on the moon and return them during the 3rd quarter of calendar year 1967, and will establish the Lunar Expedition in 1968. Completion of this plan will require the development of equipment, materials, and techniques to transport men to and from the lunar surface and to provide a lunar facility which will allow men to live and work in the extremely harsh lunar environment.

### 2.2 LUNEX PROGRAM - DESCRIPTION

The Lunar Expedition Program is primarily concerned with the development of the equipment necessary to transport men and supplies to the lunar surface.

The key development in this program is the Lunar Transport Vehicle which is composed of the Space Launching System and either the Manned Lunar Payload or the Cargo Payload.
The Manned Lunar Payload consists of a three-man Lunex Re-Entry Vehicle, a Lunar Launch Stage, and a Lunar Landing Stage. The same Lunar Landing Stage, plus a cargo package, composes the Cargo Payload. The relative effort required for the development of these

two payloads in comparison with other portions of the complete Lunar Expedition Program is shown in Figure 2-1. A breakdown of the Lunar Transport Vehicle is shown in Figure 2-2.

The Space Launching System consists of a three-stage booster capable of placing either the Manned Lunar Payload or the Cargo Payload on a lunar intercept trajectory at escape velocity. This plan does not contain development information on the Launching System since such information is contained in a separate System Package Plan being prepared concurrently. The development schedules in these plans have been coordinated to insure compatibility.

In operation, the Manned Lunar Payload, weighing 134,000 pounds, will be boosted to escape velocity of approximately 37,000 ft/sec on a trajectory which intercepts the moon. Velocity will be sufficient to reach the moon in approximately $2\frac{1}{2}$ days. As the Manned Lunar Payload approaches the moon it is oriented with the local vertical by the use of horizon scanners. The Lunar Landing Stage decelerates the Manned Lunar Payload for a soft landing at a preselected site using an altitude sensing device to determine time of ignition. Landing at the preselected site will be accomplished using terminal guidance equipment and a prepositioned beacon to effect an off-set landing.

The Lunar Launching Stage, using the Landing Stage as a base, will launch the Lunex Re-entry Vehicle on the return trajectory. In early test shots before men are included, the countdown and launch will be effected automatically by command from the earth. Small mid-course corrections may be necessary to insure re-entry into the earth's atmosphere within allowable corridor limits.

The Lunex Re-entry Vehicle will re-enter the earth's atmosphere within the allowable corridor so that it will not skip back into space again nor burn from excess heat. It will use aerodynamic braking to decelerate and will have sufficient lift capability to effect a normal unpowered aircraft landing at a base such as Edwards Air Force Base.

Several successful unmanned, completely automatic flights of the type just described must be completed in order to establish confidence in the system reliability before manned missions will be attempted.

Cargo will be transported to the lunar surface using the same procedures and equipment except that the Lunar Launch Stage is not needed. The Cargo Package will have a weight equal to the combined weight of the Lunex Re-entry Vehicle and the Lunar Launch Stage.

As a separate approach to the problem of placing large payloads on the moon, techniques of rendezvous and assembly in earth orbit are being examined. Use of these techniques would require the launch, rendezvous and orbital assembly of sections of the Manned Lunar Payload and the Cargo Payload along with the required orbital launch booster and its fuel. The assembled vehicle would then be boosted from orbital velocity to escape velocity and would proceed as described above. Details of the major developments required such as rendezvous, docking and orbital assembly are outlined in a System Package Plan titled, SAINT being prepared concurrently. All programming information and schedules have been coordinated with this plan to insure compatibility and mutual support.

## 2.3 DESIGN PHILOSOPHY

The Lunar Expedition Plan has been oriented toward the development of a useful capability rather than the accomplishment of a difficult task on a one-time basis. The use of a large booster is favored for the direct shot approach since studies have shown this to be more reliable, safer and more economical as well as having earlier availability. However, another approach using a smaller booster in conjunction with orbital rendezvous and assembly is also considered.

The manned Lunex Re-entry Vehicle is the key item in determining booster sizes. Its weight determined the size of the Lunar Launch Stage which in turn determined the size of the Lunar Landing Stage. The total weight of these three items is the amount that must be boosted to earth escape velocity by the Space Launching System. In this manner the size of the Space Launching System was determined.

A $2\frac{1}{2}$ day trajectory each way was selected as a conservative design objective. Longer flights would have more life support and guidance problems while shorter flights require higher boost velocity.

An abort capability will be included in the design insofar as possible. The next section describes the abort system in considerable detail.

Development and tests are scheduled on a high priority basis. Thus, the schedules shown in this plan are dictated by technological limitations and not by funds.

The entire program as described herein is an integrated program in that later development tests build on the results of early tests. Thus, equipment and techniques are proved out early, and confidence in the reliability is obtained by the time a man is included.

## 2.4 ABORT PHILOSOPHY

The insertion of a man into a space system creates a safety and reliability problem appreciably greater than the problem faced by any unmanned system. It is well recognized that maximum reliability is desirable, but also known that reliabilities in excess of 85 to 90% are extremely difficult to achieve with systems as complex as the Lunar Transportation System. Therefore, the need for an abort system to protect the man during the "unreliable" portions of the lunar mission is accepted.

A review of the proposed techniques and equipments to provide a "full abort" capability has shown that due to payload limitations this is not practical during the early lunar missions. Thus a reasonable element of risk will be involved. In order to decrease this element of risk and to understand where it occurs the lunar mission has been divided into six time periods. These time periods are as follows:

a. Earth ascent.

b. Earth-moon transit.

c. Lunar terminal.

d. Lunar ascent.

e. Moon-earth transit.

f. Re-entry.

The development and test philosophy for this program is to launch the manned systems as early as possible in the program, but in an unmanned status. This will provide experience and allow the system to be checked out and "man-rated" before the first manned flight. It also means that the Lunex Re-entry Vehicle will be used for orbital and circumlunar flights prior to the lunar landing and return flight. The propulsion systems used for these early flights will be used throughout the program and the experience gained from each flight will increase the probability of success in reaching the final lunar landing and return objective. Also these propulsion systems will be used concurrently in other programs and at the time of man-rating will possess greater launch experience than can be expected for the largest booster of the Space Launching System. This would indicate that a larger number of unmanned flights should be scheduled for the larger full boost system than for the early flights. It also points out the need for a sophisticated Earth Ascent Abort capability during the first manned lunar landing and return flight.

In providing an abort philosophy for the Lunar Program it should be noted that the Lunex Re-entry Vehicle, the Lunar Landing Stage and the Lunar Launching Stage all possess inherent abort capability if utilized properly during an emergency. With sufficient velocity the re-entry vehicle is capable of appreciable maneuvering and landing control to provide its own recovery system. The Lunar Launching and Lunar Landing Stages possess an appreciable $\Delta v$ capability that can be used to alter the payload trajectory to better accomplish recovery of the man. However, in either case the maneuvers will have to rely on computing techniques to select the best possible abort solution for any specific situation.

With this background, and with the understanding that in a future final design effort "full abort" may be required, the following abort design objectives for the Manned Lunar Payload are presented:

a. Earth Ascent Phase

(1) On Pad.

Full abort system will be provided.

(2) Lift-off to Flight Velocity for the Re-entry Vehicle.

Full abort system will be provided.

(3) Flight Velocity for the Re-entry Vehicle to Escape Velocity.

The basic Manned Lunar Payload will provide the abort capability.

b. Earth-Moon Transit

(1) Injection

Abort capability to compensate for injection error is desired as part of the basic Manned Lunar Payload. Computing, propulsion, etc., capabilities should be designed into the basic system to provide for the selection of the optimum abort trajectory.

(2) Mid-course

Abort capability during Earth-Moon transit is desired for the Re-Entry Vehicle by means of a direct earth return, earth orbit, or circumlunar flight and earth return. Circumlunar flight generally requires the least $\triangle v$, but the actual selection of the optimum trajectory should be accomplished when required by a computing capability, and executed by the Lunar Payload.

c. Lunar Terminal

This type of abort generally results from loss of propulsion or control of the Lunar Landing Stage. Where possible the Lunar Launching Stage will be used to attain a direct or circumlunar trajectory that terminated in an earth return. When this is not possible the Lunar Launching Stage will be used to accomplish the safest possible lunar landing. Recovery of the crew will not be provided in this system and selection of the above alternatives will be accomplished automatically on-board. Crew recovery will be provided by another stand-by Lunar Transport Vehicle.

d. Lunar Ascent

Maximum inherent reliability by overdesign of components and systems in the Lunar Launching Stage seems to be the most logical approach for this phase due to the extreme weight penalty imposed by a separate abort system.

The early missions will be faced with the highest risk, but as a facility on the lunar surface is developed, a rescue capability and the addition of an abort capability can be developed. No specific abort system will be provided for this phase, but consideration should be given to the possibility of future lunar modifications to provide for abort.

e. Moon-Earth Transit

This would generally be associated with a gross trajectory error, or loss of control on re-entry. The only solution is to utilize the on-board capability that remains to achieve an earth orbit. After achieving orbit an earth launched rescue mission would be initiated. This approach requires no additional abort system to be provided for this phase.

f. Re-entry

Exceeding re-entry corridor limits, or loss of control could cause an emergency where abort would be desirable. Should sufficient $\Delta v$ remain from the over-design of the lunar launch stage, and not be used during Moon-Earth transit this would be used to attain an earth orbit where rescue could be achieved. No separate abort capability is required for this phase, but availability of propellant should be considered.

## 2.5 EXPEDITION PLANNING

A detailed plan must be prepared for the complete Lunar Expedition operation. This plan must start from the first time man lands on the lunar surface and account for every single effort, or objective he is to accomplish during his stay on the surface. A crew of three men will be sent into a new and hostile environment where rescue or assistance from other human beings will be extremely difficult, if not impossible, for the first mission. Time will be at a premium and all items of equipment must be planned, designed and delivered in the Cargo Payloads so that they can be used in the easiest possible manner.

The procedures for first exploring the surface and then for constructing the expedition facility must all be derived, demonstrated and proven by earth operations prior to attempting the desired operation on the moon. An environmental facility that simulates the lunar surface with sufficient work area to test out equipment and procedures will be required.

The actual landing operation and the first effort by men on the surface requires detailed data about the moon's surface. The following chart represents the best available data. The chart is a portion of a Lunar Sectional having a scale of 1:1,000 (1 inch equals 16 miles) produced by the USAF Aeronautical Chart and Information Center, St Louis, Missouri. Present plans call for the eventual production of 144 charts to cover the complete lunar surface.

The best photographic resolution to date is around one-half mile on the lunar surface, which provides adequate data for charts having a scale of 1:1,350,000. Good astronomical telescopes can be used to improve on the photographic data and obtain sufficient detail to prepare sectional charts like the one included. However, larger scale, accurate lunar charts will be required to complete detailed plans. Data can be obtained for such charts from a lunar orbiting photographic satellite which will provide sufficient resolution and overlap to enable stereographic compilation of contours and elevations. The NASA proposed Lunar Orbiter program is a possible source of the required data.

Planning for construction of the expedition facility can begin only after detailed surface information becomes available. Examination of returned lunar core samples will be necessary before plans can be completed.

# USAF LUNAR CHART

SCALE 1:1,000,000

PUBLISHED BY THE AERONAUTICAL CHART AND INFORMATION CENTER,
UNITED STATES AIR FORCE
ST. LOUIS 18, MO.

# KEPLER

# LAC 57

Mercator Projection
Scale 1:1,000,000 at 11°00′45″

*1ST EDITION DECEMBER 1960*

## NOTES

This chart was prepared with advisory assistance from Dr. G. P. Kuiper and his collaborators, D. W. G. Arthur and E. A. Whitaker.

### CONTROL

The position of features on this chart was determined through the use of selenographic control established primarily from the measures of J. Franz and S. A. Saunder. A collated listing of this control was published under the auspices of the International Astronomical Union in 1935. (Named Lunar Formations - Blagg and Müller).

### VERTICAL DATUM

Vertical datum is based on an assumed spherical figure of the moon and a lunar radius of 1738 kilometers. The datum plane was subsequently adjusted to 2.6 kilometers below the surface described by the 1738 kilometer radius to minimize the extent of lunar surface of minus elevation value. Gradients of major surface undulations were established by interpolating Schrutka - Rechtenstamm computations of J. Franz's measurements of 150 moon craters. The probable error of comparative elevation values is evaluated at 1000 meters. Vertical datum, so established, is considered interim and will be refined as soon as an accurate figure of the moon is determined.

### ELEVATIONS

All elevations are shown in meters. The relative heights of crater rims and other prominences above the maria and depths of craters were determined through photographic measurement utilizing the Z. Kopal and G. Fielder Shadow Progression Technique. Relative heights thus established, have been referenced to the assumed vertical datum and have been integrated with the gradients of the surface undulations. The probable error of the localized relative heights is 100 meters. Inherent with measuring technique used, relative height determinations in general E-W direction are more accurate than in the N-S direction.

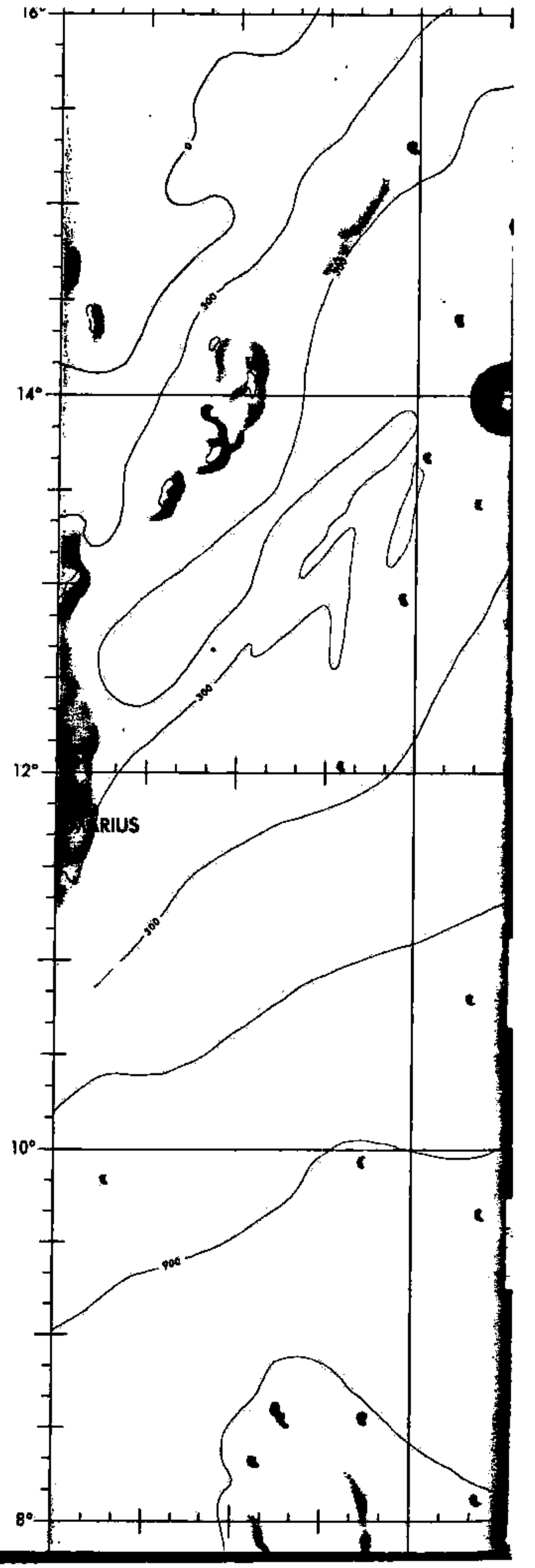
Spot Elevation (referenced to datum)...... .1100

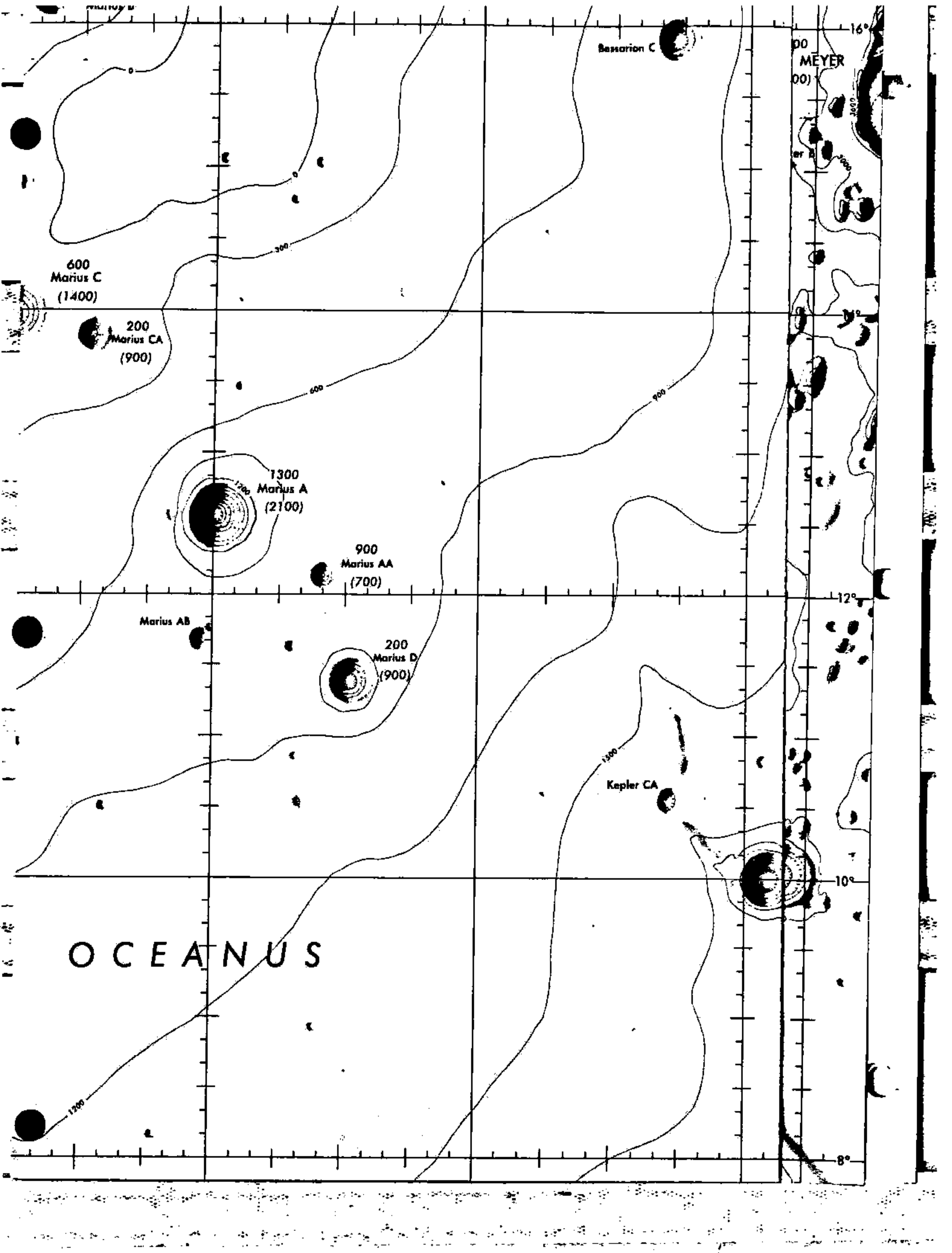
Crater Elevations

Rim (referenced to Datum).............. 300
Depth of crater (rim to floor)..........(400)

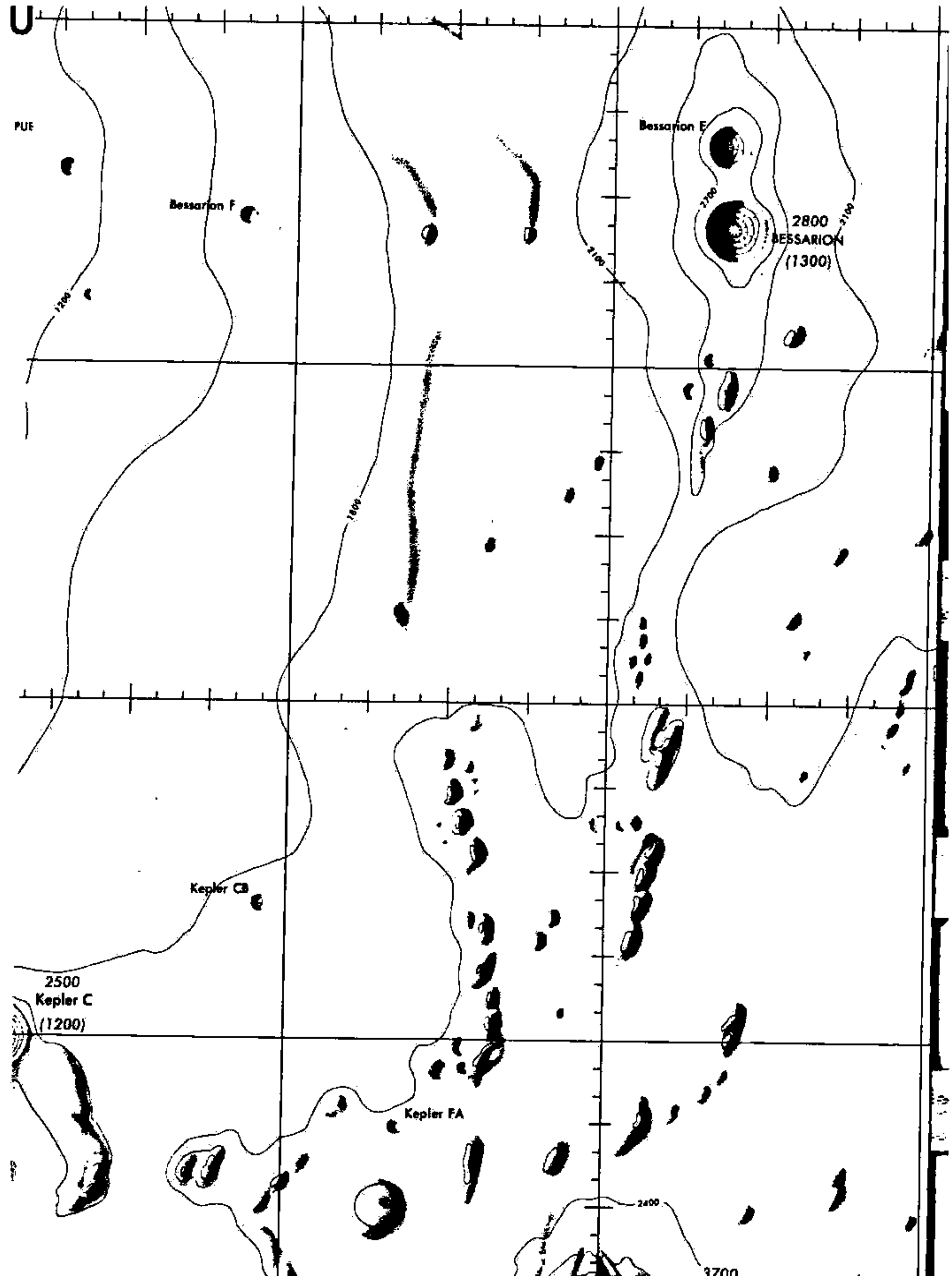
### CONTOURS

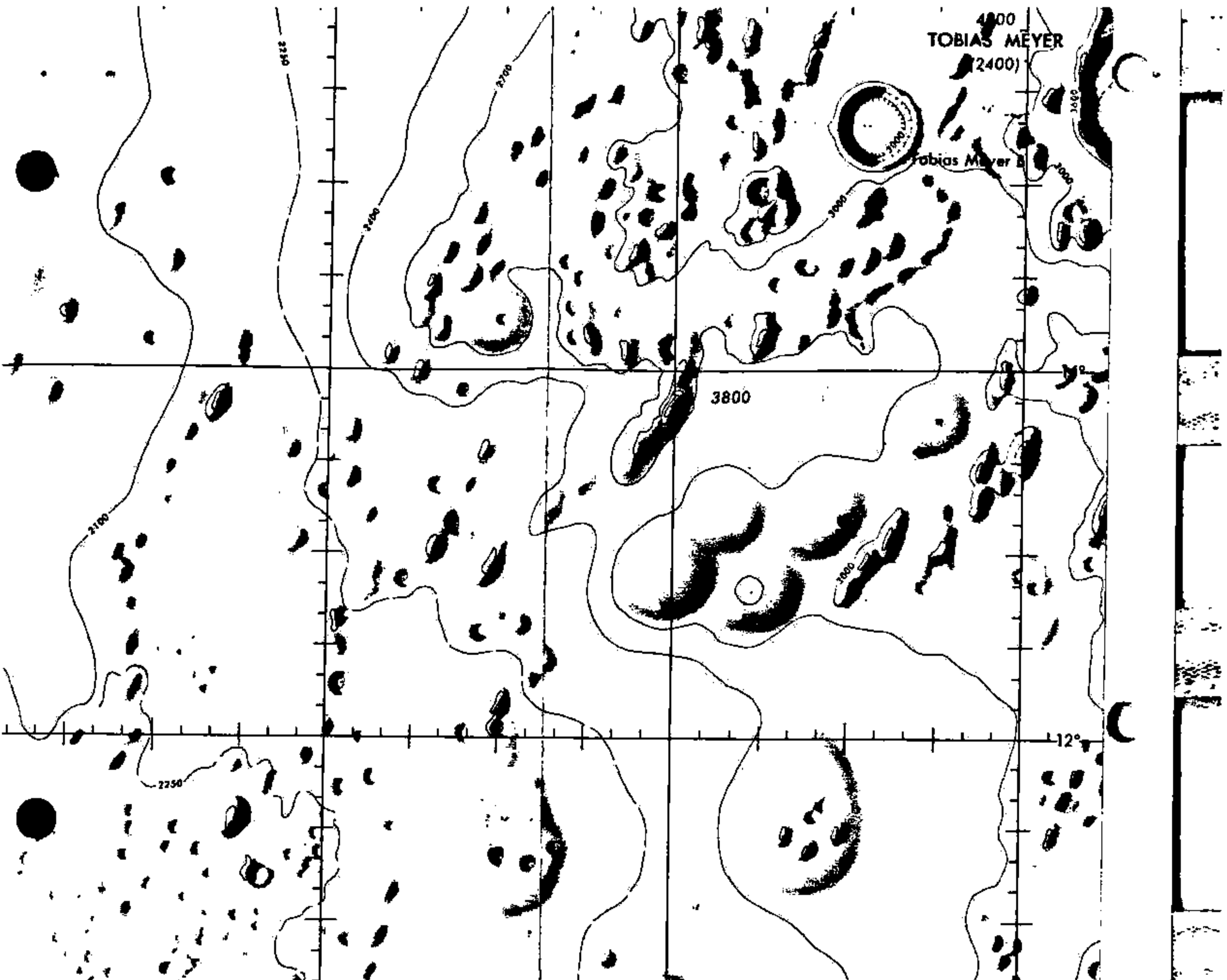
All contours are approximate
Contour interval is 300 meters
Supplementary 150 meter contours are shown in low





Bessarion C
MEYER
600
Marius C
(1400)
200
Marius CA
(900)
1300
Marius A
(2100)
900
Marius AA
(700)
Marius AB
200
Marius D
(900)
Kepler CA
OCEANUS
16°
14°
12°
10°
8°
0
300
600
900
1200
1500


U
PUE
Bessarion F
Bessarion E
2800
BESSARION
(1300)
2700
2100
1200
1800
Kepler CB
2500
Kepler C
(1200)
Kepler FA
2400
3700
KEPLER
(2600)
Kepler F


TOBIAS MEYER
(2400)
Tobias Meyer B
3800
12°
10°
8°
3500
MILICHIUS
(1000)
Milichius A
Milichius C
2250
2700
3000
2100